Eco-livelihood assessment of inland river dredging : the Kolo and Otuoke creeks, Nigeria, a case study

Eco-livelihood assessment of inland river dredging: the Kolo and Otuoke creeks, Nigeria, a case study

P. B. L. Tamuno

A Doctoral Thesis submitted in partial fulfilment of the requirements for the award of the Doctor of philosophy of Loughborough University

November 2005

Table of contents

b

Thesis access form

Certificate of originality

Dedication

For

My Wife and Friend Nana

&

Our Darling Son and my reliable “Research Assistant” Woyengitokoni

Acknowledgement

I am grateful for the support of my Supervisors: Mike Smith; and Ian Smout; as well as to Dr. Guy Howard for his continual support and encouragement during the period of this research. The assistance of Tricia Jackson (WEDC Information Officer) is appreciated, as well as the support and regular encouragement of Professor Chimay Anumba and Dr. Margaret Ince. I am also appreciative to WEDC for funding this research.

I acknowledge the contributions of: Pete Liptrot of Bolton MBC; Clair Jackson of the Environment Agency; and Ebenezer Amawhulu of the Bayelsa State College of Arts and Science (BYCAS), Yenagoa, Nigeria in the identification of the fish species. The support of Professor James R. Karr of the School of Aquatic and Fishery Sciences, University of Washington, USA is also acknowledged. Other researchers have provided useful advice and publications, especially Whitfield, A. K. and Claassen, Marius.

I am greatly indebted to all the 418 respondents of my questionnaires and especially grateful to the following fishers that participated in the ecological survey: Complete Odoko (Elebele); Pastor Isaiah Ikuru (Otuoke); Endurance Iwabara (Otakeme) and Kingsley Tarinyo (Otuogidi). I received remarkable assistance from the following persons during my field work in the Study Area: Mr. Roderick and Mrs. Idiabai Moses (Otuogidi); Glory Fabere (Otuogidi); Mrs. Esther Complete (Elebele); Mr. Benson Isomum (Otuoke); Mr. Robert Ifiola (Otakeme), and Yuri Robert (Otakeme).

A big thank you to the following friends that have supported me during this research: Douglas, Oronto; Amaduobuogha, Simon; Martin, Norline; Daworiye, Pereowei; Mr. P and Mrs. C. Mebine; Mr. G. and Mrs E. Halford; Adumien, Kogiesi; Dr Adeope, Martin, Inengite, Azibaola and Igbanibo, Otuawe. I also appreciate the support of my Research colleagues at WEDC and colleagues at the Niger Delta University.

Special thanks to my Parents, Mr. B.L. and Mrs. C. Tamuno for their encouragement and support all these years, and my siblings for being there for me always. To my cousin, Mr. Joseph B. Odede, I say a big thank you for his assistance during this research.

The support, encouragement, and understanding of my wife (Nana), and son (Woyengitokoni) has been very remarkable, particularly during this research. They are God’s special blessing to me and I can not wish for any better.

Above all I give God Almighty the Glory for making this dream a reality.

Tamuno November 2005

Abstract

Conventionally environmental assessments (EAs) have been carried out to enhance the understanding of the environment and for the purpose of developing appropriate environmental management and protection strategies. There are, however, limitations to the application of traditional EA approaches, particularly in rural communities in the developing world, where livelihood is dependent on common pool resources (CPRs), and baseline data are inadequate or unavailable. Eco-livelihood assessment (EcLA) is an adaptive approach that integrates a people-focused sustainable livelihood approach with ecological assessment, as well as exploring traditional eco-livelihood knowledge (TELK).

EcLA is identified as a promising EA tool that could help environmental professionals in planning for equitable development. This approach has been used in the Kolo and Otuoke Creeks, Niger Delta, Nigeria to investigate the ecological impact of dredging that may impact on livelihoods in such a rural setting. Ecological and social surveys have been carried out in four communities in the Study Area; two Test communities and two Reference communities (two communities from each study creek). The information collected from the social survey includes TELK, and has been used to build up a baseline scenario of the Study Area.

Abundance and diversity of fish are good indicators of the eco-livelihood impacts of inland river dredging. The research shows that livelihood characteristics, river use profile, fish species diversity and abundance are very similar among all four sample communities. In addition, all sample communities have been associated with similar natural and human induced environmental consequences except that the Test communities have had river sections dredged for the purpose of land reclamation representing the baseline scenario. The analysis of the results of the ecological survey shows a difference in fish catch per unit effort, catch per unit hour, and species diversity between the Test and Reference communities, this have been attributed to the impacts of inland river dredging. The study shows that TELK has a place in environmental assessment, and that eco-livelihood assessment is one promising environmental assessment approach that could be used in areas where livelihood is strongly dependent on common pool resources.

Key words: Eco-livelihood assessment; traditional eco-livelihood knowledge; common pool resource; livelihoods; dredging; Kolo Creek; Otuoke Creek.

Table of contents

Thesis access form .... **i**

Certificate of originality .... **ii**

Dedication .... **iii**

Acknowledgement .... **iv**

Abstract .... **v**

Table of contents .... **vi**

List of Appendices .... **xi**

List of Boxes .... **xiii**

List of Figures .... **xiv**

List of SPSS Outputs .... **xvi**

List of Tables .... **xviii**

Abbreviations and acronyms .... **xx**

Chapter 1 Introduction **1**

1. 1 Research background 1
1. 2 Research questions and hypotheses 4
1.2. 1 Overall research approach / methodology 5
1. 3 Research scope 6
1. 4 Definition of key terms and concepts 7
1. 5 Thesis structure 11
1.5. 1 Benefits and impacts of dredging 12
1.5. 2 Baseline data and good dredging practices 13
1.5. 3 Eco-livelihood assessment: how appropriate? 13
1.5. 4 The place of traditional knowledge (TK) in environmental assessment 14
1.5. 5 The study Area and field work 14
1.5. 6 Eco-livelihood baseline scenario of the Study Area 14
1.5. 7 Eco-livelihood assessment of dredging 15
1.5. 8 Conclusions and recommendations 15
1. 6 Chapter summary 15

Chapter 2 Benefits and impacts of dredging **16**

2. 1 Background 16
2. 2 Dredging: benefits, impacts and habitat recovery 16
2.2. 1 Benefits of dredging 17
2.2.1. 1 Improved navigational channel 17
2.2.1. 2 Land reclamation 18
2.2.1. 3 Socio-economic development 19
2.2.1. 4 Flood mitigation 21
2.2.1. 5 Beneficial use of dredged material 22
2.2.1. 6 Summary: Dredging benefits 23
2.2. 2 Potential impacts of dredging 23
2.2.2. 1 Hydrology and wetland / floodplain loss 24
2.2.2. 2 Sediments and turbidity 27
2.2.2. 3 Fisheries and fauna 28
2.2.2. 4 Livelihoods 30
2.2.2. 5 Summary: Dredging impacts 31
2.2. 3 Natural habitat recovery / re-adjustment 32
2. 3 Chapter summary 34

Chapter 3 Baseline data and good dredging practices 35

3. 1 Background 35
3. 2 Baseline data 35
3. 3 Good dredging practices 36
3.3. 1 Optimum dredging intervals 37
3.3. 2 Environmental Windows 38
3.3. 3 Selection of appropriate dredging techniques 40
3.3. 4 Alternate dredging 41
3.3. 5 Dredged waste treatment and disposal 43
3.3. 6 Channel maintenance and mitigation 44
3. 4 Good dredging: emerging issues 45
3. 5 Chapter summary 50

Chapter 4 Eco-livelihood assessment: how appropriate? 51

4. 1 Background 51
4. 2 Ecosystem 51
4.2. 1 Definition of ecosystem 51
4.2. 2 Characteristics of ecosystem 52
4.2. 3 Ecosystems and anthropogenic activities 54
4.2. 4 Sustainable ecosystem 56

4. 3 Concept of livelihoods 58
4.3. 1 Eco-livelihoods and common pool resources (CPRs) 59
4.3. 2 Sustainable livelihood framework 63
4.3. 3 Livelihoods and CPRs: emerging issues 64
4. 4 Environmental assessment 65
4.4. 1 Why environmental assessment (EA)? 66
4.4. 2 Environmental assessment and developing countries 68
4.4. 3 Environmental assessment: emerging issues 69
4. 5 Ecological assessment 72
4.5. 1 Principle of ecological assessment 73
4.5. 2 Indicators and ecological assessment 74
4.5. 3 Application of ecological assessment 81
4.5. 4 Ecological assessment: emerging issues 83
4. 6 Chapter summary 87

Chapter 5 The place of traditional knowledge (TK) in environmental assessment 88

5. 1 Rural people and traditional knowledge (TK) 88
5.1. 1 The concept of traditional ecological knowledge (TEK) 90
5.1. 2 Features and use of TK 91
5.1.2. 1 Localised and descriptive 92
5.1.2. 2 Historical information 92
5.1.2. 3 Modes of transmission 93
5. 2 Limitations and constraints of TK usage 94
5.2. 1 Scientific bias 94
5.2. 2 Subjectivity and validity 95
5.2. 3 Location-specific traditional knowledge (TK) 96
5.2. 4 Dynamic livelihoods and values 97
5.2. 5 Harmonisation and usage 97
5. 3 The place of TK in environmental assessment and management 99
5.3. 1 Information 99
5.3. 2 Localised livelihoods and ecological data 100
5.3. 3 Traditional knowledge as a complement to Western science 101
5.3. 4 Knowledge about seasonal variability and trends 103
5. 4 Emerging issues 104
5. 5 Ecological assessment (EcLA) and traditional eco-livelihood knowledge (TELK) 110
5. 6 Chapter summary 111

Chapter 6 The Study Area and field work 112

6. 1 Background 112
6. 2 Study Area 112
6.2. 1 Geography and ecology 113
6.2. 2 Rainfall and drainage pattern 116
6.2. 3 Population 118
6.2. 4 Livelihoods 120
6.2.4. 1 Farming 120
6.2.4. 2 Fishing 121
6.2.4. 3 Commerce 125
6.2.4. 4 Formal economic sector 125
6. 3 Field work 125
6.3. 1 Selection of sample communities 127
6.3. 2 Survey tool and approach 129
6.3. 3 Ecological survey 130
6.3.3. 1 Sampling seasons and procedure 131
6.3.3. 2 Fish species documentation and identification 134
6.3.3. 3 Limitations of the ecological survey 134
6.3. 4 Social survey 135
6.3.4. 1 Selection of respondents and sampling process 136
6.3.4. 2 Constraints of the social survey 138
6. 4 Chapter summary 140

Chapter 7 Eco-livelihoods baseline of the Study Area 141

7. 1 Background 141
7. 2 Sample and sampling 141
7. 3 Livelihood patterns and distribution 146
7.3. 1 Livelihood characteristics 147
7.3.1. 1 Years resident in the Study Area 147
7.3.1. 2 Educational level of respondents 148
7.3.1. 3 Livelihood options 148
7.3.1. 4 Fishing as a livelihood option in the Study Area 149
7.3.1. 5 Relationship between livelihood properties 150
7.3. 2 Livelihoods and common pool resource (CPR) 157
7. 4 Baseline scenario of the Study Area 163
7.4. 1 River use profile 164
7.4. 2 Fishing: fishing seasons and fisheries 170
7.4.2. 1 Fishing seasons 171
7.4.2. 2 Factors affecting fishing 176

7.4.2. 3 Fish species abundance and diversity 177
7.4.2. 4 Commercial value of fish species 182
7.4.2. 5 Current fishery trends 187
7.4. 3 Eco-livelihoods issues 191
7. 5 Chapter summary 197

Chapter 8 Eco-livelihood assessment of dredging 200

8. 1 Background 200
8. 2 The dredging projects 201
8.2. 1 The dredging projects based on TK 203
8. 3 Livelihood assessment of dredging 208
8.3. 1 Livelihood consequences of dredging 208
8.3. 2 Mitigation preferences based on TK 210
8. 4 Ecological impacts of dredging 213
8.4. 1 Fish community as an eco-livelihood indicator 214
8.4.1. 1 Fish species diversity and abundance 215
8.4. 2 Trophic structure of fish species 231
8. 5 Chapter summary 238

Chapter 9 Conclusions and recommendations 239

9. 1 Background 239
9. 2 Conclusions 240
9.2. 1 Eco-livelihoods: a livelihood source 240
9.2. 2 Baseline scenario based on TK and TELK 241
9.2.2. 1 River use profile 242
9.2.2. 2 Fish species and fishing 242
9.2.2. 3 Eco-livelihood issues 244
9.2. 3 Eco-livelihood assessment of inland river dredging 245
9.2. 4 Research constraints and limitation of eco-livelihoods assessment 246
9. 3 Recommendations and further research 247

References 249

Appendices 282

List of Appendices

Appendix 1 List of publications 282
Appendix 2 Description of ecological assessment approaches 283
Appendix 3 Fishing gears used in the Central Delta 284
Appendix 4 Questionnaire for Fishers 285
Appendix 5 Questionnaire for Non-fishers 293
Appendix 6 Gender distribution of respondents (Study Area) 297
Appendix 7 Age distribution of respondents (Study Area) 297
Appendix 8 Years residency of respondents (Study Area) 298
Appendix 9 Educational qualifications of respondents (Study Area) 299
Appendix 10 Livelihoods options (Study Area) 300
Appendix 11 Fishing as livelihoods category (Study Area) 301
Appendix 12 Palm cutting as livelihood category (Study Area) 301
Appendix 13 Farming as livelihoods category (Study Area) 301
Appendix 14 Trading and commerce as livelihoods category (Study Area) 302
Appendix 15 Pension as livelihoods category (Study Area) 302
Appendix 16 Formal economic as livelihoods category (Study Area) 302
Appendix 17 Other livelihoods category (Study Area) 303
Appendix 18 Gender of fishers (Study Area) 303
Appendix 19 Livelihoods option of fishers (Study Area) 304
Appendix 20 Fishing as livelihoods source - fishers (Study Area) 304
Appendix 21 Palm cutting as livelihoods source – fishers (Study Area) 304
Appendix 22 Farming as livelihoods source – fishers (Study Area) 305
Appendix 23 Trading as livelihoods source – fishers (Study Area) 305
Appendix 24 Pension as livelihoods source – fishers (Study Area) 305
Appendix 25 Formal economic sector as livelihood source – fishers (Study Area) 305
Appendix 26 Other livelihood sources – fishers (Study Area) 306
Appendix 27 Educational qualification of fishers (Study Area) 306
Appendix 28 Age range of fishers (Study Area) 308
Appendix 29 Years (range) of fishers (Study Area) 309
Appendix 30 Years fishing (Study Area) 310
Appendix 31 Category of fishers (Study Area) 310
Appendix 32 Average Day fishing per week (Study Area) 311
Appendix 33 Average fishing hour per day (Study Area) 311
Appendix 34 Fish diversity ad abundance based on TELK (Elebele) 312
Appendix 35 Fish species diversity and abundance based on TELK (Otuoke) 313

Appendix 36 Fish species abundance and diversity (Otakeme) 314
Appendix 37 Fish diversity and abundance based on TELK (Otuogidi).................................... 315
Appendix 38 Relationship between metrics of fish diversity and abundance (Elebele)............. 315
Appendix 39 Relationship between metrics of fish abundance and diversity (Otuoke) 316
Appendix 40 Relationship between metrics of fish diversity and abundance (Otakeme) 316
Appendix 41 Relationship between metrics of fish abundance and diversity (Otuogidi)............ 316
Appendix 42 Relationship between metrics of fish diversity and abundance (Study Area) 317
Appendix 43 Commercial value of fish species (Elebele) 317
Appendix 44 Commercial value of fish species (Otuoke).. 318
Appendix 45 Commercial value of fish species (Otakeme)... 319
Appendix 46 Commercial value of fish species (Otuogidi) 320
Appendix 47 Relationship between metrics of commercial value of species (Elebele) 320
Appendix 48 Relationship between metrics of commercial value of species (Otuoke).............. 321
Appendix 49 Relationship between metrics of commercial value of species (Otakeme)........... 321
Appendix 50 Relationship between metrics of commercial value of species (Otuogidi) 321
Appendix 51 Relationship between metrics of commercial value of species (Study Area)........ 322
Appendix 52 Relationship between metrics of commercial value of species (Elebele / Otuoke Creek) 322
Appendix 53 Relationship between metrics of commercial value of species (Kolo Creek)........ 322
Appendix 54 Relationship between educational qualifications (Otuoke-Otuogidi)..................... 323
Appendix 55 Relationship between impacts of dredging on fishing (Otuoke-Otuogidi) 323
Appendix 56 Relationship between mitigation preferences (Otuoke-Otuogidi).......................... 323
Appendix 57 Catalogue of freshwater fish species (Study Area) 324
Appendix 58 Summary of ecological survey (Elebele)... 325
Appendix 59 Summary of ecological survey (Otuoke) 326
Appendix 60 Summary of ecological survey (Otakeme) 327
Appendix 61 Summary of ecological survey (Otuogidi)... 328

List of Boxes

Box 2. 1 Navigational benefits of dredging the Niger River.. 18
Box 2. 2 Appraisal of dredging of the River Trent, UK 22
Box 2. 3 Using dredged materials for coastal defence and habitat creation................................ 23
Box 2. 4 Post dredging faunal re-adjustment at the Port Valdez, Alaska..................................... 34
Box 3. 1 Quantitative impact of dredging in the Providence Harbour, USA................................. 46
Box 3. 2 Quantitative impact of dredging (Orphire Bay, and the Bay of Ireland, UK) 46
Box 3. 3 Quantitative impact of dredging in the Southern North Sea, UK 47
Box 3. 4 Qualitative impact of dredging in the Niger Delta, Nigeria 47
Box 4. 1 Environmental assessment and dredging: A Nigeria Scenario...................................... 68
Box 4. 2 Advantages of fish as indicators of ecological status... 78
Box 7. 1 Statistical tests used in analyses of research data 142

List of Figures

Figure 1. 1 Structure of thesis 12
Figure 4. 1 “Traditional” concept (Human and human actions external ecosystem components) 52
Figure 4. 2 Natural ecosystem (Human as integral ecosystem component)................................ 52
Figure 4. 3 Microhabitats of streams 79
Figure 5. 1 Representation of the components of TEK 91
Figure 6. 1 Ecological zones of the Niger Delta 115
Figure 6. 2 Average rainfalls at Peramabiri between 1948 and 1992 116
Figure 6. 3 Map of the Study Area and drainage pattern 118
Figure 6. 4 Map of the Central Delta showing the sampling communities in Ogbia LGA 126
Figure 6. 5 Map of the Study Area showing dredged locations... 128
Figure 6. 6 A Cast net hung to dry in Otuogidi 129
Figure 6. 7 A Fisher throwing a Cast net in the Kolo Creek 130
Figure 6. 8 Map of the Study Area showing the ecological sampling sections 133
Figure 6. 9 Author in a dug-out canoe after a preliminary ecological survey 134
Figure 6. 10 Author administering questionnaire... 139
Figure 7. 1 Educational level of respondents (Study Area)... 148
Figure 7. 2 Livelihood options of respondents (Study Area) 149
Figure 7. 3 Young fishers in the Study Area... 162
Figure 7. 4 An elderly woman fishing in the Study Area 163
Figure 7. 5 Over-hung toilets by the Elebele / Otuoke Creek... 167
Figure 7. 6 Water hyacinth a constraint to fishing (Study Area)... 173
Figure 7. 7 Sorry Fisher: a log of wood not a fish (Elebele / Otuoke Creek).............................. 173
Figure 7. 8 A tree stump across Elebele / Otuoke Creek... 174
Figure 7. 9 *Heterotis niloticus* caught by one of the fishers involved in the survey.................... 185
Figure 8. 1 Stock-pile of dredged sand at Otuoke.. 202
Figure 8. 2 Stock-pile of dredged sand at Otuogidi 203
Figure 8. 3 Year of dredging based on knowledge of Otuogidi respondents 204
Figure 8. 4 Year of dredging based on knowledge of Otuoke respondents............................... 204
Figure 8. 5 Duration of dredging based on knowledge of Otuogidi respondents 206
Figure 8. 6 Duration of dredging based on the knowledge of Otuoke respondents.................... 206
Figure 8. 7 Employment of respondents’ relative by dredging company 208
Figure 8. 8 Good dredging seasons based on TELK 213
Figure 8. 9 Qualitative comparisons of Test and Reference communities................................. 217
Figure 8. 10 Qualitative Comparison of effect of fishing festival on assessment....................... 219
Figure 8. 11 Qualitative comparisons of all assessment scenarios 220

Figure 8. 12 Qualitative comparison of trophic structure (Study Area) 233
Figure 8. 13 Qualitative comparison of trophic structure (Otakeme).. 234

List of SPSS Outputs

SPSS Output 7. 1 Relationship between genders based on (Census and social survey) 146
SPSS Output 7. 2 Relationship between livelihood properties (Study Area) 151
SPSS Output 7. 3 Livelihood property (Study Area) 152
SPSS Output 7. 4 Livelihood properties (Elebele / Otuoke Creek) 153
SPSS Output 7. 5 Livelihood properties (Kolo Creek)... 153
SPSS Output 7. 6 Relationship between livelihoods properties of fishers (Study Area)............ 155
SPSS Output 7. 7 Relationship between livelihood sources (Study Area) 160
SPSS Output 7. 8 Relationship between livelihood categories (Study Area) 161
SPSS Output 7. 9 Kruskal Wallis Test on livelihood categories (Study Area) 161
SPSS Output 7. 10 Relationship of river use profile (Study Area) 169
SPSS Output 7. 11 Kruskal Wallis Test of relationship of river use (Study Area)...................... 169
SPSS Output 7. 12 Kruskal Wallis Test of river use profile (Study Area) 170
SPSS Output 7. 13 K-S Z Test of river use profile (Elebele / Otuoke Creek) 170
SPSS Output 7. 14 K-S Z Test of river use profile (Kolo Creek)... 170
SPSS Output 7. 15 Relationship between fishing seasons (Study Area) 174
SPSS Output 7. 16 Kruskal Wallis Test of fishing seasons (Study Area) 175
SPSS Output 7. 17 Fishing seasons (Elebele / Otuoke Creek) 175
SPSS Output 7. 18 Fishing seasons (Kolo Creek).. 176
SPSS Output 7. 19 Kruskal Wallis Test of factors affecting fishing (Study Area) 177
SPSS Output 7. 20 Kruskal Wallis on species diversity and abundance (Study Area).............. 181
SPSS Output 7. 21 K-S Z Test on species diversity and abundance (Elebele / Otuoke Creek) 182
SPSS Output 7. 22 K-S Z Test on species diversity and abundance (Kolo Creek) 182
SPSS Output 7. 23 Kruskal Wallis Test of commercial value of species (Study Area).............. 186
SPSS Output 7. 24 K-S Z Test on commercial value of species (Elebele / Otuoke Creek)........ 186
SPSS Output 7. 25 K-S Z of commercial value of species (Kolo Creek) 187
SPSS Output 7. 26 Relationship between trends in fishing (Study Area)................................. 189
SPSS Output 7. 27 Kruskal Wallis Test of trends in fishing (Study Area)................................. 189
SPSS Output 7. 28 K-S Z Test on fishing trend (Elebele / Otuoke Creek) 189
SPSS Output 7. 28 K-S Z Test on fishing trend (Elebele / Otuoke Creek) 190
SPSS Output 7. 29 K-S Z Test on fishing trends (Kolo Creek) 190
SPSS Output 7. 30 Relationship between the eco-livelihoods issues (Study Area).................. 196
SPSS Output 7. 31 Kruskal Wallis Test on eco-livelihoods issues (Study Area)....................... 196
SPSS Output 8. 1 K-S Z Test on impact of dredging on fishing (Study Area) 210
SPSS Output 8. 2 K-S Test of mitigation options (Study Area).. 212
SPSS Output 8. 3 K-S Z Test on good dredging season (Study Area)...................................... 212

SPSS Output 8. 4 Relationship between abundance and diversity metrics (Elebele) 221
SPSS Output 8. 5 Relationship between abundance and diversity metrics (Otuoke)................ 221
SPSS Output 8. 6 Relationship between abundance and diversity metrics (Otakeme)............. 222
SPSS Output 8. 7 Relationship between abundance and diversity metrics (Otuogidi).............. 222
SPSS Output 8. 8 ANOVA on fish abundance (Elebele / Otuoke Creek) 223
SPSS Output 8. 9 K-S Z Test on species diversity (Elebele / Otuoke Creek) 223
SPSS Output 8. 10 ANOVA of fish abundance – impacted (Kolo Creek).................................. 224
SPSS Output 8. 11 K-S Test of species diversity – impacted (Kolo Creek)............................... 224
SPSS Output 8. 12 ANOVA of species abundance – non-impacted (Kolo Creek)..................... 224
SPSS Output 8. 13 K-S Z Test on species diversity – non-impacted (Kolo Creek) 225
SPSS Output 8. 14 Species abundance of impacted and non-impacted seasons (Otakeme)... 225
SPSS Output 8. 15 Species diversity of impacted and non-impacted seasons (Otakeme)........ 225
SPSS Output 8. 16 ANOVA of species abundance (Elebele to Otuogidi) 226
SPSS Output 8. 17 K-S Z Test of species diversity (Elebele to Otuogidi) 226
SPSS Output 8. 18 ANOVA of species abundance – all season (Otakeme to Otuoke) 227
SPSS Output 8. 19 K-S Z Test of species diversity – all season (Otakeme to Otuoke) 227
SPSS Output 8. 20 ANOVA on species abundance – non-impacted (Otakeme to Otuoke) 227
SPSS Output 8. 21 K-S Z Test on species diversity – non-impacted (Otakeme to Otuoke)....... 228
SPSS Output 8. 22 Student t-test on species abundance (Test communities).......................... 229
SPSS Output 8. 23 K-S Z Test on species abundance (Test communities).............................. 229
SPSS Output 8. 24 Student t-test on species abundance – all season (Reference communities) 230
SPSS Output 8. 25 K-S Z Test on species diversity – all season (Reference communities)...... 230
SPSS Output 8. 26 Student t-test on species abundance – non-impacted (Reference communities)... 230
SPSS Output 8. 27 K-S Z on species diversity – non-impacted (Reference communities)........ 231

List of Tables

Table 2. 1 LGAs that may be affected by the proposed dredging of the Niger River.................... 19
Table 2. 2 Beneficial uses of dreadgeates (New York and New Jersey Harbours) 20
Table 2. 3 Environmental appraisal of dredging in the East Midlands, UK 32
Table 2. 4 Summary of biotic re-adjustment post-channelisation in the USA 33
Table 2. 5 Post dredging habitat sediment re-adjustment... 33
Table 3. 1 Examples of sensitive periods for aquatic biota (The UK) 39
Table 3. 2 Summary of dredging methods used in the UK 42
Table 3. 3 Summary of dredging impact 49
Table 4. 1 Properties of environmental indicators 76
Table 4. 2 Summary of the application of ecological assessment 82
Table 5. 1 Comparison between TK and knowledge based on Western Science 107
Table 6. 1 Major languages spoken in the Central Niger Delta... 113
Table 6. 2 Ranking of environmental issues in the Niger Delta 114
Table 6. 3 Major rivers and creeks in Bayelsa State 117
Table 6. 4 Projected 2004 population of Bayelsa State by LGA 119
Table 6. 5 Farming calendar of major crops cultivated in Bayelsa State 121
Table 6. 6 Commonly occurring fishes in the catch by fishers in Bayelsa State......................... 122
Table 6. 7 Inland river fish catch records for 1991 and 1992 in the Central Delta 123
Table 6. 8 Projected populations of sample communities 127
Table 6. 9 Summary of ecological survey sampling 132
Table 6. 10 Limitations of the ecological survey... 135
Table 6. 11 Population of sample communities and the target population................................ 137
Table 6. 12 Research hypotheses and methodology 140
Table 7. 1 Profile of respondents.. 143
Table 7. 2 Fishers in the sample communities 144
Table 7. 3 Specialised group in the context of all respondents.. 145
Table 7. 4 Comparison of age distribution.. 146
Table 7. 5 Kruskal Wallis H of the livelihood properties of fishers (Study Area) 156
Table 7. 6 Mann Whitney test of livelihood properties of fishers (Elebele / Otuoke Creek)........ 156
Table 7. 7 Man Whitney test of livelihood properties of fishers (Kolo Creek) 156
Table 7. 8 Summary of livelihood sources in the Study Area... 157
Table 7. 9 Minor livelihood sources in the Study Area 158
Table 7. 10 The river use profile of the Study Area.. 166
Table 7. 11 Inland river freshwater fishing seasons (Study Area).. 172
Table 7. 12 Environmental issues that affect fishing (Study Area)... 177

Table 7. 13 Major fish species (Study Area) 178
Table 7. 14 Other fish species (Study Area) 179
Table 7. 15 Fish species abundance and diversity based on TELK (Study Area) 180
Table 7. 16 Fish species of commercial value (Study Area) 183
Table 7. 17 Other fish species of commercial value (Study Area) 183
Table 7. 18 Commercial values of fish species based on TELK (Study Area)........................... 184
Table 7. 19 Trends in fishery (Study Area).. 188
Table 7. 20 Eco-livelihoods issues (Study Area).. 192
Table 8. 1 Perceived impact of inland river dredging on fishery based on TELK 209
Table 8. 2 Mitigation preferences of respondents 211
Table 8. 3 Summary of species caught during the ecological survey 215
Table 8. 5 Comparison of reliability of species abundance and diversity metrics....................... 228
Table 8. 6 Summary of ecological survey (Trophic structure).. 232
Table 8. 7 Trophic structure comparisons (Elebele / Otuoke Creek) 235
Table 8. 8 Trophic structure comparison – impacted (Kolo Creek).. 235
Table 8. 9 Trophic structure comparisons – non-impacted (Kolo Creek)................................... 236
Table 8. 10 Trophic structure comparisons across Creeks (Elebele to Otuogidi)....................... 236
Table 8. 11 Trophic structure comparison across Creeks – impacted (Otakeme to Otuoke) 236
Table 8. 12 Trophic structure comparisons across Creeks – non-impacted (Otakeme to Otuoke) 236
Table 8. 13 Trophic structure comparison between Reference communities - impacted 237
Table 8. 14 Trophic structure comparisons between Reference communities –non- impacted . 237
Table 8. 15 Trophic structure comparisons between Test communities.................................... 237

Abbreviations and acronyms

ANOVA	Analysis of variance
BALGA	Brass local government area
CARC	Canadian artic resources committee
CBD	Convention for biological biodiversity
CE	Collective experience
CEAA	Canadian environmental assessment agency
CPR	Common pool resource
CPUE	Catch per unit effort
CPUH	Catch per unit hour
DMAF	Dredged Material Assessment Framework
DV / AB	Species diversity and abundance
EA	Environmental assessment
EcA	Ecological assessment
EcIA	Ecological impact assessment
EcLA	Eco-livelihood assessment
EIA	Environmental impact assessment
EKELGA	Ekeremor local government area
EM&A	Environmental monitoring and audit
FGN	Federal government of Nigeria
GNP	Gross national product
IK	Indigenous Knowledge
KOLGA	Kolokuma / Opokuma local government area
LGA	Local government area
MDG	Millennium development goal
NEDECO	Netherlands Engineering Consultants
NELGA	Nembe local government area
OGBALGA	Ogbia local government area
PPR	Private property resource
RSPB	The Royal Society for the Protection of Birds
SALGA	Sagbama local government area
SD	Sustainable development
SILGA	Southern Ijaw local government area
SLF	Sustainable livelihood framework
SSA	Sub-Sahara Africa
TEK	Traditional ecological knowledge

TELK	Traditional eco-livelihood knowledge
TK	Traditional knowledge
UK	United Kingdom
US (A)	United States of America
WIPO	World intellectual property organisation
YELGA	Yenagoa local government area

Chapter 1 Introduction

1. 1 Research background

According to Pindar, an eminent Greek Philosopher, water “is the best of all things” (Biswas, 1997). The management of this vital resource is becoming increasingly difficult, and despite decades of efforts towards protecting surface water resources, there have been a continuous decline in the value of surface water resource (Biswas, 1997; Karr and Chu, 1999). This may not be unconnected with the fact that most water resources management objectives have not been holistic. This therefore calls for water resource assessment and management options / approaches that are holistic as well as address the issue of equitable development. Equitable development implies projects aimed at the fair distribution of the benefits of development, particularly to those that may be negatively affected by development projects.

The capacity of ecosystem to support living organisms (including humans) and the functioning of the world’s economies constitute ecosystem service (Miller, 2002). Developing sound and acceptable approaches for assessing adverse impacts on natural resources and associated service loss, is one of the many challenges facing environmental professionals, policy makers and all other environmental stakeholders (Barnthouse and Stahl, 2002). Environmental professionals include: Engineers; Planners; Biologist; Geographers; Architects; and Archaeologists (Canter, 1996). The fact that, there are no right or wrong conditions that could be universally applicable to all ecological systems; makes it difficult for environmental professionals to respond appropriately to the demands of policy-makers and politicians who depend on them to define and assess environmental consequences.

The information environmental professionals present in environmental assessment (EA) reports are crucial to achieving the goals of environmental protection and equitable development. Therefore, environmental professionals are expected to develop EA approaches that could offer information, which could be appropriately communicated to other stakeholders. Furthermore, it has been suggested that, it is essential that environmental decisions are made within rational and holistic frameworks, if socio-economic developments are to continue with minimum adverse impact on natural systems (Edwards-Jones, *et al.* 1995).

Currently, environmental scientists and managers in developing countries are confronted with environmental problems that are even more complex than have been associated with the EAs conducted in the developed countries. The complexity of the problem is compounded by other factors, such as the absence or inadequacy of baseline data. The absence of adequate data and expertise in developing countries has been re-echoed by Okpanefe (1991), who believed this may have hampered the management of fishery resources. Furthermore, Kwak *et al.* (2002), reported that within the existing circumstances in Korea, large-scale development projects have been carried out without sufficient scientific consideration of the consequences of the resulting destruction of valuable natural resources and degradation of the environment. Such a situation has given rise to a number of problems, namely:

- Conflicts between the central government and local residents;
- Less efficiency in the implementation of policy; and
- Indiscriminate development at the expense of the nation's natural resources.

The situation in industrialised countries is not very different; for example Bella (2002), reported that salmon in the Pacific Northwest of United States (U.S.A) are in widespread decline despite countless EA studies conducted over three decades and costing billions of dollars. The main purposes of the EA studies have been to identify trends in the decline of salmon as well as identify the most appropriate approach to mitigate this decline. The continual decline of salmon may be an indication that established assessments and management practices are fundamentally deficient. Therefore, current EA methodologies or approaches have not been able to meet the target of environmental protection and sustainable environment, which has been one of the reasons for conducting EAs. The inability of EAs to meet anticipated targets and expectations of environmental stakeholders may not be unconnected with the complexity of ecological systems.

Ecological assessment (EcA) exclusively employs biological parameters in assessing the status of ecological systems. EcA is focused on identifying biological attributes (indicators) that are: most sensitive to human impacts; minimally affected by natural variation, cost-effective to measure (Karr and Chu, 1999). EcAs are specifically aimed at identifying and documenting anthropogenic impacts. However, the high variability of ecological and social characteristics of natural resources demand locally driven solutions to address the issues of environmental modifications due to human impacts.

One of the most difficult tasks in achieving the integration of ecological and social characteristics is developing a framework for research and planning that views science and traditional eco-livelihood knowledge (TELK) as complementary forms of knowledge. However, despite over two decades of efforts towards involving indigenous / aboriginal / local / traditional peoples in the management of their local environment, there is hardly any information that indicates the actual involvement of indigenous people in the management of their environment (Klubnikin, *et al.* 2000; Nepal, 2002). The priorities and knowledge of local / indigenous / traditional peoples have often been disregarded in environmental and water resource policy formulation. Rather, most development projects have relied solely on data and information from “hard science” and technology. The integration of the sustainable livelihood framework (SLF), tenets of TELK and the principles of ecological assessment may serve as a tool that could link the social, livelihoods priorities, and ecological facets of EAs (see section 1.4 for definition of SLF and TELK).

Specifically, appropriately designed studies to address dredging impacts are very limited and the lack of relevant data continues to increase the controversy on dredging impact assessments. Therefore, Clarke and Wilber (2000), are of the opinion that until adequate data are available, quantifying biological responses to the potential impacts of dredging, must unfortunately remain subjective. Furthermore, the effects of dredging on aquatic resources remain an issue of increasing environmental concern; but relatively little research has been done to detect the effects of dredging at population-level of macro-invertebrates and fish (Ault, *et al.* 1998). Therefore, it is necessary that appropriate approaches are developed that could address the impact of dredging at population-level, particularly in areas where the environment and livelihoods are intrinsically linked.

Generally, much research attention and publications are on the physico-chemical consequences of dredging and the management of dredged material, with less attention on the physical effect of dredging projects on biota (particularly fish species). The possible effects of dredging may be on the physical environment, ecosystem, economics, and socio-political spheres. Ecological impacts of dredging are deterministic, if sufficient knowledge is available, and if science is sufficiently advanced to predict probable effects of proposed projects. On the other hand, an economic benefit to one person may have a negative impact on another. Political effects are also dependent on the viewpoint of a person or group of people, and may be positive or negative depending on their livelihoods situation (Bray, *et al.* 1998). This implies that, if peoples' perceptions are influenced by their livelihood situation; therefore the impacts of dredging may not be the same across different socio-economic strata even in the same geographical locations. It is therefore, expedient that the knowledge of those whose livelihoods are at risk from the negative impacts of dredging is accessed and used for dredging and other developmental projects impact assessment. Such an approach could make development projects equitable to all concerned.

Generally, there are seemingly numerous photographic illustrations of the adverse impacts of dredgers on aquatic biota (Stolpe, 2001). Despite these photographic illustrations and description of the impacts of dredgers; the quantification of the degree of these consequences is generally lacking and there has been very little discussion about the impacts of dredging on the ecological components that have been supposedly so dramatically affected. In addition, Stolpe (2001), reported that the direct impacts of dredging are often described, and seldom quantified.

This research has been designed to identify and propose an EA approach / tool that could facilitate equitable development, therefore equitably “spreading” the benefits of inland river dredging among stakeholders. Stakeholder groups range from government to local residents; these local residents are most likely to be affected directly by dredging activities, because dredging impacts are often localised.

1. 2 Research questions and hypotheses

This research has been developed to explore approaches that could be appropriately used in assessing anthropogenic impacts on ecological systems that could have consequences for livelihoods, particularly in areas where people depend on the local ecological systems, especially common pool resources (CPRs) for livelihood sustenance. This research has been designed to identify, explore, test and develop an environmental assessment approach that would be relevant in the planning and execution of projects. Such an approach could help in the equitable distribution of the benefits and costs of projects among all stakeholders (including the rural / indigenous people), in developing countries where baseline data are inadequate, sometimes non-existent and eco-livelihood is a major source of livelihood. Putting people at the centre of development could favour the equitable distribution of the benefits of development projects such as inland river dredging. The research questions have been the basis on which the research hypotheses have been developed. The research questions are:

- ***Does in-land river dredging have impact on freshwater fisheries that could be of livelihood significance in rural communities of developing countries?; and***
- ***Can the eco-livelihood assessment (EcLA) approach appropriately measure the impacts of inland river dredging in areas where there is high dependence of livelihoods on common pool resources?***

Based on the above questions the research hypotheses have been developed to explore approaches that could be appropriately used in the context of the Study Area in assessing the eco-livelihood impacts of dredging. These research hypotheses are listed below:

- ***Eco-livelihood is a significant livelihood component in the Central Niger Delta (specifically the Study Area) and in similar areas in most developing countries;***
- ***Traditional eco-livelihoods knowledge (TELK) can provide useful baseline data for EA especially where eco-livelihood is a major livelihood source and baseline data are inadequate and or unavailable;***

- ***Fisheries can be used as good indicators in the retrospective assessment of the impacts of inland river dredging on the ecosystems that are of livelihood significance; and***
- ***Eco-livelihood assessment (EcLA) is an appropriate EA tool in areas where the dependence on the ecosystem is a major livelihood component.***

To investigate and demonstrate the validity or otherwise of the above hypotheses the researcher planned to review relevant literature, and to carry out ecological and social surveys in an area in which inland river dredging have been executed. A brief description of the approaches used in this research to investigate the research hypotheses have been presented in section 1.2.1

1.2. 1 Overall research approach / methodology

Generally the methods intended for use in investigating the above research hypotheses are: desk study (literature review); correspondence with researchers in the areas relevant to this research; the field work and data analyses. The review of relevant literature has been planned in the context of this thesis to:

- Understand the issues of dredging as a development project that may have environmental consequences, and to review approaches that may have been proposed and or implemented that may reduce the environmental consequences of dredging;
- Present ecosystems as livelihood sustaining systems; environmental assessment as a tool aimed at understanding and monitoring anthropogenic impact on the environment, and a relevant tool in environmental management;
- Show that the sustainable livelihood framework is an assessment tool that puts people at the centre of development;
- Show that ecological assessment is an environmental assessment approach that uses biota to investigate anthropogenic impacts on the environment;
- Test the relevance of traditional knowledge (TK), traditional environmental knowledge (TEK) and traditional eco-livelihood knowledge (TELK) in understanding the baseline scenario in places where baseline data are not available or inadequate, and to understand livelihood priorities; and
- Obtain relevant literature about the Study Area.

To access relevant literature in the above areas, articles will be sourced from: peer reviewed academic journals, conference publications; literature from the internet; correspondence with researchers in the above areas of interest; reports; books, book sections, grey literature, including unpublished academic theses. The information from these sources is intended to be used to design the fieldwork methodology as well as to identify appropriate analytical tools for analysing the fieldwork results in this research context.

The field work is intended to test whether eco-livelihood assessment is a sensitive and relevant EA tool in areas where livelihood are strongly dependent on the local ecosystem and baseline data are unavailable or inadequate. Specifically the field work will be used to:

- Identify the livelihood issues in the Study Area;
- Use TK, TEK and TELK to build the eco-livelihood baseline scenario for the Study Area;
- Test the livelihood consequences of inland river dredging in the Study Area;
- Understand the issues of inland river dredging in the Study Area;
- Test the validity and reliability of TK, TEK and TELK as knowledge sources; and
- Show that ecological assessment is a sensitive tool in the retrospective assessment of the impact of inland river dredging in the Study Area.

In addition, identification of the various fish species that will be caught during the ecological survey required literature searches, correspondence with researchers, and local knowledge that will be accessed during the field work. The quantitative results from the field work will be analysed with the aid of Microsoft spreadsheet (Excel) and the Statistical Package for Social Scientists (SPSS 11). In addition to collecting data and information, interim findings have been disseminated through conferences and journal papers. A list of publications based on this research is included in Appendix 1. The scope of this research as well as the limitations of this study is briefly explained in the next sub-section.

1. 3 Research scope

The Study Area (Kolo and Otuoke Creeks) is the focus of this research, and inland river dredging the environmental issue of concern. The Study Area is located in the southeast region of Bayelsa State (Central Niger Delta), which is within the mangrove swamp ecological zone in the Niger Delta region of Nigeria. Four communities have been used as sample communities; two of these communities are Reference communities (communities in the same eco-livelihoods region, but have not been affected by the environmental issue under investigation) and the other two, which are both downstream of the Reference communities have been selected as Test communities (communities in the same eco-livelihoods region, but have been affected by the environmental issue under investigation). Fisheries have been used as the indicator for assessing the impacts of inland river dredging that may have had both livelihood and ecological significance in the Study Area (See section 6.3.1 for details of the selection criteria for sample communities).

The researcher identified five fishing seasons in the Study Area, however due to limitations of funds, the ecological survey could only be carried out during three of the five fishing seasons. The ecological sampling has been carried out during the day (during hours of daylight between 0600 hours and 1900 hours) by the researcher with the help of fishers of varying years of experience from the respective sample communities.

The sample population of interest for the social survey consist of residents in the sample communities who are twenty (20) years of age and above. Face-to-face (interview) administered questionnaires have been completed by the researcher for 5% of the target sample population. Two questionnaire types have been used: one was specifically designed for inland river fishers; and the other was for all other residents within the sample group in the Study Area.

1. 4 Definition of key terms and concepts

This section contain the definitions of some concepts and key words that has been used in this thesis, as well as further explanation of these concepts as they apply to this thesis. However, this is not an exhaustive list of concepts used in this research. Other concepts have been defined and explained in relevant sections of this thesis.

Livelihood – Livelihoods comprise people's capability, assets and activities required for making a living. A livelihood is socially sustainable when it can cope with and recover from stress, shocks and maintain or enhance its capabilities and assets both presently and in the future (Chambers and Conway, 1992; Carney, 1998). Furthermore, a livelihood is environmentally sustainable when it maintains or enhances the natural assets on which livelihoods depend, and has net beneficial effects on other livelihoods (Chambers and Conway, 1992).

A livelihood is socio-environmentally sustainable when it can withstand stress (externalities) while maintaining livelihood quality and not inherently compromising ecological integrity. This research is focused on surface water resources as a common pool resource (CPR) that is of livelihood significance; **eco-livelihoods** have been used in this thesis to imply livelihood dependent on local common pool resources (both eco-livelihoods and common pool resources are described below)..

Eco-livelihood – Eco-livelihood is a word that has been coined from two words by this researcher, these are: ecology and livelihoods. Eco-livelihood means livelihoods that are intrinsically linked or dependent on the local ecological systems. In the context of this research the ecological resources that of major concern are common pool resources.

Common pool resources (CPRs) – CPRs are resources of communal ownership and are typically associated with village and rural settings and significantly contribute to the livelihood of particularly poor people in these areas. Examples of such resources are: pastures; wastelands; and water sources (Jodha, 1996). A CPR could be a natural or man-made facility with use values that are not exclusive and could be used for different purposes by different individual at the same time. Therefore, exclusion of individuals or groups from enjoying the services of CPRs is difficult or very expensive to achieve, because CPRs can be utilized by more than one individual or group simultaneously or sequentially (Gupta, *et al.* 2001).

Sustainable livelihoods framework (SLF) – The sustainable livelihoods framework is an analytical framework that aids the identification of when and where environmental issues are important to human lives and in relation to livelihoods (Neefjes, 2000). The framework puts people at the centre of a development project and starts with an assessment of people's strengths and opportunities by focussing on the assets available to them. Achieving sustainable livelihoods requires the integration of local knowledge with "established" scientific tools to understand the complexity and variability of livelihoods in rural communities, particularly in developing countries. Such an understanding if appropriately applied can facilitate the equitable distribution of the benefits of development.

Sustainable development (SD) – The WCED (1987) report, presented a concise definition of SD as development that "*meet the needs of the present without compromising the ability of further generations to meet their own needs*". The concept of SD recognises the that there is need to take cognisance of the fact that ecosystem capacity limited, hence human developmental activities should be carried out in such a way as not to compromise ecosystem services.

SD as presented above favours and advocates for inter-generational equity (i.e. considering future generations). However, SD in this context implies a development that will be beneficial to all, or with fairly distributed benefits among all stakeholders, irrespective of socio-economic, or socio-cultural status. The type of equity that has been advanced in this thesis is intra-generational equity (i.e. equity for current stakeholders), and if such an equity is pursued and achieved, the benefits of development could be easily transferred or converted to future generation, if at the same instance the tenets of inter-generational equity is not neglected by environmental professionals.

Stakeholders – Individuals or groups who have an interest or "stake" in a given project or programme or those who can affect change, or those who will be most affected by change have been identified as stakeholders. In the context of this thesis stakeholders are:

- Those whose interests are affected by anthropogenic activities;
- Those who control relevant implementation instruments (environmental managers / policy-makers);
- Those who possess relevant information and expertise (environmental professionals); and
- Those whose activities or operation could aggravate anthropogenic consequences on the environment.

Indigenous people - Indigenous people are often regarded as the original or oldest surviving inhabitants of an area. Typically long-term residency in a geographical location, may be associated with language, history, values and, or customs (Nepal, 2002). In the context of this research indigenous, aboriginal, traditional and rural people have been used interchangeably to represent long-standing residency in a geographical location, such people have a high dependence either directly or indirectly on the local environment for their livelihoods.

Traditional knowledge (**TK**) **-** TK is the cumulative knowledge of people in a given community that has developed over time, and continues to develop. It is empirical knowledge based on experiences that have most often been tested over centuries of use, adapted to local culture and environment, such knowledge could be dynamic, complex and variable (Berkes, 1999; Paci, *et al.* 2002; Sillitoe, *et al.* 2002). TK and indigenous knowledge (IK) have been used interchangeably in the context of this thesis to imply the knowledge of indigenous people.

Traditional environmental knowledge (TEK) - TEK has been variously labelled as folk ecology, ethno-ecology, traditional environmental or ecological knowledge, and knowledge of the land. Traditional environmental or ecological knowledge is probably the most common term to describe TEK; however, there remains no universally accepted definition of the concept (Berkes, 1999)

Generally, TEK has been defined as a collective body of knowledge of a group of people through generations of living in close contact with nature. It includes a system of classification, a set of empirical observations about the local environment, and a system of self-management that governs resource use. The quantity and quality of TEK varies among community members, depending upon gender, age, social status, intellectual capability, and profession. TEK is both cumulative and dynamic, that has been passed down from generations and adapted to the meet present challenges (Johnson, 2005).

Traditional eco-livelihood knowledge (TELK) – TELK is empirical knowledge of local people about their environment for the specific purposes of earning a livelihood or livelihoods sustenance. In the context of this thesis, TK / TEK that has been linked to livelihoods have been termed traditional eco-livelihoods knowledge (TELK). TELK has been used by rural, indigenous, aboriginal and traditional people to monitor the variability and uncertainty of ecological systems for the specific purpose of sustenance of their livelihood and their local environment. Fishers have used their knowledge of fish spawning grounds and habitat for fishing; similarly, farmers have used their TELK of planting season; crops adaptation and pest control for the sustenance of their livelihoods; and hunters their knowledge of animal migration and “life style” for successful hunting.

Baseline data – Baseline data are data collected pre-project that can be used as bench-mark to measure and interpret changes over time usually after some condition has been changed. These data constitute a fundamental unit of basic inventory information that are important to ensure the sustainable use, management and exploitation of ecological resources that are crucial for sustainable development. In addition, baseline data are a basic requirement to measure change. Conroy and Rangnekar (2000), described baseline data as information that must be collected prior to construction, dredging or other environmental disturbances. In the context of this research baseline data has been identified as long-term, comprehensive, scientific environmental information, collected, stored and available for use in understanding the historical status of the area of interest.

Environmental assessment (EA) - EA entails an analytical tool aimed at finding ways of attributing predicted or observed environmental changes to certain activities or policies and modifications of development practice (Neefjes, 2000). EA is a process designed to contribute relevant environmental information to the decision-making process. In addition, EAs in the context of this research are regarded as approaches aimed at investigating environmental issues that are appropriate for the management of environmental resources and anthropogenic impact on the environment.

Environmental Impact Assessment (EIA) – EIA is also referred to as EA; however the specific purpose of EIA is to ensure that the environmental effects of a proposed project are fully considered before the project is implemented. EIA process is an advanced assessment of the likely environmental impact of a planned development, together with opinions of people and interest groups and the information gathered is passed to environmental managers and decision-makers. The major difference between EA and EIA is that EIA is far more than an assessment tool, it is a process required by governments prior to the approval of development projects.

Ecological assessment (EcA) – Generally, EcA is an evaluation of the biological condition of an ecological system by using biological surveys and other direct measurements of biota resident in the biological system of interest. EcA is an example of the EA process that considers biota rather than broader environmental parameters (physico-chemical indicators). Specifically, EcA uses biological parameters as indicators for anthropogenic impacts.

Eco-livelihood assessment (EcLA) – EcLA is an adaptive EA approach that has been developed in this research based on the premise that livelihoods in most rural communities in the developing world is dependent on ecological resources (most often common pool resources). EcLA is an EA approach that explores the principles of EcA, the SLF, and the tenets of TELK in the assessment of anthropogenic impacts on ecological systems that may be of livelihood consequences.

Study Area – Both creeks studied (Kolo and Otuoke Creeks) are within the Ogbia local government area (LGA) in the Central Niger Delta (Bayelsa State), Nigeria. The Ogbia LGA is a large area. For the purpose of this research the term Study Area has been used to describe the two creeks (Kolo and Otuoke Creek) The Otuoke Creek in the context of this research is termed Elebele / Otuoke Creek. See section 6.2 for a description of the Study Area.

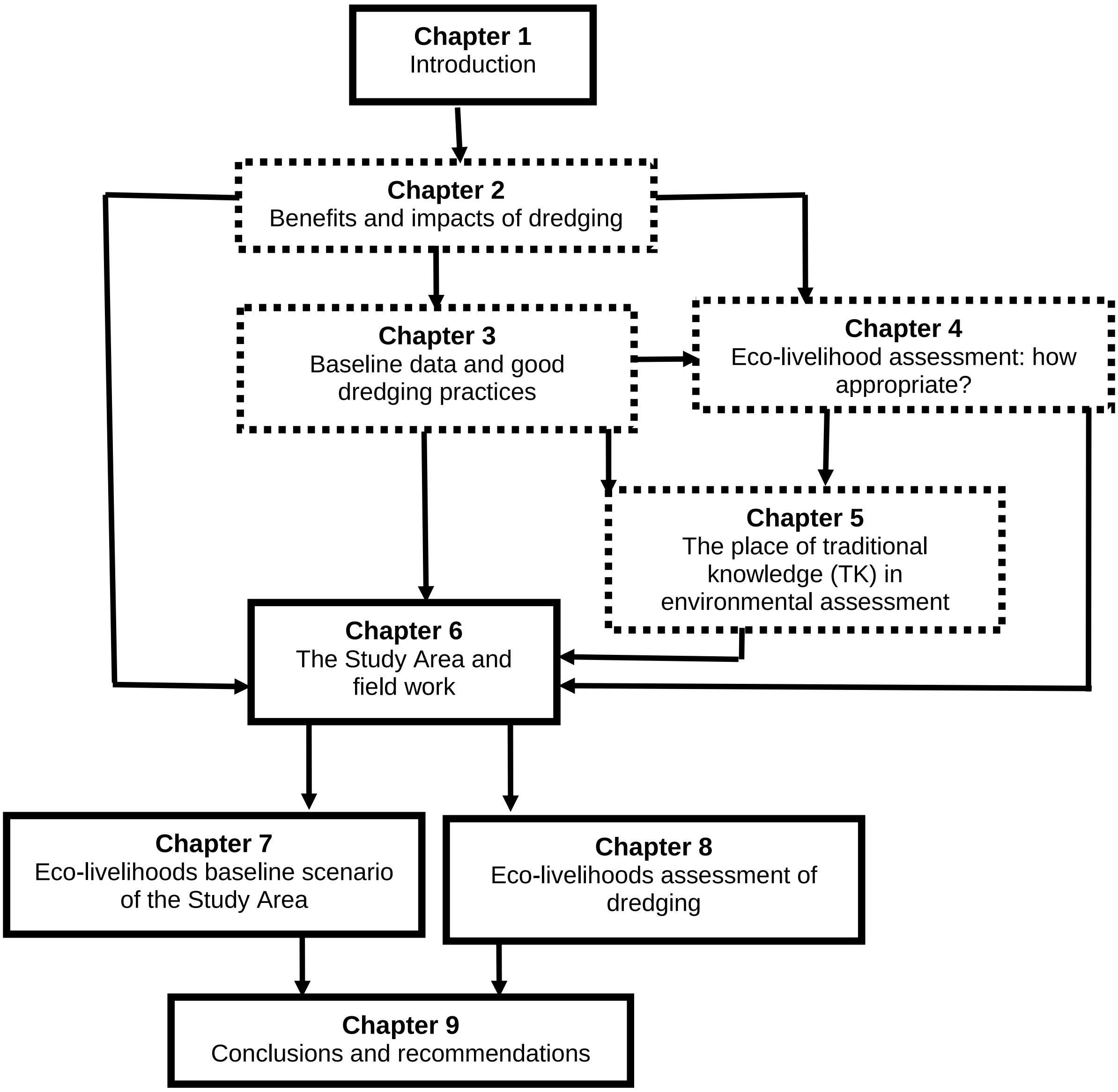
1. 5 Thesis structure

The structure of the thesis is as shown in Figure 1. 1. The literature review sections have been shown by dotted lines. From this diagrammatic representation, it shows that this thesis has been divided into five major sections, these are:

- Introduction (Chapter 1) – Contains the research background, research question and hypotheses;
- Literature review (Chapters 2, 3, 4 and 5) – Different aspects of the study has been reviewed within the respective sections;
- Methodology (Chapter 6) – Contains the background of the Study Area and the research approach used for this study; and
- Field work outcome: This encompasses: research results, analyses and discussions (Chapter 7 contain the assessment baseline scenario, and Chapter 8 contains the assessment results);
- Conclusions and recommendations (Chapter 9).

Sections 1.5.1 to 1.5.8 inclusive provide a brief description of Chapter 2 to 9 (see figure 1.1)

Figure 1. 1 Structure of thesis



1.5. 1 Benefits and impacts of dredging

To provide the study context, a review on inland river dredging as a development project aimed at providing economic benefits has been undertaken. However, dredging has detrimental consequences which are most often localised. Improved navigational channels; land reclamation; socio-economic development; flood mitigation; and beneficial usage of dredged materials constitute the benefits associated with inland river dredging. On the contrary, alteration of hydrological regimes; loss of wetland and floodplains; sediment suspension and increased turbidity; impacts on flora and fauna; and impacts on livelihoods have been recognised as the localised adverse impacts of dredging.

Furthermore, the natural re-adjustment properties of surface water plays a major role in the determining the severity and duration of the impacts of dredging. However, the duration of biota re-adjustment is longer than that of physico-chemical attributes of surface water. In response to the environmental consequences of dredging, environmental professional and managers have developed approaches aimed at reducing the impact of dredging as well as to enhance dredging benefits. These approaches in the context of this research have been termed good dredging practices (Section 3.3 contains a discussion of good dredging practices).

1.5. 2 Baseline data and good dredging practices

Good dredging as practised in industrialised countries have been shown to rely on the quality and quantity of available baseline data. Optimum dredging interval; Environmental Windows; selection of appropriate dredging techniques; alternate (river bank) dredging; dredged waste treatment and disposal; and channel maintenance and mitigation have been recognised as the commonly practiced good dredging approaches.

The argument presented in this section is that good dredging practices could be achieved even in areas where conventional baseline data are unavailable or inadequate. Suggestions has been made on the use of TELK as an appropriate knowledge source in understanding baseline scenarios as well as well as EcLA in understanding the environmental consequences of dredging, especially in areas where livelihoods is significantly dependent on local ecosystems. EcLA could be used in planning for good dredging practices.

1.5. 3 Eco-livelihood assessment: how appropriate?

This section contains a review, of the concepts of ecosystem and livelihoods. Ecological systems have been recognised as complex and highly variable of which humans and their actions constitute an integral part. In addition, livelihoods of residents particularly in rural communities in the developing world have been demonstrated to be linked and dependent on the local ecosystems. Such scenarios in which livelihoods and ecological systems are interdependent require an environmental assessment approach that could adequately assess anthropogenic impact on the environment.

Eco-livelihood assessment (EcLA) is an adaptive approach that explores the principle of sustainable livelihood and the tenets of ecological assessment in assessing human impacts on the local environment that sustains livelihoods. Furthermore, EcLA integrates TK and TELK. TK and TELK have been shown as options for understanding localised environmental baseline and environmental issues that are of livelihoods significance.

1.5. 4 The place of traditional knowledge (TK) in environmental assessment

The concept and general application of TK as an approach for sustainable development has been presented. The specific benefit of the use of TELK in areas where livelihood is closely linked with local ecological systems has also been advocated. An argument has been presented that TK have a place in EA aimed at achieving the targets for equitable development as presented in the World Earth Summit in Johannesburg, South Africa, 2002 (United Nations, 2002).

The application of this wealth of knowledge based on long-term inter-relationship and interdependence of indigenous / rural people have been proposed as a viable knowledge source. This knowledge source could be used in building baseline scenarios in areas where baseline data are unavailable or inadequate, such as in most rural communities in the developing world.

1.5. 5 The study Area and field work

Brief highlights of the Study Area and the research approach have been presented. In addition, the sampling procedures as well as the constraints towards carrying out the field work of this research have been discussed. Social and ecological surveys have been carried out in four sample communities in the Study Area between January and August 2004. The fieldwork has been used to test the research hypotheses presented in section 1.2.

1.5. 6 Eco-livelihood baseline scenario of the Study Area

The results, analyses and discussions have been presented in the light of the research hypotheses. The result from the field work has been analysed using Excel spread sheet and Statistical Package for Social Scientists (SPSS 11). Other results from the social survey has been qualitatively analysed and presented. River use profile, livelihoods diversity, fishing and fishery and eco-livelihoods issues that have occurred or are part of the Study Area have been used in building the baseline scenario of the Study Area in the context of this study.

1.5. 7 Eco-livelihood assessment of dredging

Furthermore, TK, TEK and TELK has been used to understand issues about the dredging projects in the Test communities as well as understand the livelihood consequences of dredging in the Study Area. The ecological survey shows that dredging has ecological (using fish as indicator) impacts, which may be of livelihood significance in the Study Area.

1.5. 8 Conclusions and recommendations

EcLA as developed in this research have been adequately demonstrated as an appropriate environmental assessment tool in areas where there is high dependence on the local ecological system as livelihoods source and where baseline data are inadequate or unavailable. Recommendations have been made on the application of this adaptive EA approach, as well as recommendations of areas for further research and usage of EcLA. EcLA has been demonstrated as appropriate in the retrospective assessment of the consequences of inland river dredging in the Study Area.

1. 6 Chapter summary

Surface water resources are resources of common pool value and these resources have continually served for livelihoods sustenance particularly in rural communities in developing countries. Baseline data are unavailable or inadequate in most developing countries, which usually affect the validity of environmental assessment studies carried out in these countries. EcLA has been proposed as an adaptive environmental assessment tool that explores the use of TELK in understanding the local environmental baseline. In addition, EcLA integrates the principles of sustainable livelihoods and the tenets of ecological assessment in the assessment of impacts on the ecological system that are of livelihoods significance.

This thesis has been focused on investigating the validity as well as justifying the use of EcLA in investigating the ecological impact of inland river dredging that are of livelihood consequences in the Study Area. Ecological and social surveys has been carried out in the Study Area between January and August 2004 in four sample communities in the Study Area to investigate the validity or otherwise of the research hypotheses.

Chapter 2 Benefits and impacts of dredging

This chapter contains a review of the benefits, adverse impacts of dredging operations, and issues associated with natural habitat readjustment. Most of the available literature is about dragging in coastal areas, which may be the reason why most references in this chapter have been based on dredging in coastal areas.

2. 1 Background

River modification dates back from the earliest days of human settlement on the floodplains of the Nile, Indus and the Mesopotamian (Mesopotamian is an ancient region of southwest Asia between the Tigris and Euphrates rivers in modern-day Iraq) rivers; and human occupation and settlement on floodplains has increased steadily throughout history (Brookes, 1988). In its simplest form dredging consists of the excavation of material from a sea, river or lake bed, as well as the disposal of the dredged material. Dredging has been commonly carried out to improve the navigable depths of ports, harbours and channels (such as streams and rivers), to win minerals from underwater deposits, and or as a flood mitigation measure. Moreover, dredging may also be executed to improve drainage, reclaim land, improve sea defence or clean up the environment (Bray, *et al.* 1998). River dredging is one of the channelisation processes, but in the context of this thesis channelisation and dredging have been used interchangeably to mean the widening or deepening of water courses except where otherwise stated.

2. 2 Dredging: benefits, impacts and habitat recovery

Under the right circumstances, dredging may play a useful role in human developmental aspirations. However, the negative impacts of dredging are most often localised (Bray, *et al.* 1998). In industrialised countries national and regional benefits are commonly translated to localised benefits. The case is different in the developing world where national and regional development does not necessarily imply localised benefits (Tamuno, *et al.* 2003c). Therefore, the identification and determination of dredging consequences should transcend economic and environmental indicators; and should go further to address all localised issues related to dredging projects that may compromise the benefits from dredging.

It is therefore necessary that EAs and water resource management approaches in the developing world should facilitate the equitable distribution of the benefits from dredging projects to all stakeholders, particularly the “voiceless” and “powerless” residents of rural communities. The livelihoods of this stakeholder group are most often affected by dredging projects. The benefits of dredging are discussed in the succeeding subsections.

2.2. 1 Benefits of dredging

From the very beginning of human civilisation, people, equipment, materials and commodities have been transported by water, and dredging has historically been a development project aimed at meeting the rising demand for the use of the “aquatic highways” (Rivers, streams, canals and other aquatic habitats) for cost-effective transportation. Aquatic transportation is currently the most economical and environmentally friendly means of transportation, which is vital to domestic and international commerce (CEDA, 1999); dredging for the purpose of channel improvement has also served as a basis for socio-economic development (CEDA, 1999; Stolpe, 2001).

Furthermore, dredging projects has been carried out for various purposes, which are considered individually including the following:

- Improved navigational channel;
- Land reclamation;
- Socio-economic development;
- Flood mitigation measure; and
- Beneficial use of dredged material.

2.2.1. 1 Improved navigational channel

Dredging involves the clearance of aquatic vegetation and other in-stream debris to reduce the roughness of the channel and improve flow, thereby increasing the capacity and hydraulic efficiency of rivers. In the UK, dredging is currently carried out on a local scale by some organisations for navigation purposes (Environment Agency, 2005). Dredging is normally a temporary method of increasing channel depths for the purpose of navigation (Naturally river channels become replenished by silt as a result of sedimentation) (CIRIA, 1997). Therefore, maintenance dredging is required to sustain the navigational benefits of capital dredging projects. Box 2. 1 contains a summary of the historical perspective of the dredging of the Niger River in Nigeria for the purposes of enhancing the navigability of this important river. The periodic dredging on the river Scheldt, Belgium has facilitated shipping traffic in the river (Vandecasteele, *et al.* 2002). The navigational benefits of dredging cut across the developing and industrialised world. Niger River is located in a Developing country (Nigeria) and River Scheldt is situated in an industrialised country (Belgium). In addition, dredging is often carried out in the Niger Delta to improve accesses for oil exploration, marine / coastal transportation and other water borne commerce (Ohimain, 2004).

Box 2. 1 Navigational benefits of dredging the Niger River

Historically, the River Niger was first successfully dredged in 1965 by the Netherlands Engineering Consultants (NEDECO). Between 1978 and 1984, Westminster Dredging also successfully dredged the River Niger and demonstrated the technical feasibility of sustaining navigable conditions of the River Niger through dredging. The dredging project by Westminster Dredging enhanced the use of the waterway for transportation of goods. Presently a contract has been awarded for the dredging of the Lower Niger for the purpose of building inland river ports in northern Nigeria. The proposed project has, however, been hampered by opposition to the project by communities downstream of the proposed inland river ports, because of fears of the anticipated environmental impact of the proposed project.

The economic benefits of the dredging projects (in Nigeria) has been based on the premise that, water transportation, especially for low value, time insensitive commodities, is about five times more cost-effective than rail transport and about 5% of the cost of road transportation (However, this may not be the case in all situations). Therefore, in the absence of river dredging, the contribution of the Lower Niger to the transportation of high volume goods, for which it has economic advantage, will continually be low. Furthermore the temporary removal of water hyacinth (see section 7.4.3 for the consequences of water hyacinth on inland waterways in the Study Area) during dredging operations could also increase the ease of navigation.
(PTF, 1999)

2.2.1. 2 Land reclamation

Worldwide, land reclamation and dredging are a common practice in many estuaries (Van der Wal, *et. al.* 2002), and has been an important way of providing sands and gravels for construction and reclamation projects (CEDA, 1999; PTF, 1999). Since 1980, the demand, and the associated extraction rates, for such aggregates have significantly increased due to increases in population and demand for development. The mined aggregates from dredging works have been used for land reclamation, as construction materials, and to create underwater foundations (CEDA, 1999).

Presently land reclamation (The creation of new land or stabilising existing marshland from dredged materials) is a priority in many countries. For example, the only option for Singapore to expand its land area to accommodate its increasing population is to “create” new land from the sea. Creating new land from the sea can be possible in Singapore by using dredged materials reclaimed from the sea. This developmental option is technically acceptable as long as there is sufficient volume of suitable dredged material to create the required platform (Riddell, 2000).

Habitat creation, restoration and enhancement projects are among the most environmentally acceptable and technically feasible options for dredged material placement in modern ports and harbours. Several steps have to be undertaken in order to implement these beneficial uses of dredged material, such as a site impact evaluation for an individual project. Specifically, all of the proposed use of dredged material in the Port of New York (NY) and New Jersey (NJ) are viewed as technically and economically feasible (Yozzo, 2004). Table 2. 2 contain a summary of various alternative use of dredge material that has been explored in the New York and New Jersey area in the US.

2.2.1. 3 Socio-economic development

Dredging has been proposed as a development project to meet developmental aspirations, such as social economic development. Social economic development in the context of this research has been regarded to include: increased employment opportunities; and increased commercial activities.

The purpose of the proposed dredging of about 600 kilometres stretch of the Lower Niger River to a depth of about 2.5 metres is to promote the economic development in Nigeria (Wolf, *et al.*,2005). Dredging of the lower Niger has the potential of making the river navigable year-round, thereby boosting socio-economic activities in the area where inland river ports has been proposed to be located such as Kogi Sate, where four of the proposed ten inland river ports are to be located (This Day, 2002). The proposed dredging project would cut across approximately 50 communities along the River Niger (PTF, 1999; This Day, 2002), and will administratively, cover 7 states and 31 local government areas (LGAs) in Nigeria. Table 2. 1 shows the states and LGAs along the Niger that the proposed dredging covers. Of these seven states, only Kogi and Niger states would most likely directly experience long-term benefit from the location of the proposed inland river ports (permanent employment opportunities). This shows that inland river dredging projects usually directly impacts a wider area (upstream, downstream and project location) and people with different developmental aspirations.

Table 2. 1 LGAs that may be affected by the proposed dredging of the Niger River

State	Number of LGAs	Location	Expected benefits
Kogi	8	Upstream of ports	Long-term socioeconomic benefits
Niger	2	Upstream of ports	Long-term socioeconomic benefits
Anambra	8	Downstream of ports	Short-term socio-economic benefits
Bayelsa	1	Downstream of ports	Short-term socio-economic benefits
Delta	8	Downstream of ports	Short-term socio-economic benefits
Edo	3	Downstream of ports	Short-term socio-economic benefits
Rivers	1	Downstream of ports	Short-term socio-economic benefits
Total	31		

Modified from: (PTF, 1999)

Table 2. 2 Beneficial uses of dreadgeates (New York and New Jersey Harbours)

Beneficial use alternative	Placement capacity (MCY)	Estimated Cost ($/CY)	Potential environmental benefits	Environmental / other concerns
Artificial reefs (rocks)	Unlimited	24	Potential increase in near shore and offshore fish production	Navigation hazard (inshore reefs)
Landfill and Brownfield's remediation	100+	10 – 35	Habitat for upland bird and wildlife species	Trophic transfer of contaminants, human health concerns
Borrow pit reclamation	40	5 – 10	Improved benthic, hydrodynamic and water quality benefits	Potential loss of fish habitat, trophic transfer of contaminants, contaminant mobility
Intertidal wetland and mudflat creation	7 – 10	15 – 35	Point source effluent polishing, habitat for estuarine-dependent fish and wildlife species	Odour, trophic transfer of contaminants, navigation hazard, loss of shallow-water habitat
Filling dead-end basins	3 – 5	35	Hydrodynamic benefits and water quality improvement	Contaminant mobility, urban infrastructure concerns
Bird / wildlife habitat	1 – 3	7 – 10	Nesting habitat for wading and shore birds, mammals	Navigation hazard, habitat trade-off, trophic transfer of contaminants
Oyster reef restoration	0.5	5 – 15	Habitat for residents and transient finfish and crustaceans, water column filtration	Navigation hazard, trophic transfer of contaminant

Source (USACE, 2002)

Key: MCY – Million cubic yard; CY – Cubic yard

The EIA report (PTF, 1999), suggested that the proposed dredging of the Lower Niger could provide extensive job opportunities for the riverine communities (communities that are downstream of the proposed ports) during the dredging project phase. Furthermore, it is expected that the dredging companies would employ a variety of skilled and unskilled labour from these communities. Disposal of dredged spoil would generate the need for trucking to inland disposal sites. It is expected the dredging companies would employ local sub-contractors for such disposal operations (PTF, 1999). These job opportunities would be temporary and most likely last only during the project or its winding-up phase. Could this short-term socio-economic benefits justify the long-term eco-livelihood impacts of dredging on these riverine communities? Could these eco-livelihoods consequences be adequately measured? These questions have been addressed later in this thesis (Chapter 8).

2.2.1. 4 Flood mitigation

Flood defence is one of the purposes for executing inland river dredging projects (CEDA, 1999). The extensive floodplain of the Niger Delta is usually inundated for about six months annually, which has constituted one of the major livelihood limiting factors in the Delta and has constrained development (Tamuno, *et. al.* 2003b). The Niger floodplains get alluvial deposits from upstream areas and are as such very fertile for agricultural purposes. However, the use of this floodplain for agricultural purposes has been restricted because of the annual inundation. Therefore, the proposed dredging of the lower Niger could increase the time interval between reoccurring floods and reduce the severity of flooding, thereby reducing the loss of cultivable land due to flooding, thereby, enhancing agricultural productivity on the floodplains (PTF, 1999).

In the US, in an effort to control floods on the largest river in North America (River Mississippi), private landowners and the US Army Corps of Engineers have performed a wide range of river engineering activities, including: dredging, channel alignment; construction of levees; flood-ways; artificial cut-offs; bank revetments; and training dikes. These river engineering activities during the last 100 years has been aimed at re-structuring meandering river stretch in order to facilitate free flow and discharge in large rivers in the US and to control flooding (USACE, 2002).

Dredging could theoretically increase the capacity of the channel during flood events, by mechanically removing sediment from the river bed to increase the capacity of the river channel. Dredging could have positive environmental impacts through decreasing flood risks and possibly improving navigation (Environment Agency, 2005). In addition Brookes (1988), presented two examples of cases where rivers has been dredged as a flood mitigation measure. These examples are: in the Coastal Ranges in California USA, where farmers and ranchers dredged streams to control floods; and in the UK, where dredging has been carried out either for the purpose of making rivers navigable or for flood alleviation or agricultural drainage.

Box 2. 2 contains a summary of an appraisal of the technical and environmental feasibility of dredging as a flood mitigation option in the East Midlands, UK, based on two case studies by the UK Environment Agency (Environment Agency, 2005). Despite a variable Benefit / Cost ratio as well as Priority Score (priority score imply project preference and anticipated benefits), dredging has been regarded as environmentally unacceptable but technically acceptable as a flood mitigation approach in the UK.

Box 2. 2 Appraisal of dredging of the River Trent, UK

Willington and Weston - The dredging of river between Willington and Weston (15km) to a depth of 300mm could reduce water levels slightly for more frequent flood events (<25 years). However, it would have negligible impact on peak flood levels during the 1 in 100 year flood event. This has been identified as technical acceptable, but environmentally unacceptable due to potential impacts on biodiversity and riverside structures. This project has been estimated to have an economic cost of £5.3 million; a Benefit / Cost (B / C) ratio of 0.1; and a Priority Score (P.S.) of 4.8

Clifton Bridge and Holme Pierrepont - The dredging of the river between Clifton Bridge and Holme Pierrepont to a depth of 300mm through Nottingham, could reduce peak flood levels for all return periods by 300mm along the dredged reach, making this approach technically acceptable. This approach is environmentally un-acceptable and this strategy failed, however, due to significant disturbance of river and bankside habitats. This project has an economic cost of £3.8M; a B/C of 5.3; and PS. 24.
(Environment Agency, 2005).

2.2.1. 5 Beneficial use of dredged material

Dredged Material Assessment Framework (DMAF) recognises that about 90% of sediments from navigation dredging are unpolluted, and these may be considered for a wide range of uses (CEDA, 1999). Furthermore, dredged materials have been used extensively, to create or to restore large areas of wildlife habitat.

Beneficial uses of dredged materials include: wetland construction; borrow pit reclamation; landfill cover; habitat development or enhancement; beach nourishment; land reclamation, and amenity development or enhancement (Bray, *et al.* 1998). Box 2. 3 present a summary of the uses of dredged material for coastal defence and habitat creation in the UK. Furthermore, a variety of options for the use of dredged materials are available, and some of the main options have been listed below:

- Agriculture, horticulture, forestry;

- Habitat development or enhancement, e.g. aquatic habitats, bird habitats, mudflats, wetlands;
- Amenity development or enhancement, e.g. landscaping;
- Raising low-lying land;
- Land reclamation, e.g. for industrial development, housing, infrastructure and
- Production of construction material, e.g. bricks, clay, aggregates; construction works, e.g. foundation fill, dikes

(CEDA, 1999).

Box 2. 3 Using dredged materials for coastal defence and habitat creation

Several experimental intertidal recharge schemes have been carried out between 1993 and 1994 at the Parkeston Marshes Copperas Bay on the north bank of the Stour Estuary with the aim of using the coarse dredged sediments to protect eroding saltmarshes and the infrastructure behind these saltmarshes. About 250,000m^3 of dredged sands from Harwich Harbour has been sprayed onto the intertidal mudflats raising these mudflats by approximately 2m in height. This project was funded by the UK Environment Agency.

Post-project monitoring of the shore profile, sediments and animal communities shows that erosion of the foreshore has been mitigated and the wetland have naturally being restored. Within two years after the project a diverse benthic community have colonised the dredged material. However, due to the coarser nature of the dredged sands these communities are different from those previously inhabiting (biota re-adjustment). The change in benthic biota has been accompanied with reduced food supplies for feeding birds and foraging fish, but the new material may provide alternative habitats for breeding and roosting birds (Murray, 1994).

<u>2.2.1. 6 Summary: Dredging benefits</u>

Dredging, like many other developmental projects has benefits that are spread from localised to regional and national level. Appropriately designed and executed dredging operations are most often technically acceptable and have economic benefits. Potential benefits of dredging include: socio-economic development; flood mitigation; use of dredged materials for land reclamation; and improvement of navigational channels. Despite the above benefits from dredging, the negative consequences of dredging are generally localised.

2.2. 2 Potential impacts of dredging

Dredging, like every developmental project has environmental consequences, and these consequences are affected by the following factors, listed below:

- Magnitude and frequency of dredging activities;
- Methods of dredging and disposal;
- Channel size and depth;

- The size, density and quality of the dredged material;
- Inter-tidal area;
- Background levels of water and sediment quality, suspended sediment and turbidity;
- Tidal range;
- Seasonal variability and meteorological conditions, affecting wave conditions and freshwater discharges;
- Proximity of the marine feature to the dredging or disposal activity; and
- Presence and sensitivity of animal and plant communities (including birds; sensitive benthic communities; fish and shellfish)

(UK Marine, 2002a).

Major modification of the hydrological characteristics (such as channel depth, river discharge and velocity) of rivers, and substrate characteristics have changed or altered the nature of the interactions between rivers and their floodplains thereby adversely affecting aquatic biotic communities (Gore, 1989). These alterations usually result in environmental consequences (Balchand and Rasheed, 2000). Furthermore, channel dredging has been identified as one of the factors that has resulted in the environmental deterioration of Danube Delta (Pringle, *et. al.* 1993), the Okavango Delta (Ellery and McCarthy, 1994), and the Niger Delta (Nwankwo, 1996; Abam, 2001; Ohimain, 2004; Ohimain, *et al.* 2005).

2.2.2. 1 Hydrology and wetland / floodplain loss

Floodplain river habitats are among the fastest disappearing of all ecological systems (Hoggarth, 1999). Physical disturbance caused by dredging projects generally involves either the generation of noise, which may disrupt nesting / breeding activities, or damage of critical habitats. Disturbance of fish spawning grounds or their spawning seasons is one of the major categories of physical disturbances from dredging. Activities near bird nesting sites are likely to disrupt reproductive and parental care behaviours, which may lead to lowered hatching success rate or nest abandonment (Reine and Clark,1998). Lemly (1997) reported that, in the US, dredging for navigational purposes has disrupted the balance necessary for riparian wetlands to effectively intercept and moderate flows, and has resulted in water-quality degradation associated with storm-water and agricultural runoff.

Channel alteration may create shallow and unnatural flows, which may result in an unsuitable habitat for fish and may present topographical difficulties for fish migration (Brookes, 1988). In the Niger Delta, the long-term problems from dredging are beginning to emerge and perhaps the greatest impact is the alteration of discharge distribution, causing flooding in some areas and depriving other areas of water (Abam, 2001). The alteration of river discharge in the Niger Delta due to dredging is a typical example of inequitable distribution of the benefits of dredging; in this case mitigating flooding at one location, while depriving other areas from water which is necessary for the survival of riparian biota.

Dredging as a flood mitigation approach, could increase the flood return period, giving rise to drier terrestrial (non-aquatic) conditions in floodplains, denser vegetation, and an increase in woody dominance. A long-term change in water level could lead to major changes in riverine communities and species abundance diversity (Timoney, 2002). A study of 42 channelisation sites in North America revealed that channel modification destroyed the habitats of various organisms by removing the bank-side vegetation, encouraging bank instability, and preventing the development of a stable stream-bed (Little, 1973).

Dredging has caused widespread hydrological changes in the Niger Delta, such as salt water intrusion into freshwater swamps (Nwankwo, 1996). In the Delta about 200 km^2 of wetland has been impacted as a result of dredging coastal erosion and retreat, which have caused hydrological changes. Until the 1980s the Ogbia area (the LGA where this study was carried out) was a freshwater area, but saline water intrusion occurred after dredging operations in the Ogbia area, which has given rise to the dominance of mangrove vegetation over freshwater vegetation (Abam, 2001). In Elem-Sangana and Opobo channel areas (also communities in the Niger Delta), dredging may have been responsible for the incursion of saline water into otherwise freshwater or low brackish water areas (Nwankwo, 1996).

Similarly Oil prospecting activities in the Niger Delta created canals that separated habitats and cut off nutrient flows. For example dredging activities by Chevron Nigeria Limited resulted in salt water intrusion into an otherwise freshwater swamp forest, leading to the complete destruction of an area of 20 km^2 in the Opuekeba area of Tsekelewu (World Bank, 1995a). All the hydrological consequences that have been presented from various research projects in the Delta shows that dredging induced impacts are specifically localised, affecting the environment around the dredged stretches of rivers.

The dredging of the Boro River in the Okavango Delta, Botswana, resulted in a deep channel in the centre of the river, the removal of its natural meanders, and the deposition of spoil heaps along the river banks. This dredging project seriously damaged the natural vegetation in the Okavango Delta and provided a new and more hostile environment for indigenous plant species. In addition, there has been massive elimination of submerged and floating-leaved plant communities, thereby resulting in the encroachment by terrestrial vegetation into these traditionally aquatic habitat (Ellery and McCarthy, 1998).

It is an emerging reality in the US that physical alterations are having a far greater impact on the integrity of wetlands than are chemical and biological threats (Lemly, 1997). Analysis of wetland loss in coastal Louisiana from 1932 to 1990 by Turner (1997), using statistical analytical tools, showed that virtually all wetland loss has been caused by channelisation, that land loss was insignificant in the absence of channel modifications. The result above (loss of wetland) is therefore an indication of one of the consequences of dredging that needs to be investigated further to include the livelihood implication of such ecological modifications on the local catchments. This is based on the premise that local people (particularly in developing countries) may be dependent on wetland for their livelihoods.

Floodplains and backwaters provide spawning habitats and refuges for fish during periods of poor water quality in the main channel. Channelisation could bring about the isolation of the main river from its alluvial plain, elimination of access to backwaters, floodplain lakes, and marshes. These alterations have had a major effect on both the ecological diversity of the highly productive alluvial corridors and riverine fish populations, especially within tropical flood rivers (Gore and Petts, 1989). Lowering water levels could destabilise any bankside structures, some of which may be of historical importance. Dredging also has the potential to physically damage archaeological features (Environment Agency, 2005). This could be directly from dredging or by removing layers of protective sediments over these archaeological artefacts.

River dredging has been associated with reduced hydrological connectivity between rivers and their floodplains (Brookes, 1988; RSPB, 1995) as well as caused the loss of backwaters / back swamps, and significant decline in fish and other aquatic biomass (RSPB, 1995). This may negatively affect floodplains, which have been identified by Hughes and Rood (2001) as highly productive. Floodplains play an important role in flood attenuation and pollutants re-routing between surrounding areas and the river (See Hughes and Rood (2001) for details of the importance of floodplains).

Water-level changes may also cause changes in the vegetation, with loss of aquatic and wetland species and replacement by common terrestrial ones. Such changes could affect invertebrate communities (RSPB, 1995). Dredging and other engineering activities along the Danube channel have disconnected the river from its usual floodplain in Romania (Pringle, *et. al.* 1993). The use of vertical profiles of turbidity during spring and neap tides on November 14th and 22nd, 1997 showed that the extensive dredging in the Brisbane estuary, Australia has increased the estuary dry season flushing time significantly by more than 300 days. Hence, the pollutant attenuation capacity of the estuary has been significantly reduced (Hossain, *et al.* 2004).

Dredging of the swamps, creeks and rivers of the Niger Delta has caused further habitat fragmentation, created azoic conditions (devoid of living organisms) and loss of nursery grounds for migratory fish. For instance, along the Olero creek, in Nigeria, fragmentation of habitats in some areas has caused longer retention of flood conditions and creation of numerous water pools (Nwankwo, 1996). Back swamps and floodplains are good agricultural land that has been used for seasonal cultivation of subsistence food crops in the Central Niger Delta (Tamuno, 2001). Fragmentation of habitat may have serious livelihood impacts on such areas, where livelihoods are highly intrinsically linked to the local environment.

2.2.2. 2 Sediments and turbidity

The physical disturbances from dredging alone are often sufficient cause for concern and the impacts to ecological health might be even more extensive if the disturbed sediment contains elevated chemical concentrations. Specifically, suspension and dispersal of contaminated sediments could have ecological impacts that extend well beyond the time the physical effects caused by mechanical disturbances have returned to baseline conditions, particularly if persistent and bio-accumulative chemicals are involved (Su, *et al.* 2002).

One of the major environmental effects of concern when dredging and disposing of non-contaminated fine materials in estuaries and coastal waters is increase in turbidity associated with suspended sediments. All methods of dredging release suspended sediments into the water column, during dredging excavation as well as during the flow of sediments from hoppers and barges. In many cases, the locally increased suspended sediments and turbidity associated with dredging and disposal is obvious from the turbidity “plumes” which may be seen extending downstream from dredgers or disposal sites (UK Marine, 2002c). Increases in suspended sediments and turbidity levels from dredging and disposal operations may under certain conditions have adverse effects on marine floral and fauna by reducing light penetration into the water column and by physical disturbance (UK Marine, 2002c).

Pennekamp and Quaak (1990), identified four variables that affect the degree of re-suspension of sediments and turbidity from maintenance dredging and disposal, these are:

- The sediments being dredged (size, density and quality of the material);
- Method of dredging and disposal (see Table 3. 2);
- Hydrodynamic regime in the dredging and disposal area (current direction and speed; mixing rate, tidal state); and
- The existing water quality and characteristics (background suspended sediment and turbidity levels).

In general, the effects of suspended sediments and turbidity are generally short term and localised (lasting about 1 week after activity) and near-field (about 1km from activity site) (UK Marine, 2002c). However, increased concentrations of suspended solids and potential release of contaminants during dredging or disposal, and leaching of contaminants from disposal sites, may have longer-term consequences than the obvious aesthetic consequences (CEDA, 1999). The release of silt into surface water could significantly affect fisheries and other riparian flora.

Increased suspended sediments can affect filter feeding organisms, such as shellfish, through clogging and damaging feeding and breathing equipment (Brehmer, 1965; Parr, *et al.* 1998). Young fish are most vulnerable to suspended sediments, and increased fatalities of young fish have been observed in highly turbid water (Wilber, 1971). However, adult fish are likely to migrate from, or avoid, areas of high suspended solids, such as dredging sites, unless food supplies are increased as a result of increases in organic material (UK Marine, 2002c).

<u>2.2.2. 3 Fisheries and fauna</u>

The sustainability of biotic resources has been threatened by impacts from engineering modifications of aquatic habitats. Such modifications reduce fishery productivity and may produce drastic changes in the composition of the fish fauna (Hoggarth, 1999). The effects of dredging on aquatic organisms have been a source of environmental concern for several decades. One category of concern that has frequently arisen in connection with projects involving dredging for navigational purposes deals with mortality of fish and shellfish entrained during the dredging process (Reine, *et al.* 1998). Furthermore, the UK Environment Agency (2005), presented a report in which dredging has been described as an environmentally disruptive and unsustainable flood mitigation option, that can result in significant direct impacts on the channel and bed habitats, and their associated biota.

Channel modifications often cause changes in the water level. Reductions in normal water level could have serious effects on invertebrate communities not only within the channel but also along the river margins. In the short term, invertebrates may be stranded and subject to drying; more mobile species, such as water beetles, may be able to migrate; while less mobile species, such as molluscs, may be significantly affected (RSPB, 1995). In addition, the release of organic rich sediments during dredging and disposal can result in localised oxygen depletion in the surrounding water. Depending on the location and timing of the dredging, the anoxic condition may lead to the suffocation of marine animals and plants within the localised area or may deter migratory fish or mammals from passing through (UK Marine, 2002d).

Channel blockage, by the physical presence of the dredge and/or disposal operation or by the presence of a turbidity plume, have an effect on the migration of juvenile and adult anadromous fishes (Fish species that migrate between fresh and saltwater), thereby negatively affecting fish populations (Reine, *et al.* 1998). Mortality of aquatic organisms is differentially affected by the dredging season and the life stages of impacted organisms. However, information on the impact of dredging on Atlantic invertebrates is mostly lacking, inadequate and / or undocumented (Ault, *et al.* 1998; UK Marine, 2002c).

Phytoplankton productivity has been hampered by increased turbidity, as it interferes with photosynthesis by limiting light penetration (Bray, 1998). Benthic algae are particularly susceptible to inhibition resulting from decreased light intensity, and the clogging effects associated with dredging. An increased level of turbidity will probably affect fish gills as well as the membranes of filter feeding organisms (Brehmer, 1965; Bray, *et al.* 1998; Parr, *et al.* 1998). Short-term dredging impacts indicate that immediately after dredging there is a likelihood of inhibition or reduction of bottom fauna (Balchand and Rasheed, 2000).

Furthermore, dredging and related activities could disrupt fisheries and / or damage spawning grounds which may also have adverse impacts on key fishery resources and, to some extent, the fishing industry (Gebhards, 1973; Ault, *et al.* 1998). For example, the dredging of streams in Champaign County, Illinois, USA, resulted in an increase in silt accompanied by a reduction of aquatic vegetation, and elimination of habitats essential for fish production. This resulted in a reduction of fish diversity from 90 species in 1929 to 74 species in 1959 (Brookes, 1988).

Hopper dredging activities have affected five endangered species of sea turtles that occur along the south-eastern coast of the USA (Dickerson, *et al.* 1995). Based on a calculated annual shrimp population of 80 million, Reine and Clark (1998) estimated that total loss to shrimp population from entrainment during the course of a "typical" dredging project could range from 1.2 to 6.5 percent (Dickerson, *et. al.* 1998). In addition, dredging has been commonly associated with between 30 and 70% reduction of species diversity, a 40 to 90% reduction in population density and a similar reduction in the biomass of benthic fauna existing within the boundaries of dredged areas (Newell, 1998). Similarly, Hydraulic dredging can affect biota composition. Video survey shows that mortality rate of clams appear high two weeks post dredging in 1998 at the Scotian shelf, southeast Atlantic Canada (Gilkinson, *et al.* 2003).

Disposal of dredged sediments can cause short and long-term, as well as on- and off-site effects on macroinvertebrates (primarily lobster). Ecosystem (food web) effects may occur, as well as losses of recreational and commercial fish species can be expected. Furthermore, the nature and scale of the impacts on fisheries depend upon the site considered, the amount and nature of material to be disposed of, and the size of the mound created at a disposal site. Specifically, short-term effects are economic losses due to reductions in catch during the disposal period as a result of mortality to adult fin fish, shellfish, and molluscs (Grigalunas, *et al.* 2001). Furthermore, data compiled of fish harvests as at 1993, from the Danube Delta in Romania, showed that the fish catch of between 500 and 600 fishermen that use traditional methods dropped to about half after severe channel modification. This implies a significant livelihood consequences to fishers in the Danube Delta (Pringle, *et al.* 1993).

Inland River dredging could result in significant habitat alterations, and in many cases the numbers and biomass of fish have been reduced by up to 100%. Furthermore, a study of the Lost and Gordon Creeks, Canada revealed that there had been drastic changes in the numbers of various fish species between 1887 and 1938 in channelised reaches; while the dredging of a section of the Colorado River resulted in a 100% loss of fisheries in 1953 (Brookes, 1988). In the Niger Delta, following the dredging of an oil well access canal within the Benin River drainage area, leacheates that were trapped behind a dredged material back swamp were found to have a pH of 2.3 (a pH of 2.3 is highly acidic which does not favour most biota). The deposited dredged materials prevented tidal flushing, and a few months after several hectares of mangrove vegetation were killed followed by fish mortality (Ohimain, 2004).

In North America, the number of published works on the effects of channelisation on fish and fisheries far exceeds those concerned with other biological consequences. Habitat alteration and elimination of spawning and feeding grounds of fishes inevitably affects the species diversity (Brookes, 1988). The quantity of literature on channelisation and its effects on fish and fisheries could be related to the fact that the natural recovery period for fisheries takes a longer time than that of other aquatic flora and fauna.

Fisheries provide a livelihood source, and local people may be dependent on water resources for a wide range of livelihood purposes. Any impacts that affect biotic resources or the quality of surface water resources are therefore likely to have livelihood consequences, particularly in rural areas in the developing world.

2.2.2. 4 Livelihoods

There is paucity of information on the quantitative impact of dredging on livelihoods; most information has been descriptive, while some researchers have described the argument that dredging directly affects livelihoods as qualitative and subjective. The tributaries of the Niger River have been vital for navigational purposes and a source of fisheries to those living in the Niger Delta. Dredging of the Niger River may cause adverse ecological consequences by the destruction of agricultural lands and fishing grounds, hence affect the livelihood of residents of the affected communities in the Niger Delta (Roberts and Giya, 2002).

The proposed dredging of the Niger River (this is the most recent plan of dredging the Niger River) was stalled in 2002 due to political pressures from communities along the proposed dredging path, and based on the demand for an EIA by communities that would most likely to be adversely affected by the project (Roberts and Giya, 2002). However, in 2003 this dredging project was re-awarded by the Federal government of Nigeria, based on the government's interest in the project. Despite the re-awarding of the proposed dredging contract, about 200 communities in the Niger Delta are opposed to the project based on fears of associated negative environmental and livelihoods consequences (Olaniyi, 2003).

In the Okavango Delta, Botswana, changes in the distribution of water post dredging operation have resulted in the disruption of livelihoods for local people (Ellery and McCarthy, 1994). In the Niger Delta channel construction in the Apoi-Gbauraun flooded Gbauraun town, displaced over 25 thousand people and disrupted fishing activities. Fishing constitute a major livelihood source in the Niger Delta (Abam, 2001).

2.2.2. 5 Summary: Dredging impacts

Generally, change in hydrological regime, wetland / floodplain loss, sediment release and increased turbidity, adverse impact on aquatic biota, and livelihood consequences have been identified as the common impacts of dredging. However, these impacts of inland river dredging are localised compared to the benefits of dredging that could range from local to national benefits. If maintenance of rivers is not undertaken following capital dredging, these areas would naturally undergo habitat re-adjustment which will be associated with the establishment of a new balance in biodiversity (as a result of re-colonisation). Furthermore, Table 2. 3 contain a generalised summary of the impact of inland river dredging as a flood mitigation measure in the Midlands Region of the UK. The ranking of impacts have been in the range of -3 to +3 (major negative impact to major positive benefits; while # represents changes that are uncertain).

Table 2. 3 Environmental appraisal of dredging in the East Midlands, UK

Issue	Specific issue	Impact
Humans	Provision of goods and services	0
	Health and safety	-1
	Quality of life / Standard of living	#
Flora and fauna	Habitat and species	-3
Land and visual amenity	Land and visual amenities	-1
Water	Water quality	-3
	In-channel hydraulics	-2
	Water quantity	0
Land use	Built environment	-1
	Agriculture and forestry	0
Cultural heritage, Archaeological and material assets	Archaeological sites and monuments	-3
Transport and travel	Transport and travel	-1
Soil geology and hydrology	Geological and geo-morphological features and processed	1
	Hydrology	1
	Soil and land quality	#
Use of natural resource	Sustainable use	-3

(Environment Agency, 2005)

2.2. 3 Natural habitat recovery / re-adjustment

Streams and rivers have considerable natural recovery powers. The result of a number of fishery studies suggest that, in many cases, fish populations may never completely recover without some form of mitigation being undertaken (Swales, 1989). McCauley (1977), proposed that the term “recovery” should not be employed when studying re-colonisation processes after cessation of dredging, as “recovery'” implies a return to prior ecological abundance levels and pathways, which may have taken years to develop.

Changes induced by dredging may significantly alter the pre-dredging ecological pathways; even if the resulting aquatic biota return to its pre-dredging species abundance and diversity state, it may never return to its pre-dredging structure and internal integrity. Therefore, the term re-adjustment has been used in this thesis in preference to “recovery”. However, in some cases recovery has been used for specific reference to research outcomes by other researchers, for the purpose of not losing the information from these publications.

A study by Robinson, *et al.* (2005), suggested that the impacts of aggregate dredging and subsequent re-adjustment of the benthic biota are likely to reflect complex interactions between the rate of extraction, screening and the extent to which the resident organisms are adapted to environmental disturbance. This shows that there are inherent difficulties in the application of generic impact / re-adjustment predictions to dredged sites with varying environmental characteristics. Generally, the re-adjustment of disturbed habitats following dredging depends upon the nature of dredge site, sources and types of colonising organisms, and the extent of disturbance (UK Marine, 2002b).

Table 2. 4 shows a summary of research results on the degree of re-adjustment that has been achieved after channel modification. From this summary, it could be inferred that there is yet to be complete re-adjustment even 86 years post-modification. In the author's opinion, such long recovery or ecological re-adjustment periods after river modification imply a significant long-term impact on livelihoods. This is especially likely in rural riverine communities such as in sub-Saharan Africa (SSA) if residents depend on subsistence fisheries as a major source of their livelihood and primary source of protein in their diet.

Table 2. 4 Summary of biotic re-adjustment post-channelisation in the USA

River	Time elapsed since channel modification	Observation
Yankee Fork, Idaho	30 years	3% reduction in the productivity of bio-diversity compared to non-channelised sections of the same stream
North Carolina	40 years	20% difference in fish populations compared to non-channelised sections.
Blackwater River, Missouri	50 years	23% difference in fish population compared to unaltered rivers
Portneuf River, Idaho	86 years	17% reduction in fish population compared to unaltered river section

(Brookes, 1988) pp 140

Table 2. 5 Post dredging habitat sediment re-adjustment

Location	Habitat type	Physical Recovery time
Coos Bay Oregon (USA)	Disturbed mud	4 weeks
Gulf of Cagaliari, Sardinia (Canada)	Channel mud	6 months
Mobile Bay, Alabama (USA)	Channel mud	6 months
Goose Creek, Long Island (USA)	Lagoon mud	> 11 months
Klaver Bank, North Sea (UK)	Sands-gravels	1 – 2 years
Chesapeake Bay, (USA)	Mud-sands	18 months
Lowestoft, Norfolk, (UK)	Gravels	> 2 years
Dutch coastal waters (Holland)	Sands	3 years
Boca Ciega Bay, Florida (USA)	Shells-sand	10 years

(UK Marine, 2002b)

Furthermore, Table 2. 5 contain the outcome of a review of dredging works in coastal areas in selected countries. This shows that the rates of "recovery" of channel sediments following dredging in various habitats varied greatly, ranging from about 4 weeks to 10 years, but shorter than the re-adjustment time for aquatic biota (see Table 2. 4).

Furthermore, a study by Ellery and McCarthy (1994), shows that very little natural ‘recovery’ of the Okavango Delta floodplain, Botswana following the dredging of the Boro channel has taken place after two decades. Similarly, the ecological conditions of the Niger Delta are continuously adjusting to the changing patterns of discharge due to dredging, but the adjustment rates may be slow or fast or may involve irrecoverable losses due to anthropogenic habitat modification for the purpose of development (Abam, 2001). Box 2. 4 contain a summary of an example of faunal recovery post dredging at Port Valdez in Alaska. This shows that faunal re-adjustment is dependent on the severity of disturbance and timing of the dredging operation.

Box 2. 4 Post dredging faunal re-adjustment at the Port Valdez, Alaska

The shallow sub-tidal macrobenthos (large bottom dwelling organisms) at Port Valdez, Alaska, has been examined to assess faunal adjustment following disposal of dredged sediments over a three-year period. Prior to sediment disposal, resident fauna consisted of a relatively highly diverse species assemblage dominated by sessile (non-motile) polychaetes and bivalves. Six months after the disposal of dredged material, virtually all taxa present prior to the dredging operations became rare or absent while opportunistic taxa became dominant. Surveys performed eighteen months after sediment disposal indicated faunal re-adjustment was in progress; large, sessile polychaetes and bivalves were still present in low numbers after two and half years.

The trends in the faunal assemblage suggest that environmental conditions were still in a state of flux two and half years after the dredging event. The composition of a re-adjusted benthic community is influenced by the timing and severity of disturbance as well as by the reproductive biology and motility of the resident fauna.
(Blanchard and Feder, 2003).

2. 3 Chapter summary

The structural modification of river courses by dredging has both benefits and costs (consequences), which have not been equitably distributed. The adverse impacts of dredging operations are localised and most often borne by the rural populace who live and earn their livelihoods along or around the local surface water resources which is a CPR (Refer to section 1.4).

Dredging need not have adverse environmental impacts, if appropriate approaches are adopted (CIRIA, 1997). Appropriate dredging approaches could optimise the benefits from such projects as well as minimise the adverse impact on the environment of which man is an integral component. Principles of good dredging attempt to facilitate the equitable distribution of the benefits and costs of dredging among the stakeholders.

Chapter 3 Baseline data and good dredging practices

3. 1 Background

Historically the primary objective of dredging practices was to meet the target of technical efficiency of dredging operations and economic benefits with little regard to the environment. Good dredging practices, are aimed at reducing the potential adverse effects of development projects on the environment as well as optimising the benefits from these operations (NRA, 1994; UK Marine, 2002e). However, a precautionary approach should be considered in cases where adverse effects have been anticipated, to reduce or avoid the environmental consequences of dredging operations.

National economic growth does not necessarily result in equitable development. Economic growth may result in profits for a company or government, and it may generate some jobs, but that alone is not sufficient for furthering development, because it does not necessarily imply poverty alleviation in the developing world (Friends of the Earth, 2000). Obviously, Friends of the Earth is not an impartial source but there is a wealth of academic literature which makes the same argument. For example, some World Bank research acknowledges that economic growth and poverty alleviation are not necessarily linked. In a study of its lending in the poorest countries, the Bank acknowledges that poverty rates increased between 1987 and 1993 from 29% to 33% in spite of increased economic growth rate (World Bank, 1997).

Economic development alone is not a sufficient end goal for delivering development that is equitable (WCED, 1987; Friends of the Earth, 2000). Hence, it is necessary that good dredging practices be developed that are appropriate to the developmental aspirations in the developing world, by addressing the endemic issue of poverty. This requires the collection of relevant information / data that could help the planning and management of dredging operations.

3. 2 Baseline data

The knowledge base of African rivers is presently highly localised and largely out of date. This implies that data needed for the formulation of appropriate water resources management strategies are largely lacking in many Africa countries. Furthermore, the present lack of systematic study and lack of a core body of reference information for African rivers has been a serious constraint to assessing anthropogenic impacts on African rivers (Crisman, *et al.* 2003).

The lack or inadequacy of baseline data is not exclusive to the developing world. Ault, *et al.* (1998) for example, reported that in the US, where substantial dredging projects are annually executed, there is a paucity of data in most regions. The dearth of ecological data in some regions in the US may be as a result of the inherent difficulty in accurate sampling of biological resources during large-scale dredging projects. However, the relevance of baseline data to good dredging cannot be over emphasised.

LegCo (2001), recommended that prior to commencing dredging works, water quality monitoring should be conducted to provide a measure of the background levels, thereby enabling impacts due to the works to be more easily identified. LegCo (2001) also recommended that the actual impacts of the dredging project be measured once the works have started. In addition, the level of suspended solids in freshwater has been recommended by Environment Canada (1997), not to exceed 10% of the pre-dredging concentrations, and not more than 30% of the benthic population be removed during dredging operations. These requirements have been aimed at meeting the tenets of sustainable development. Hence, collection of baseline data could be considered as a prerequisite for good dredging practices.

Generally, good dredging practices are approaches aimed at making dredging less detrimental to the environment and optimising the benefits from dredging operations to the national or regional government. The justification for advocating good dredging in industrialised countries has been for optimising a balance between potential national / regional economic growth and environmental protection (CIRIA, 1997). “Hard science” information concerning rates of siltation, sediment characteristics, hydrological attributes, riparian components and ecosystem structure have been used in determining good dredging practices in industrialised countries.

However, due to the inadequacy or unavailability of baseline data in sub-Sahara Africa (SSA) countries the reliance of good practices on “hard science” information could be one of the constraints of directly transferring the paradigm of good practices as practised in industrialised countries to the developing world. This therefore calls for a paradigm shift and basis for the promotion of good dredging that could be very appropriate to the development aspirations in developing countries; make development projects as much as practicable equitable, as well as adopt appropriate data collection approaches to help in the design of appropriate good dredging approaches.

3. 3 Good dredging practices

Dredging today is a service industry, but since the 1970s and 1980s the dredging industry has faced huge challenges regarding the perceived impact of dredging on an increasingly fragile and vulnerable environment. The main concerns have been environmental issues such as disturbance of contaminated sediments, turbidity from dredging operations and disposal of dredged materials (see sub-section 2.2.2.2 for the discussion on impacts of sediments from dredging projects). However, the dredging industry has met most of these challenges by carefully addressing these issues with large investment in technology and equipment aimed at promoting environmentally sound dredging (Riddel, 2000). The realisation that the flora and fauna of rivers have been adversely altered may have given rise to a greater concern for ecologically sound river management. However, given appropriate management approaches, both economic and environmental management goals can be simultaneously pursued within the context of sustainable development (Gore and Petts,1989).

The good dredging practices that have been reviewed in this thesis are:

- Optimum dredging intervals;
- Environmental windows;
- Selection of appropriate dredging technique;
- Alternate dredging;
- Dredged waste treatment and disposal and;
- Channel maintenance and mitigation

This list may not be exhaustive but it covers some of the major advances that have been made to minimise the consequences of dredging operations, as well as enhance the benefits of dredging projects to a wider range of the stakeholders.

3.3. 1 Optimum dredging intervals

It is important when planning dredging works to carefully consider the optimum technical dimensions the project has been designed to achieve. The difference between the maximum and minimum acceptable bed levels, when divided by the average annual rate of loss of depth due to siltation, will give the optimum interval between dredging operations. This may be very variable, especially in water courses which receive substantial sediment input following heavy rainfall or where sediment deposition is relatively localised (CIRIA, 1997). The optimum interval between maintenance dredging is dependent on local site conditions, hence proposed dredging catchments should be individually assessed to determine the most appropriate interval between maintenance dredging campaigns.

Dredging at optimum intervals also maximises the socio-economic benefits of dredging projects. Determining optimum dredging interval may become difficult in the absence of appropriate and adequate data on the rate of siltation and specific catchments' environmental information. Therefore, a possible option to determining optimum dredging interval is to identify operational efficiency and local eco-livelihood situations. Management goal(s) and

TELK could help planning dredging project so that these projects may become less detrimental on the environment and livelihoods dependent on the environment.

To ensure that valuable aquatic resources are adequately protected and to prevent unwarranted delays in dredging, a more complete understanding of the scope and nature of seasonal restrictions is needed to assist in planning and implementing dredging operations (USAEWES, 1989). Seasonal restrictions placed on dredging operations are known as Environmental Windows.

3.3. 2 Environmental Windows

Environmental Windows are temporal constraints placed on the conduct of dredging or dredged material disposal in order to protect biotic resources or their habitats from potentially detrimental effects. Environmental Windows have usually been based on the simple logic that potential detrimental effects can be avoided by preventing dredging or disposal during times when important biological resources are present or most sensitive to disturbance (Reine, *et al.* 1998). Environmental Window periods are based on the logic that adopts the precautionary principle, rather than conclusive scientific information. The precautionary principle states that when there is reasonable suspicion of harm, lack of scientific certainty or consensus must not be used to postpone preventative / mitigative action(s). Environmental Windows differ by region, population type and habitat type, but are formulated to coincide with times when dredging activities could potentially adversely affect the aquatic biotic community of interest.

For several decades in the USA, there have been routine requests that various aspects of dredging projects be restricted to specified periods of the year (Reine, *et al.* 1998). In addition, whenever possible in the UK, dredging projects are planned to minimise adverse impact on the local environment, such as the avoidance of the nesting season of waterfowl, or the growing season of arable crops (CIRIA,1997). For appropriate Environmental Windows of sites to be established, the spawning grounds, seasons and periods of sensitive biological activity of ecological components that are potential at risk should be ascertained, as well as migratory periods and pattern. This approach has been aimed at ensuring that valuable natural resources receive adequate protection without compromising the need for economic efficiency.

In the USA, the majority of Environmental Windows constrain dredging operations during spring and summer months (March – September) to avoid potential conflicts with biological activities such as migration, spawning, and nesting. Consequently, many dredging projects in the USA have been restricted to winter months (USAEWES, 1989; Reine, *et al.* 1998; Aldridge, 2000). Furthermore, the restrictions on dredging operations are used to protect various types of aquatic biotic resources. The US Corps of Engineer Districts are often required to restrict or suspend dredging operations during a defined period to prevent real or perceived detrimental impacts on important species of invertebrates, fish, and birds. The magnitudes of these potential impacts may be speculative or not absolutely technically defensible, but are imposed nonetheless until new information becomes available to prove otherwise (USAEWES, 1989).

In addition, in order to limit levels of suspended sediments released from dredging during sensitive periods that may be detrimental to animals and plants near dredge and disposal sites. Dredging operations can be planned to avoid important breeding, migrating and spawning times, egg, larval and juvenile stages or periods of greatest growth. A recent coastal survey by the Great Lakes District of the US Corps of Engineer indicated that dredging has been delayed, or even cancelled because of potential effects of elevated suspected sediment concentrations on fish survival, reduction in aquatic species, and physical disturbance of spawning and feeding grounds. In addition, the most common subject of seasonal restrictions was related to either individual species or groups of sport and anadromous fishes. Other topics included endangered species (sturgeon, mussels), water quality, migratory waterfowl, and nesting birds (USAEWES, 1989). Examples of some general sensitive periods in the UK are summarised in the Table 3. 1.

Table 3. 1 Examples of sensitive periods for aquatic biota (The UK)

Type of organisms	Sensitive stage in life cycle	Period
Benthic animals	Spawning.	Spring.
	Highest growth rates (shellfish).	Early summer (May-July).
	Highest number of eggs and larvae stages (shellfish).	Early summer (March-July).
Fish	Migration of salmon and sea trout young (smolt) from rivers to the sea.	Spring and early summer.
	Highest numbers of eggs and larval stages.	Early summer.
Microalgae (Phytoplankton)	Highest growth rates (highest potential for algal bloom formation).	Between April and July.
Seals	Breeding.	Summer.

(UK Marine, 2002f).

Restrictions have historically been placed on dredging operations occurring in coastal systems. However, as dredging of freshwater navigable waterways increases, resource management agencies are imposing new restrictions resulting in contractual delays of dredging in freshwaters. Resource management agencies in the US often restrict the time and location of dredging / disposal operations to minimise potential impacts to important aquatic resources (USAEWES, 1989). In addition, it is important to be aware that the sensitive periods for different marine animal and plant species vary and in some cases, such as when also considering sensitive periods for over wintering waterfowl, this could restrict dredging periods to impossibly small windows of opportunity. In such cases it will be required to determine the most important period in the year to avoid, as well as measures to mitigate any adverse effects (UK Marine, 2002f).

These restrictions have constituted a major concern, because they create an added impact on the cost and scheduling of dredging operations. In many cases, the imposition of restrictions has been based on limited information relating to the behaviour and survival of species such as fish, birds, and invertebrates (USAEWES, 1989). However, as a result of the economic costs and restrictions associated with Environmental Windows, dredging engineers and proponent have advocated for careful consideration of all dredging techniques and the most appropriate techniques used based on specific catchments characteristics.

To address the issues of increased economic cost and restrictions associated with Environmental Windows of dredging. The solution would seem to carry out more research to gain a better understanding of the real effects of dredging, and further investigation into ways of mitigating the impacts of dredging. It will also be essential to communicate the results of the research in an effective way so that policymakers, decision makers and stakeholders understand, accept and support Environmental Windows (Burt and Hayes, 2005).

3.3. 3 Selection of appropriate dredging techniques

Environmental impact could be minimised and benefits from dredging optimised if appropriate dredging techniques are adopted. The factors that are usually considered for the selection of appropriate dredging techniques in the UK are: task definition; access; vegetation cover; season; quantities and sediment characteristics; disposal; security of machinery during dredging; and environmental issues. However, no dredging technique is appropriate for all situations, and the time / period of proposed dredging is one of the major determinants in identifying an approach that could be referred to as the most appropriate (CIRIA, 1997).

The dredging industry in industrialised countries has been affected by two major, but often opposed factors; market and the environment. The changes and development of dredger types since the mid-1970s have been market driven (Bray, 1998). Environmental protection is one of the emerging criteria influencing the selection of dredgers. However, in most developing countries, selection of dredging technique based merely on market forces and environmental protection, without regard to local livelihoods issues, may fail the test for equitable development, because most residents of rural communities in these countries depend on their local environment for livelihoods.

Dredging practice and equipment has evolved considerably in recent years in favour of increasing dredging efficiency and minimising the potential adverse effects on the environment (Bates, 1998; Bray, 1998). To some extent the environmental effects due to the re-suspension and settlement of sediments during the excavation process can be minimised by selecting the most appropriate method of dredging approach.

The characteristics of the dredging sites have a significant bearing on the type of dredger which can be used and on the extent that precautions to minimise sediment re-suspension are needed (Bray, *et al.* 1998). Table 3. 2 present a summary of the main dredging methods that are currently used in the UK. These methods have universal application, because the dredging business cuts across nations (Developed, Developing and Countries in Transition).

Similarly, both hydraulic and mechanical dredgers have generally been used in the Niger Delta. Hydraulic pipeline dredgers are mostly used for reclamation and maintenance dredging and in few cases where dredged material placement is at some distance from the dredging site. Mechanical dredgers such as buckets, draglines, swamp buggies and such are mostly used for the creation of new accesses (Ohimain, 2004).

3.3. 4 Alternate dredging

Enlargement of channels by modifying only one bank while leaving the opposite bank almost entirely untouched, is a common good dredging practice in many industrialised countries aimed at reducing the potential impact of dredging on the ecological system (Dickerson, *et al.,*1998). In the opinion of the author, inland River dredging carried out alternatively allows for recovery in the local catchments. This approach, if appropriately implemented, could enhance natural ecological recovery and presumably allow for faster habitat re-adaptation after the dredging project.

Table 3. 2 Summary of dredging methods used in the UK

Technique	Description	Benefits	Impacts
Grab Dredgers	Simple hydraulic dredging method involves the collection of sediments in a crane mounted bucket. Over-dredging can be avoided by using a 'cable arm grab' which closes horizontally.	Designed for different types of environment such as mud grab, sand grab, and the heavy digging grab.	Suspended sediments due to seepage due to poor closure and from overflow of barges or hoppers. Not suitable for dredging thin layers of sediment.
Bucket dredgers	A simple and the oldest type of dredger equipped with a bucket dredge that picks up sediment by mechanical means, often with many buckets attached to a chain. Difficult to operate but relatively accurate.	Reduced the spill of contaminated material during dredging and had a limited amount. The limited amount of water implies reduced cost of dewatering.	Suspension of sediment most likely during operations.
Backhoe dredgers	Can be used in marine environment, especially where ground conditions are difficult, such as shallow waters and confined spaces.	This method of dredging is highly accurate and which may be of particular benefit when working in environmentally sensitive areas or contaminated sediments.	Suspended solids can be released into the water column during excavation.
Trailing suction hopper dredgers 'trailer'	Trailer is commonly used for maintenance dredging in coastal areas. modifications can be made to equipment to minimise the release of suspended solids including. Increased under keel clearance to minimise propeller scour; use of degassing to maximise pump performance in organic materials; and use of underwater pumps to maximise solids concentrations.	Trailer dredgers can be used for maintenance dredging in environmentally sensitive areas if special care is taken. For example, they were successfully used for the deepening of the navigation channel in Lough Foyle, Northern Ireland without adverse affects to important shell fisheries in close proximity. Use of special dragheads which minimise sediment suspension.	Suspended sediments can be generated.
Water injection dredging	Water injection "Jetsed' is relatively new method of dredging which operates by injecting water into certain fine-grained sea bed materials, reducing their density to the point where they act as a fluid and flow over the bed through the action of gravity to lower levels.	The aim of this type of dredging is not to raise sediments into the water column, and where properly applied environmental affects due to suspended solids are restricted to the vicinity of the seabed and are minimised greatly. At present this practice is exempt from FEPA licensing, as the sediments are not raised from the surface of the water and therefore no disposal takes place. However, this situation may be subject to review.	Some re-suspension of sediment may occur. This option has exempt from FEPA licence as sediments are not raised from the surface of the water and no disposal take place.
Seabed levelling	This technique does not require FEPA licensing because there is no disposal with the use of seabed levelling. A seabed leveller is usually towed behind a suitable boat to flatten areas without lifting material from the seabed (which would have given rise to increased turbidity). The seabed is scraped to produce a more even profile	There is no available information on the potential for this dredging technique to increase levels of suspended sediments, although this is likely to occur during sediment movements.	Exempt from FEPA licensing, because there is no disposal at seabed.

(UK Marine, 2002f).

3.3. 5 Dredged waste treatment and disposal

The disposal of dredged material is a technically more challenging and expensive task than the dredging process. The treatment and disposal of dredged materials should be considered simultaneously for appropriate and acceptable good approaches to be implemented. For example, if dredging is by floating cutter suction dredger, which discharges via a pipeline, then the operations of dredging and disposal are a single continuous process and should be considered as such (CIRIA, 1997). Wherever important species are present or in large numbers, it may be practical to “rinse” dredged materials before disposal on the river bank. For example, dredging beds of reed sweet-grass from the River Beane in Hertfordshire, UK, by using the “rinsing” technique, resulted in a 40% reduction in the number of crayfish being removed (RSPB, 1995).

Material arising from the dredging of drainage ditches, channels, and rivers are most commonly disposed by spreading on the adjacent bank, or on adjoining agricultural land, or used to improve flood embankments. For instance, in the UK, as at 1997, the British Waterways disposed about 72% of dredged materials on bank-side or agricultural land, while disposal on dedicated tips, and to lagoons and off-site (third party) tips accounted for 10% and 18% respectively (CIRIA, 1997).

Most coastal communities in the Niger Delta are fishing villages, and they largely depend on an external food supply even in the midst of rich mangrove vegetation. The dredged materials could therefore be used to support farming. However, only crops that have been documented to thrive well in mangrove areas could thrive in acidic soils. Such crops include: rice; yam; pineapple; cassava; plantains and sugarcane, but toxicity tests need to be carried out to assure the public of the safety or otherwise of the crops. In addition, canal backfilling with dredged materials has been variously tested and found to be effective in mitigating dredged material impacts and wetland loss, as this has encouraged natural mangrove restoration (Ohimain, 2004).

The use of dredged materials for construction purposes has been illustrated by beneficial use schemes undertaken by the Port of Truro in the Fal and Helford rivers, in the county of Cornwall UK. The feasibility of mixing de-watered dredged material with china clay waste sands and other waste substances for composting to cap derelict land on two sites of former arsenic works has been investigated. Vegetation became established at both sites where no plants had grown before the placement of dredged material, with the first site taking just three years to become established through wind-borne seeding of native grasses, and the second sown site developing considerably more quickly (Brigden, 1996).

A number of schemes have been undertaken in Essex UK, to investigate the feasibility of using fine maintenance dredged material for intertidal recharge, whilst providing both the benefits of coast protection and habitat restoration. The experimental scheme undertaken on Horsey Island in Hamford Water was unsuccessful in that material sprayed on to a small area of salt marsh was washed off the recharge site by Spring tides. In Trimley Marshes on the Orwell Estuary, fine mud and sands were sprayed on to the intertidal mudflats in between gravel groynes placed perpendicular to the eroding shoreline with fencing and straw bales used to retain the material on the site (Carpenter and Brampton, 1996).

In addition, at Harwich Harbour, Essex, two experimental intertidal recharge trials have been carried out, each using over 20,000m^3 of maintenance dredged mud. In the North Shotley scheme in the lower Orwell Estuary, 22,000m^3 of maintenance material was pumped through a pipeline into a gravel bunded area to protect a sea wall and the internationally important freshwater wetlands behind. In the Horsey North and Horsey Beach scheme, 20,000m^3 of silt has been placed on a degraded marsh at Island Point to protect and regenerate saltmarsh (Woodrow, 1998).

Further initiatives for the future use of maintenance materials are being investigated by Harwich Haven Authority, as part of their proposals to provide a beneficial use for dredged material arising from the deepening of approach channels for the Ports of Felixstowe and Harwich. These schemes include intertidal recharge, dispersion of mud within the estuary system (trickle charge) and the placement of material behind seawalls to raise to intertidal levels (UK Marine, 2002d).

Generally, there is no universal disposal, or treatment methods for dredged materials that would be appropriate for all situations. The quality of the dredged material, the value of the proposed disposal sites and the potential or anticipated use of the dredged spoils should determine appropriate treatment and disposal methods. Another good dredging alternative is the maintenance of channel for technical efficiency of the project and mitigation to reduce potential consequences associated with dredging projects.

3.3. 6 Channel maintenance and mitigation

Habitat lost or degraded through channelisation could be rehabilitated by using habitat improvement techniques. Mitigation through habitat protection and restoration has gained much wider acceptance (Swales, 1989). Furthermore, channel mitigation measures have been effective in providing fish habitats comparable to the non-mitigated channels (Brookes, 1989). Maintaining natural river courses by appropriate designs has given rise to the preservation of the natural biotic community in dredged rivers with minimal consequences on the biota.

Enhancement could be achieved by providing some local resource or facility. Enhancement may not be connected to environmental mitigation, but may be provided for the good of a local community where a development project, such as dredging, has been undertaken for the benefit of the affected communities or region. For example when a fishing area is affected by dredging and a significant drop in the value of future catches is expected as a consequences; monetary compensation could be given to fishermen who use the affected area to earn their livelihoods (Bray, 1998). This approach is aimed at redistributing the benefits of dredging, thereby favouring intra-generational equity.

Mitigation attempts to reduce the adverse impacts of dredging on those most vulnerable to alterations of local ecological systems. The participation of those whose livelihoods are affected in the evaluation (either ecological or economic) and mitigation process could make this strategy more effective in reducing inequity associated with the costs and benefits of dredging.

3. 4 Good dredging: emerging issues

Box 3. 1 to Box 3. 5 present summaries of the consequences of dredging in selected industrialised and developing countries. Results from the industrialised countries (Box 3. 1 and Box 3. 3) have been based on quantitative analyses of research findings, while those from the developing world (Box 3. 4 and Box 3. 5) are qualitative / descriptive. The differences in the type of analyses are probably due to the fact that baseline data are scarce or unavailable in most developing countries; baseline data are required for quantitative assessment of impact and understanding trends. The implication may be that there is need for appropriate tools to be developed for assessing the quantitative impact of dredging in the developing world. The case studies presented in Box 3. 1 to Box 3. 5 generally represent assessments of the ecological consequences of dredging. Comparisons between the various summaries are shown in Table 3. 3.

Box 3. 1 Quantitative impact of dredging in the Providence Harbour, USA

There is increasing pressure on Ports Authorities all over the world to dredge channels for the purpose of meeting the capacity of deep-draft vessels. Disposal of dredgeate into coastal waters, have often been controversial because of the potential impacts on commercial and recreational fisheries. An integrated framework employing engineering, economic, and biological data and concepts has been used to estimate the economic costs of the disposal of clean dredged sediment on fisheries in the Providence Harbor, Rhode Island, USA. Short-term, long-term, direct, and indirect consequences of the disposal have been considered.

Conservative assumptions have been used in the evaluation of the economic cost of dredged sediment disposal on commercial and recreational fisheries for seven potential disposal sites. Damage cost across different sites ranges from about $256 thousand to $1.9 million. Furthermore, using a series of sensitivity analyses that recognises the uncertainties involved in cost evaluation have been undertaken. The sensitivity analyses show an increase (between $460 thousand and $3.4 million) in the general estimated disposal costs, but do not affect the costs across sites. In this study sensitivity analyses suggest that increases in mound area, recovery time, trophic structure effects, and use of a lower discount rate raise the estimated incremental costs of disposal, but do not substantially change the ranking of sites.
(Grigalunas, *et al.* 2001).

Box 3. 2 Quantitative impact of dredging (Orphire Bay, and the Bay of Ireland, UK)

Orphir Bay and Bay of Ireland, on the south coast of Orkney, were chosen as study sites because of the presence of extensive *E. arcuatus* beds, their similar water depth (3 – 6 m), sediment type (fine sand and broken shell), and the contrasting degree of dredging activity. Orphir Bay was selected as a control site because the seabed was known to be undisturbed. Mallow Bank in the Bay of Ireland is a site impacted by hydraulic and suction dredging and was extensively dredged in 1995 using a combination of hydraulic and suction dredge systems. In 1996 samples of the population of *E. arcuatus,* and dislodged razor clams *were* collected from Orphir Bay between 28 June and 8 July and from the Bay of Ireland between 9 July and 9 August. Analysis of variance has been used to compare the study locations.

The density and structure of the two razor clam populations suggest that dredging has directly affected the size-class structure of the population in the Bay of Ireland. The population structure in the Bay of Ireland in 1996 has been compared with data from a previous survey in a similar locality in 1989. McDonnell, (1992), reported that in 1989 33% of the total population of razor clams were >150 mm in length, whereas in 1996 (post-dredging) only 15% were > 150 mm. Normally, razor clam populations are skewed towards the larger size classes.
(Robinson and Richardson, 1998).

Box 3. 3 Quantitative impact of dredging in the Southern North Sea, UK

Multivariate analysis of the benthic community structure suggests that marine aggregate dredging, at the level of intensity employed in the Southern North Sea (Area 408) prior to sample collection, has had a limited impact on benthic community composition compared with that reported from studies elsewhere. This has been attributed to the likely rapid rates of re-colonisation by the mobile opportunistic polychaetes and crustaceans that dominate the macrofauna of the sandy gravel deposits at the dredged sited in Southern North Sea. Analysis of variance showed, however, that significant differences existed between the sample treatments in terms of species evenness. Dredged samples were found to have the lowest mean species evenness (0.71) when compared to non-dredged sites (0.77).

(Robinson, *et. al.,* 2005).

Box 3. 4 Qualitative impact of dredging in the Niger Delta, Nigeria

The dredging of a 2.5 km riverbed stretching from Asamabiri to Agbere-Odoni has deepened the River Nun and introduced higher flow velocities. These impacts, if sustained, could eventually result in drastic changes in the ecology of the entire Niger Delta. Canal construction in the Apoi-Gbaraun canal resulted in the flooding of Gbaraun town displacing over 25, 000 people and disrupting fishing activities. Until the 1980s, the Ogbia area immediately south of Otuoke (one of the sample communities of this study), was a pure freshwater area. The freshwater vegetation soon disappeared in preference to mangrove vegetation that is presently dominant in the Ogbia area due to the dredging operations. Furthermore, dredging by Chevron Nigeria Limited in the Opuekeba area of Tsekelewu resulted in salt water intrusion into an otherwise freshwater swamp forest, leading to the complete destruction of vast areas of land (over 20 km^2).

Between 1980 and 1988 there have been over 300 km canal network undertaken by government and oil companies in the Niger Delta. These operations have created new conditions that have affected both flow patterns, salinity and the ecosystem. The greatest impact may be the alteration of discharge distribution, causing flooding in some areas and depriving other areas of water.

(Abam, 2001).

Box 3. 5 Qualitative impact of dredging in the Okavango Delta, Botswana

4.5 km of the Boro River, Okavango Delta, Botswana was dredged between June 1971 and December 1974. The longer duration of this project has been due to mechanical problems with the dredger. Various conservation groups in Botswana vocally opposed the dredging of the Boro River based on the ecological consequences of dredging operations. The major and visible detrimental effect was the creation of spoil heaps of dredged mud and sand deposited along the floodplain of the river. Further major disturbances to the whole ecosystem were anticipated in view of the changes in the hydrological character of the river and creation of new and different habitats.

The dredging of the Boro resulted in a deep channel in the centre of the river, the removal of its natural meanders, and the deposition of the spoil heaps along the river banks. Despite levelling the spoil heaps by bulldozing, the effect of these deposits, gave rise to a new and more hostile environment for the natural succession of plant species. Consequently, large amounts of natural floodplain vegetation have been smothered by spoil dumping.
(Lubke, *et. al.*, 1984).

Table 3. 3 Summary of dredging impact

Box	Study Area / Country	Region	Research approach	Research approach and Analytical tool	Outcome
1	Rhode Island / USA	Industrialised	Quantitative	Date used: Engineering, economic and biological; Tool used: Conservative assumption and sensitivity analysis. Analyses that determine the impact of changing one or several variables in a model or analysis on the outcome of the analysis. A sensitivity analysis allows a range of reasonable inputs to be considered when there is uncertainty about the true value of an input (Harvard Center for Risk Analysis, 2005).	Conservative assumption: $256 thousand to $1.9 million cost of fisheries; Sensitivity analysis: $460 thousand to $3.4 million
2	Orphir Bay and Bay of Ireland, / UK	Industrialised	Quantitative	Methodology: Test and control sites compared; Sampling: Ecological sampling carried out; and direct physical measurement Analytical approach: Analysis of variance	Dredging affected the size and population of *E. arcuatus,* and razor clam
3	Southern North Sea, / UK	Industrialised	Quantitative	Methodology: Comparison with other research results Analytical approach: Multivariate analysis; analysis of variance	Multivariate analysis: limited impact on benthic community Analysis of variance: Significant differences in species evenness (an approximately 7.8% difference)
4	Niger Delta, / Nigeria	Developing	Qualitative	Description - No methodology or analytical method stated; The impacts has most likely been visually assessed (by observation)	Changes in ecology; changes in river discharge; impact on human settlement; and alteration of habitat characteristics;
5	Okavango Delta / Botswana	Developing	Qualitative	Descriptive – no methodology analytical stated; The impacts has most likely been visually assessed (by observation)	Alteration of habitat, ecological entity, and river discharge

Historically livelihood issues and traditional eco-livelihoods knowledge (TELK) are usually not taken into consideration during baseline data collection and in determining good dredging practices (the concept of TELK has been presented in section 1.4 and a detail discussion is presented in Chapter 5). There is the need for the introduction of survey approach(es) that allow for rapid data gathering, analysis and interpretation that explore approaches that is / are relevant to livelihoods in rural communities where dependence on CPR constitute a major livelihood source.

3. 5 Chapter summary

Good dredging practices in industrialised countries have been aimed at balancing national / regional economic growth and environmental protection, with assessment of potential impacts being dependent on baseline data. The good dredging approaches that have been reviewed are: dredging at optimum intervals; restriction of dredging to seasons or periods of local biotic activities (Environmental Windows); the selection of the most appropriate dredging technique; treatment and disposal of dredged material; and channel maintenance and mitigation. All these approaches has been aimed at reducing the environmental consequences of dredging as well as maximising the gains from dredging operations, hence have a place in water resources management for sustainable development.

The need for baseline data in assessment of the environmental consequences of dredging, as well as in determining good dredging practices, cannot be overemphasised. However, the absence or inadequacy of baseline data, particularly in the developing world requires approaches to obtaining information on environmental trends and seasonality. The use of the TELK available in sub-Saharan Africa could be a very appropriate option to obtaining baseline data that is necessary to identifying and developing cost-effective and livelihoods sensitive dredging approaches. Such good practices could make dredging more equitable to all stakeholders, particularly to those whose livelihoods may be negatively affected by dredging operations.

The focus, therefore, of good dredging practices in developing countries should be to optimise the balance between national/regional economic growth and the enhancement of livelihoods of those vulnerable to the potential impacts of dredging. This focus does not in any way imply that environmental protection is not relevant to sustainable development in the developing world. This is an approach recommended for the realisation of equitable development. There is also an urgent need for developing countries to develop appropriate data base on aquatic biota, which could contribute to sustainable water resources management.

Chapter 4 Eco-livelihood assessment: how appropriate?

4. 1 Background

This chapter presents an appraisal of the concepts of ecological systems, livelihoods and the relationships between ecosystems and livelihoods. This chapter has been structured by building a scenario detailing issues that eco-livelihood assessment is aimed at, addressing issues such as: livelihood diversity; anthropogenic impact of ecosystems; and the issue of the absence or inadequacy of baseline data as a limitation to environmental assessment, particularly in rural communities in most developing countries.

4. 2 Ecosystem

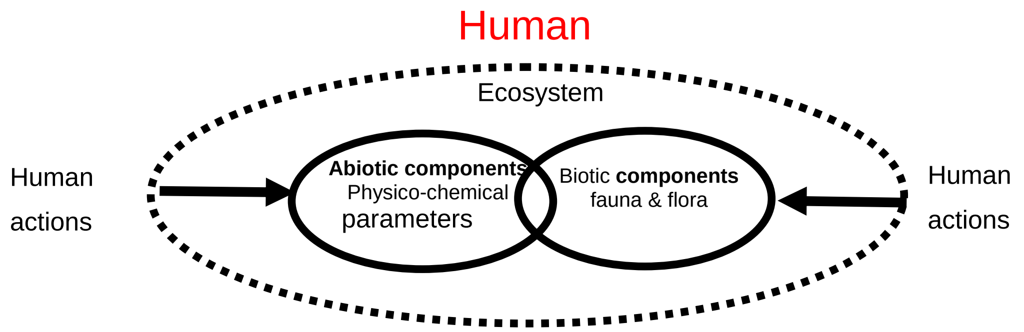
4.2. 1 Definition of ecosystem

Ecosystem is a unit made up of the interaction of living organisms and their physical environment (Miller, 2002). The concept of ecosystem needs to be broadened from what ecologist have traditionally considered as a system in which humans are considered as outsiders (Vitousek, *et al.* 1997), to a more holistic definition in which humans are the dominant integral component (Vitousek, *et al.* 1997; Rapport, *et al.* 1998b). The appropriate inclusion and use of human values has assisted in the holistic understanding of ecosystem functions and processes (Rapport, 2002).

Figure 4. 1 and Figure 4. 2, illustrate the traditional and natural concepts of ecosystems respectively. In both concepts, human actions constitute stress on the ecosystem, while the dotted lines show the ecosystem boundary, which in reality is not clearly defined or distinct. The traditional ecosystem concept has humans as outsiders, while the natural concepts have humans as part of the biotic ecosystem components. Figure 4. 2 is a more holistic representation of the concepts of ecological systems that considers all the factors that influence ecosystems properties.

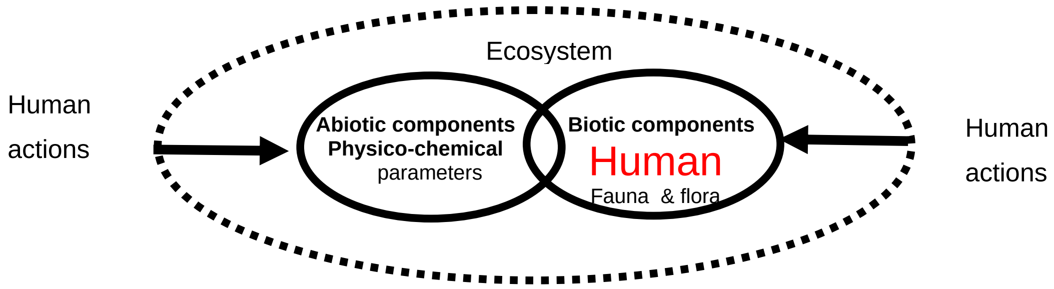
Therefore, human, anthropogenic actions and natural processes are the major factors that may influence and control the inherent characteristics of ecological systems. Therefore, a careful consideration of these natural process is fundamental to sustainable management of these vital resources (Al Bakri, *et al.* 1999).

Figure 4. 1 "Traditional" concept (Human and human actions external ecosystem components)



Source: (Tamuno, *et al.* 2003a).

Figure 4. 2 Natural ecosystem (Human as integral ecosystem component)



Source: (Tamuno, *et al.* 2003a).

4.2. 2 Characteristics of ecosystem

The obvious characteristics of ecosystems are that they are extremely complex systems, that are dynamic in time and space (O'Neill, *et al.* 1982; Kay, 1991; Arrow, *et al.* 1995; Landis, *et al.* 1995; O'Brien, 1995; Pavlikakis and Tsihrintzis, 2000; Karr and Chu, 2002; Folke, 2004). The complexity of ecological system may make it difficult for the effects of stressors to be easily understood or explained (Rapport, *et al.* 1985; O'Brien, 1995; Pagel, 1995). However, the use of an appropriate assessment and monitoring tool could help in understanding ecological systems.

Furthermore, understanding the linkages between ecosystems characteristics and the functions they generate is necessary to determine the importance of ecological systems (McGregor, 1993; De Groot, *et al.* 2003). Natural processes and ecological functions are the result of complex interactions between biotic (living organisms) and abiotic (chemical and physical) ecosystem components (See Figure 4. 1 and Figure 4. 2). Ecological attributes (such as, characteristics of soil, water, air and biota) have been used as direct and indirect indication of ecological status (integrity and resilience) and goods and services (natural capital) provided by these systems to man (De Groot, *et al.* 2003).

The attributes of water resources are functions of a dynamic and complex interaction of: the biophysical system; the social system; and the economic systems. In addition, there is increasing recognition that these systems are interlinked, and that both social and economic objectives are dependent on long-term health and sustainability of the natural environment (Al Bakri *et al.* 1999).

Furthermore, ecological systems do not exist in isolation, but are intrinsically linked. Each system's state is not only influenced by its own attributes, but the dynamics of other closely linked systems due to migrants (migratory species) (Barbier, *et al.* 1994; Belovsky, 2002; Karr and Chu, 2002). Therefore, ecosystem boundaries do not really exist but are convenient for study and assessment purposes. Also, neighbouring ecosystems have an impact on one another because migratory species, water and air cross from one system to another (Pavlikakis and Tsihrintzis, 2000; Belovsky, 2002). In response to the complexity and the indistinct boundary of ecological systems, environmental professionals have defined ecological problems in ways that could be easily addressed scientifically. Such delineation of ecosystem may be irrelevant to policy and to those whose livelihoods depend on such systems.

In summary, the complexity and high variability of ecological systems can make it very difficult to detect anthropogenic induced impacts. For example, natural fluctuations in marine fish populations are often large, with seasonal variability of population levels covering several orders of magnitude (U.S. EPA, 1998). In addition, Pagel (1995), reported that, despite over twelve years of field research on peregrine falcons in northern California, Oregon, and Washington, (all located in the USA) that each field season brings to the realisation of how little is presently known about the biology and ecological relationships of peregrine falcon. Nevertheless, there is the need to maintain biodiversity, ecological attributes and integrity (Folke *et al.* 1994). Peregrine falcons are widely distributed, swift-flying birds of prey *(Falco peregrinus),* having grey and white plumage, much used in falconry (training birds for hunting falconry) **-** Also called duck hawk.

4.2. 3 Ecosystems and anthropogenic activities

No two ecological systems are identical, and events that alter the structure or function of populations within ecological community become part of the history of the community and are difficult to erase (Landis, *et al.* 1995; Wang, *et al.* 2000; Rapport, 2002). Therefore, human impacts on the environment are not completely lost. These impacts on ecological systems may increase or decrease with time, or remain hidden, unmeasured or immeasurable for definite time periods.

Currently, ecological systems that have supported the earth's diverse complex of social systems are facing unprecedented changes (Garibaldi and Turner, 2004). These human-induced modifications of the environment have degraded natural resources, which have affected the stability of both the social and ecological systems on which society thrives (Ahmad, 1993; Hoggarth, 1999; Morley and Karr, 2002; Munns and MacPhail, 2002; Garibaldi and Turner, 2004).

Loss of biodiversity is one of the environmental impacts of greatest concern for sustainability of ecological systems (George, 1999). Some projects that may cause adverse stress on the ecosystem have been allowed to be executed, in a controlled manner, due to the socio-economic benefits of these projects (Wang, *et al.* 2000; Rapport, 2002). It is therefore necessary that the management of natural resources and developmental aspirations be done in such a way as to ensure ecological sustainability (Jooste and Claassen, 2001). Those most vulnerable to localised anthropogenic consequences from development in particular have experienced risks without receiving adequate benefits. Therefore, identifying the priorities of this stakeholder group should be one of the preconditions for determining equitable development.

However, although all life-forms in some way influence human survival and the diversity of species used in any given region is immense, some species have more direct relevance and recognition in peoples' lives and have developed particular significance or importance (Garibaldi and Turner, 2004). However, understanding the long-tern net cost and benefit of large-scale construction projects is often uncertain. This uncertainty in knowledge may be reduced by research, but in most cases it cannot be completely avoided (Wang, *et al.* 2000). Ecological impacts are highly uncertain because the probability of the presumed response of the system to anthropogenic actions is unknown and cannot be effectively estimated (Bojorquez-Tapia, *et al.* 2002). Furthermore, the inadequacy or unavailability of baseline data makes it even more difficult to fully understand impacts on ecological systems.

Biotic and abiotic ecosystems components are the most frequently used and established indicators of anthropogenic impacts. For example, fisheries are potentially impacted upon by many anthropogenic influences. These impacts can have a direct influence on the food resources, distribution, diversity, breeding, abundance, growth, survival and behaviour of both resident and migrant fish species (Whitfield and Elliot, 2002). Specifically, fisheries in the Danube Delta have long played a crucial role in the Romanian economy. However, engineering works have compromised the ability of the wetlands of the river delta to recycle plant nutrients delivered from the river, hence the ability of the river to retain the affluent biotic communities along its course have been reduced (Pringle, *et al.* 1993).

Furthermore, the diversity and abundance of fisheries of many local and regional aquatic resources are declining (Karr and Chu, 2002). There has been growing awareness of the need to manage ecosystems. Threats to ecosystems often reflect a combination of unsustainable exploitation of natural resources and the modification of natural habitats and hydrological regimes. These threats not only undermine ecosystem productivity, but also affect the long-term sustainability of livelihoods dependent on these systems. The links between poverty eradication and appropriate natural resource management are not yet well understood. However, it is clear the degradation of the ecosystems could be detrimental to those whose livelihoods depend on these systems (Soussan, 1998).

Karr (2003), states that the links between biology and human impacts came to the forefront more than a century ago when pollution, particularly from raw sewage, was found to harm living systems. However, much effort to trace the productivity and integrity of water bodies have focused on the use of chemical parameters. The assumption has been that chemically clean water was sufficient to protect the productivity and integrity of surface waters. This assumption has been proved wrong. It has been demonstrated that human influences on living systems are not limited to chemical aspects. Human influences on ecosystems have been divided into five major categories:

- Changes in energy sources;
- Chemical pollution;
- Modification of seasonal flows;
- Physical habitat alteration; and
- Shifts in biotic interactions.

(Karr, 2003).

The productivity, integrity or health, of aquatic biota is the best means of understanding and managing the impact of human activities on the Earth's water resources (Karr, 2000). Hence, human impacts on ecological systems require an appropriate approach to natural resource management that acknowledges the complexity and unpredictability of ecosystem behaviour (Tengö and Belfrag, 2004). According to Al Bakri (1999), the key biophysical impediments to sustainability of water resource management are:

- The violation of the biophysical principles governing the dynamic status of ecological systems – Ecological systems are complex and variable, and the attributes of these systems is a factor of the inter-relation between the biotic and abiotic component and human impacts on these systems;
- Human impacts that alter the balance of ecosystems;
- Ignoring reinvestment in living systems – for example reinvestment in business ventures and appropriate management have been responsible for sustainable business; and
- Disregarding the inherent limitations of the ecosystems – Uncontrolled human impacts on ecological systems could eventually result in the degradation (the point of degradation is the ecological stress limit) of these living systems.

Floodplain river systems are both highly valuable and highly vulnerable. The high values of floodplain river systems are due to: the high biological productivity; their high resilience to heavy exploitation levels; their biodiversity, and their multiple alternative livelihood opportunities. The high vulnerability of floodplains is due to: their often conflicting demands of different sectors (e.g. fisheries, agriculture, transport, forestry, water abstraction, water drainage, housing industry), and negative impacts from upstream sources (e.g. pollution and deforestation). Despite their high values, floodplain river habitats are now among the fastest disappearing of all ecological systems, due to human impacts on these systems (Hoggarth, 1999).

4.2. 4 Sustainable ecosystem

Historically, the concept of health (the state of well being) has almost exclusively been used in describing the state of individuals. However, over the past 50 years, this concept has been broadened to also apply to populations. Traditionally the health of individual organisms can be assessed easily using indicators, but the case is different for a population or community that requires an acceptable and scientifically defensible group of indicators. To apply the concept of health to ecosystems will require acceptance of a new group of indicators that are contextually specific, because ecosystems are inherently complex and variable (Rapport, 2002).

Like humans, ecosystems or landscapes could be “unhealthy”. An unhealthy person may be suffering a disease condition; while an unhealthy landscape may be degraded by loss of a few sensitive species or all of its vegetation; an unhealthy river may have depleted game fish populations, have no fish at all or only a few of the river's tolerant invertebrates as a result of anthropogenic consequences. Therefore, the healthiest of ecological systems are those that have experienced little or no human induced disturbances. Healthy ecosystems support the full range of biotic components, and processes characteristic of the region and therefore retain the capacity to regenerate, reproduce, sustain, adapt, develop, and evolve (Karr, 2003; Karr and Kimberling, 2003).

Unlike the physiological states examined in health sciences, ecological systems often exhibit considerable variation in their states over time even in the absence of anthropogenic impacts. These deviations from a desired state cannot be termed "unhealthy" because these may not have been brought about by any externalities (Belovsky, 2002). Rapport, *et al.* (1998a), identified three broad holistic dimensions (these can be measured using biotic and or abiotic ecosystem components) of ecosystem health, these are:

Resilience – ability to cope with, recover / readapt, after human induced consequences;

Organisation – maintenance of biodiversity and supporting and complex interrelationships between ecosystem components (biotic and abiotic components); and

Vigour – maintenance of the productive and trophic relationships that are attributes of the regional ecological system.

Healthy ecosystems indeed are the essential conditions for human welfare locally (Rapport and Whitfield, 1999). Chapman (1992) argued that healthy ecosystems have been defined based on human values as a grouping of different interacting species which has been recognised by a qualified ecologist as an ecosystem, and accepted as healthy by a consensus of stakeholders. A healthy ecosystem is likely to be a sustainable ecosystem, in the absence of external interference. In the context of this thesis healthy ecosystem is recognised as closely correlated to sustainable ecosystems, and has been viewed as such.

Generally, people place value on a natural resource based on the services provided by the resource. A loss or reduction in these services implies declining value. A "service" loss refers to the reduced opportunity such as for fishing, nature viewing, hunting, or natural water treatment (an example of natural water treatment is the removal of suspended solids by wetlands) due to anthropogenic stressors on the resources (Barnthouse and Stahl, 2002). Therefore, the basis for determining a sustainable ecosystem is usually both the degradation of the resource in question, and the services loss. This does not in anyway override the fact that ecosystems components have intrinsic functions that are of ecological significance.

It is therefore logical to define environmental sustainability as the maintenance of important environmental functions that are dependent on the capacity of the natural capital stock to provide these services (Ekins, *et al.* 2003). Ecological sustainability is an integral tenet of sustainable development. George (1999) simply defines sustainable development (SD) as "*development that improves the quality of human life while maintaining the carrying capacity of supporting ecosystems*". This definition favours balancing ecological service and ecological integrity and productivity. In the context of this thesis, sustainable development has been recognised as development that is equitable to all stakeholders; and a sustainable ecosystem is a system whose services and functions have not being severely compromised from providing equitable benefits to all that are dependent on the system.

Furthermore, sustainable development implies a positive interaction between humans and nature. This entails a relationship in which anthropogenic consequences on the environment remain within bounds so as not to destroy the health and integrity of these service-providing systems. In addition, ecologically sustainable systems are areas where ecological integrity and human welfare both increase over time or remain constant. In contrast, an unsustainable ecological system would thus be a place where human welfare has increased or remained high, while ecological integrity has decreased or remained low (Troyer, 2002).

Design and implementation of a sustainable management system of water resource is necessary so as to achieve a balance between the ecological integrity and productivity of ecological systems and the demand for socio-economic development. However, the main constraint to developing a sustainable natural recourse management approach is the reconciliation of long-term environmental objectives with the short-term political, social and economic needs (Al Bakri, *et al.* 1999).

4. 3 Concept of livelihoods

Human welfare relies either directly or indirectly on the natural resources and life support systems provided by healthy ecosystems (Troyer, 2002). Livelihoods are means or processes by which people earn a living and comprise the capabilities, and assets (both material and social resources) of individuals or family units. Singh and Gilman (1999) are of the opinion that livelihoods consist of a complex and diverse network of economic, social, and physical strategies.

In many developed countries the concept of a single wage earner in a career job is largely common. In contrast, the situation is markedly different for most families in developing countries. Livelihood structures are complex, and people earn their livelihoods in most cases from a variety of sources (probably as complex and variable as ecological systems). Livelihoods structure in most rural communities in developing countries usually revolve around the incomes, skills, educational qualifications and services of all members of the family.

The dependence of residents of rural areas of most Third World countries on ecological systems is critical to these residents, because most inhabitants of these communities earn their livelihoods directly or indirectly from the agricultural sector that is linked to the local or regional ecological units. Any significant alteration or modification of these natural resources could have severe livelihood consequences in such countries.

Livelihood diversification is a means of insurance against risks (Alderman and Paxson, 1992; Farrington and Lomax, 2001). It is a strategy adopted to minimise or mitigate risk, and to cope with vulnerability. The strategies of the rural poor of diversifying livelihood are for the purpose of safeguarding household income (Saith, 1992; Farrington and Lomax, 2001). The rural poor in developing countries earn their livelihoods in multiple, rather than specialised livelihood sources. Six main ways in which the poor earn their livelihoods are:

- Small-scale agriculture (farming, fishing and hunting);
- Local labour market;
- Long-distance labour migration;
- Forest product collection;
- Livestock production; and
- Self-employment in micro-enterprise

(Osman, *et al.* 2001).

Rural and indigenous people have continuously used localised natural resource system for satisfying their needs and improving their life, but development projects may adversely affect such an ecological service (Pavlikakis and Tsihrintzis, 2000). Such a scenario may give rise to the *“Tragedy of the Commons”* in which local livelihoods priorities are sacrificed for the purpose of national or regional socio-economic development (Hardin, 1963). Plans aimed at sustainable ecosystem should therefore, ensure an equitable distribution of benefits to all stakeholders, especially those dependent on the ecosystem for livelihoods.

4.3. 1 Eco-livelihoods and common pool resources (CPRs)

Jodha (1986), defines common pool resources (CPRs), as *'the resources accessible to the whole community or a village and to which no individual has exclusive property rights”*. In addition, Conroy (2002) describe CPRs as resources that are difficult to physically exclude potential users.

The environmental functions of natural resources could either be of “goods” or “services” values. The “goods” value are usually provided by the ecosystem components (such as plants, animals, minerals, etc.); and the “services” functions are related to human value (e.g. waste recycling) that are provided by the ecosystem processes (such as the biogeochemical cycling) (De Groot, 1992). Generally, CPRs are resources that can be used by members of the community, and are not managed or owned by specific individuals or groups.

CPRs have contributed substantially to the poor people's employment, income and assets accumulation in several direct and indirect ways. CPRs can reduce income disparities in the rural areas and serve as buffers when agriculture or other livelihood strategies fail in most rural areas of developing countries (Adolph, *et al.* 2001; Anwar, *et al.* 2001). The livelihood contribution of CPR depends on the availability and quality of these resources and the socio-cultural traditions of the communities. Hence the availability of CPRs and their importance varies from region to region and from social group to social group (Adolph, *et al.* 2001; Anwar, *et al.* 2001). CPRs are dynamic and are characterised by large seasonal and annual fluctuations in productivity, extent of exploitation, and role in poor people's livelihoods. The role of CPRs is generally high as they offer some cushioning to the rural poor, particularly during periods of economic stress (Osman, *et al.* 2001).

Furthermore, in most rural communities of developing countries, there is widespread dependence of the populace on ecological systems for their means of earning or winning a living. This may be because much of the world’s biodiversity occurs on or adjacent to traditional indigenous territories (Nabhan, 1997). CPRs such as pastures, forests, wastelands and water sources contribute significantly in some areas to the livelihood of poor people (World Bank, 1999).

Theoretically, relationships between society and nature within one place and between different places may range from mutualistic to competitive, but mutualistic, along with cooperative and commensal relations, are preferred if development is to be sustainable (Troyer, 2002). Open access CPRs such as forest and surface water resources are apparently unregulated with no effective ownership or secured rights. However, some groups, such as castes, communities or government agencies may lay claim to access, control and use of these resources which may result in ownership crises (Adolph, *et al.* 2001).

CPRs such as community pastures, forests, and wetlands, are an important form of natural resource endowment in rural areas of developing countries. CPRs, particularly in drier regions, are a major source of forage for livestock owned by resource-poor people (Conroy and Rangnekar, 2000). It may be almost impossible for humans to live without rivers. Historically, rivers have been the source of food, drink, domestic use, waste removal, transportation, commerce and recreation (Karr, 2000).

Furthermore, CPRs make important contributions to the livelihoods of a large proportion of rural populations in developing countries, not only of those countries, but also of the world. A significant proportion of the inhabitants of the planet are dependant on natural resources (Jodha, 1990; Chen, 1991; Iyengar and Shukla, 1999; Castillo, 2000; Adolph, *et al.* 2001; Osman, *et al.* 2001; Conroy, 2002). Approximately 95% of those involved in agriculture are inhabitants of rural communities in developing countries (Castillo, 2000). It is widely acknowledged that CPRs play an important role in the livelihood strategies of the poor. In India, for example it has been estimated that CPR contribute about US$5 billion annually to the incomes of poor rural households, or about 12% to household income (Beck and Ghosh, 2001; Osman, *et al.* 2001).

In addition to their farms, farmers often depend on natural resources such as, grazing land, forest, water bodies, rivers and streams. These CPRs comprise a sustainable part of the resource base of the economy and play a crucial role in providing goods and services to the rural population. Depletion of common lands can either be in the form of reduction in CPR areas, which could be easily quantified and documented, or degradation of the quality and density of CPRs that cannot be precisely and quantitatively assessed (Anwar, *et al.* 2001).

Surface water resources play a key role in most economic activities, particularly in developing countries, ranging from agriculture to industry, and fishing in many parts of the world is a major source of income for the poor (Adolph, *et al.* 2001; Osman, *et al.* 2001). For example, fisheries are important CPRs in a number of Latin American countries, not only contributing to export earnings, but also providing invaluable employment opportunities in coastal regions (Ibarra, *et al.* 2000). In the Niger Delta, fishing is a major livelihood component in the Niger Delta region of Nigeria (Sikoki and Otobotekere, 1999). In addition Lake Chad provides the basis of many thousands of livelihoods which depend on its seasonal fluctuations to renew fish stocks, farmland and rangeland (Sarch, 2001).

As populations grow, and with the breakdown of traditional management systems, available CPRs decline in both area and quality, the contributions of CPRs may decrease, but CPRs will continue to be important for generations to come, particularly for the poor in rural areas (Iyengar and Shukla, 1999; Beck and Ghosh, 2000; Jodha, 2000; Adolph, *et al.* 2001; Conroy, 2002; Gupta, *et al.* 2003). In situations where CPRs have become severely degraded their rehabilitation may even increase the size of the benefits that may be derived from them. Therefore, increasing the stress on CPRs tends to increase the likelihood of conflicts over access to these resources.

This in turn suggests that approaches are required that can address conflict situations about CPRs (Conroy, 2002).

Some CPRs are used by specific user groups defined by gender, occupation and caste (for example mining of clay from CPR lands by potters). The productivity and diversity of CPRs to some extent determines the pattern of usage of CPRs. For example, educated and skilled individuals are likely to be less dependent on CPRs. On the other hand, a highly productive CPR may be subjected to increased pressure from privatisation, from the elite, eventually leading to access being denied to CPRs by the rural poor (Osman, *et al.* 2001). There is a lack of formal involvement of both Government and community-based organisations to manage water as a CPR. A strong political will is necessary to allocate water as a true CPR by breaking the CPR-PPR (private property resource) boundary, to the benefit of the landless and the poor (Osman, *et al.* 2001).

Generally, some of the key features of CPRs in rural areas of developing countries are as follows:

- CPRs are important to the rural poor in the Developing World, particularly in the lean or pre-harvest season, or at times of environmental stress;
- Women are involved in accessing and using CPRs, and are not usually excluded from the management of CPRs;
- CPRs are of greater importance to the poor than to the rich and elites;
- Poor people are being progressively excluded from these resources by privatisation and commercialisation;
- Indigenous institutions for CPRs management are under strain due to modernisation and globalisation pressures, and conflicts between users are apparent; and
- The extent of influence of the poor on such indigenous institutions is limited.

(Nunan, *et al.* 2002).

Water has been a natural resource with which the livelihoods of both the rich and the poor are directly or indirectly dependent (Beck and Ghosh, 2000; Gupta, *et al.* 2001). Until the early 1970s, the Swampy Cree community of Southern Indian depended on commercial fishery. In 1970, the outflow of the lake was dammed; raising the water level by several metres and the original location of the community is now submerged. Commercial fishery was adversely affected and there has been low fish catches, and poor fish quality. The community was relocated to a place with modern houses and a recreational complex. However, the recreational facilities do not seem to have replaced fishing, trapping, and hunting as a centrepiece for these people's lives. Poverty, depression, and alcohol abuse have resulted (Rosenberg, *et al.* 1995). Due to the failure of such top-down management strategies, there has been active interest in promoting community-based management of CPRs (Muller and Vickers, 1996).

4.3. 2 Sustainable livelihood framework

The concept of well being has been given various interpretations: to some researchers it is a state of mind, by others as human capability for satisfying needs (Chiesura and De Groot, 2003). Despite the weak agreement over what constitute human needs and well being, there is the need to appropriately extend the benefits of today's benefits to future generations. See section 1.4 for the explicit definition of livelihoods and sustainable livelihoods.

"*A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural supporting resource base*" (Carney, 1998). Based on the understanding of livelihood systems and strategies, Singh and Gilman (1999), defined sustainable livelihoods as those derived from people's capacities to exercise choice, access opportunities and resources, and use them in ways that do not adversely affect the options of others to make their living, either now, or in the future. In the context of this thesis well being and sustainable livelihood have being used interchangeably to imply the state of guaranteed livelihoods or a state in which human livelihood are able to meet their socio-economic needs.

The livelihoods approach puts people at the centre of development which could increase the effectiveness of development (DFID, 2000; Nunan, *et al.* 2002). At a practical level, sustainable livelihoods framework is an approach that:

- Starts with an analysis of people's livelihoods and livelihoods trends;
- Fully involves people and respects their views, as expressed in their traditional knowledge (TK);
- Focuses on the impacts of different policy and institutional arrangements upon people / households / communities rather than on resources;
- Stresses the importance of influencing policies and institutional arrangements for the purpose of poverty reduction; and
- Aims at supporting people to achieve their own livelihood goals

(DFID, 2000).

Natural capital is one of the five principal capital that make-up the sustainable livelihood framework (see DFID 2000 for details of the sustainable livelihood framework). The Natural capital provides the material, energy, processes and information which people combine to produce and accumulate other capital stocks – from which are derived positive livelihood outcomes. Biodiversity represents a major part of natural capital and should therefore be seen as a means of contributing to sustainable rural livelihoods (Koziell, 1998). The sustainable livelihood approach stresses the need for higher level policy development and planning to be informed by experiences and knowledge gained at the local level. This may increase the overall effectiveness of policies and simultaneously give local people a stake in policy and development (DFID, 2000).

The livelihoods approach is flexible in application, but it does not mean that its core principles (People-centred, holistic, dynamic, building on strengths, macro-micro links, sustainability) should be compromised during application of this approach. The sustainable livelihood approach has historically successfully been used since the mid-1980s and has been used in a number of poverty reduction strategies by many development agencies (DFID, 2000).

Furthermore, the sustainable livelihood approach has aimed at refocusing the objectives, scope and priorities of development for the purpose of poverty reduction (Ashley, *et al.* 1999; Neefjes, 2000). The livelihood approach attempts to gain a holistic understanding of what shapes people's diversified livelihood strategies and how the various factors can be adjusted so that, taken together, they produce more beneficial livelihood outcomes (DFID, 2000; Nunan, *et al.* 2002).

The sustainable livelihoods approach recognises the importance of natural environment (particularly CPRs) to the rural poor, and focuses on supporting policies and actions which promote equitable use of these vital resource by promoting more secure access to, and better management of, natural resources (DFID, 2000). A considerable proportion of the world poor live and earn the livelihoods in vulnerable areas such as floodplains, and halving this proportion by 2015 (one of the millennium development goals MDGs) may be daunting. Adopting the holistic "resultant vulnerability" approach in the flood mitigation and in developing appropriate and effective poverty reduction strategies could improve the present trends towards achieving this MDG in developing countries. (Tamuno, *et al.* 2003b)

4.3. 3 Livelihoods and CPRs: emerging issues

CPRs plays a major role particularly in rural people's livelihoods and coping strategies in marginal and vulnerable areas, but the level of contribution of CPRs to livelihoods varies from place to place. However, the contribution made by CPRs and other coping mechanisms associated with them has declined in many areas, and in some cases have altogether disappeared due to anthropogenic consequences (Adolph, *et al.* 2001).

Maximising the net benefits of the declining CPRs requires rehabilitation of these vital resources. Researches are needed to fill this knowledge gap, so that policymakers and programme implementers have a sound basis for prioritising investments and ensuring that public funds are judiciously spent on projects that could bring about more equitable benefits (Adolph, *et al.* 2001). Therefore, the use of appropriate environmental assessments tools is necessary for understanding the environmental consequences of anthropogenic impact on CPRs and livelihoods. This understanding is relevant so that policies and development strategies could be developed and implemented that would have widespread benefits and hence be sustainable in the long-term.

4. 4 Environmental assessment

This section contains the features and aims of environmental assessments as a general tool designed for determining the environmental consequences of development projects or human activities on the environment. Environmental impact assessment (EIA) has been recognised as a legal prerequisite for conducting projects that may have adverse impact on the environment. In contrast, environmental assessments (EA) are tools for understanding human impacts on the environment or monitoring environmental changes, but which may not be a legal or regulatory pre-requisite for project approval. Furthermore, EIA have defined structures, while EAs are usually designed for specific purposes without any universal structure.

One major aim of EA has been to ascertain the nature of the existing characteristics and conditions of the environment (CIRIA, 1994). EAs have traditionally been confined to "scientific" facts and figures about the environment. Environmental professionals have carried out and written EA documents without regard to the values and perceptions of other environmental stakeholders.

It is an emerging reality that the quantity and quality of scientific data alone will usually not provide a clear undisputed solution to most environmental problems (Alton and Underwood, 2003). Furthermore, EAs have been designed to identify and predict anthropogenic impacts: on the environment; on human health; livelihood, as well as interpret and communicate the information about these impacts to environmental managers (Alho, 1992; Toth and Hizsnyik, 1998; Bella, 2002). It is therefore necessary to incorporate rational "social values" with available "scientific" information in the assessment processes in order to address societal environmental issues, which more or less holistically address all environmental issues.

EA professionals are presently faced with the challenge of acquiring relevant scientific information that will be more relevant in the decision making process, and that can be understood and appreciated by all key stakeholders (Alton and Underwood, 2003). The purpose of developing EA approaches has been to understand the environment and the potential consequences (pre-project assessment) and or actual consequences (retrospective assessment) of development projects on the environment (Gough, *et al.* 1998).

CIRIA (1994), recommended that EA statements should include the following components:

- A description of the proposed development project;
- Identification and assessment of the effects of the proposed project on the environment;
- A description of the effects on the environment that are significant;
- A description of the mitigation measures; and
- An explanation of technical terms.

The above list is, however, generic. It is the responsibility of environmental professionals involved in the EA process to decide the specific structure of the EA report. EA should be designed and carried out in such a way that the EA statement can be appreciated and understood by all stakeholders, and appropriately addresses all relevant environmental issues of interest.

4.4. 1 Why environmental assessment (EA)?

Environmental impact assessment (EIA) is the major environmental assessment (EA) tool from which other assessment protocols or procedures have been developed, and in some cases adapted, to address specific environmental issues. A concise description of EIA as a typical EA tool is presented in this subsection. (Canter, 1996) defined EIA as *"the systematic identification and evaluation of the potential impacts (effects) of proposed projects, plans, programmes, legislative actions relative to physical-chemical, biological, cultural, and socioeconomic components of the total environment"*. Therefore EIA reports and statements could help proponents of development and environmental managers in project planning and implementation in ways to achieve the tenets of sustainable development.

The core aim of the EIA has been to protect the environment from anthropogenic impacts associated with project implementation through:

- Predicting the nature and extent of impacts arising from development projects;
- Assessing the acceptability of these impacts;
- Identifying appropriate mitigation measures, that can be included into the project design, so as to avoid, minimise, and mitigate adverse impacts; and

- Designing a comprehensive programme of environmental monitoring and audit (EM&A), so that project impacts can be restricted within limits acceptable to stakeholders.

(LegCo, 2001).

Drawing upon the wide range of knowledge available among environmental professionals and stakeholders is one of the aims of EIA. Such an initiative has been for the purpose of the formulation of informed and effective environmental decisions that could be socially and environmental relevant and understood by environmental managers (Canter, 1996; Toth and Hizsnyik, 1998). These goals are still relevant to environmental assessment even after over thirty years since the EIA system was first established in the United States of America (USA) (in the early 1970s).

The cost of EIA often depends on, the stage of the project the assessment is undertaken; the nature of problems that are identified and how much analysis is needed. Furthermore, the cost of analysis is dependent on the scale of the project under investigation; its relation to resource problems; and the availability of baseline and other relevant data. Olokesusi (1992), proposed that ideally 0.5 - 1% of the project cost be set aside for the purpose of EIA. The exact percentage of project cost that may be set aside for EIA may vary from project to project and region to region.

According to Barret and Therivel (1991), an ideal EIA should:

- Apply to every project that is expected to have adverse environmental consequences, and address all impacts that are expected to be significant;
- Compare alternatives to a proposed project (including the no development or “do nothing” option);
- Management techniques, and mitigation measures;
- Result in a clear environmental impact statement (EIS) which conveys the importance of the anticipated environmental impacts and their specific characteristics, to non-experts and experts in the field;
- Include broad public participation with transparent administrative review procedures;
- Be timed so as to provide information for decision making;
- Have recommendations that are enforceable; and
- Include monitoring and feedback procedures

However, ideal situations are rarely achievable in real life. Those involved in the EIA process should therefore adapt the generic ideal scenario to suit their situation, without losing the main tenets of EIA. The tenets of EIA that should not be lost are: the identification of project impacts (predicted or actual); evaluation of all project options; the “do nothing scenario; mitigation and management options; and procedure for EM&A.

4.4. 2 Environmental assessment and developing countries

In developing countries, environmental problems that have arisen as a result of anthropogenic activities are increasingly becoming an issue of economic and political interest (Agarwal, 1997). Furthermore, there is an absence or inadequacy of baseline data due to the dearth of scientific research in most Third World Countries. There is therefore limited reliable scientific data available for the purpose of planning for equitable development aimed at socio-economic growth (Agarwal, 1997; Kwak, *et al.* 2002).

The prediction of the magnitude or the likely impact of a development project and the quantitative evaluation of the significance of anthropogenic impact on the environment requires specialist skills and a thorough understanding of the environment under assessment. However, the lack of technical expertise, weak institutional structure, and financial constraints are limitations to the quantitative assessment of environmental impacts in developing countries, and Sub-Saharan Africa in particular.

The above statement has been buttressed by a report by Lee and George (2000), that South Africa is the only Sub-Saharan Africa country that has a generally applicable EIA system; while several other Sub-Saharan countries have EIA legislation or procedures that are at early or developmental stages of implementation. In Nigeria, for example, EIA is evolving in a somewhat haphazard and unstructured manner (Olokesusi, 1992). Box 4. 1 contains a summary of an example of the situation of environmental assessment in Nigeria.

Box 4. 1 Environmental assessment and dredging: A Nigeria Scenario

In Nigeria, until recently, there were no regulations guiding the placement of dredged materials in wetlands. Enforcement of regulations is very weak, hence there were cases where dredging was carried out across wildlife sanctuaries, cultural sites and other protected areas. The Department for Petroleum Resources, the federal government’s organ responsible for regulating the management of petroleum exploration and allied processes had mandated that it is the responsibility of the lessee to manage the dredged materials generated during exploration and production activities and recommended an EIA study for any dredging activity exceeding a cumulative area of 500 m^2 (DPR, 2002). Ideally, if these provisions were strictly adhered to, the issues of disposal and treatment of dredged materials would have been adequately addressed in the EIA. Unfortunately, because of the subjectivity of impact assessment / evaluation process dredged material management is still largely unaddressed in most EIA reports in Nigeria.
(Ohimain, 2004)

Castillo (2000), advocates the formulation of better and more efficient strategies for the maintenance of ecological systems in Developing Countries. Such strategies should be of livelihood significance to residents of rural communities, and require the integration of information from environmental professionals and the perceptions of rural resource managers. This therefore calls for the design and implementation of assessment protocols that are locally relevant, flexible, transparent, iterative, tiered, as well as allow for the integration of livelihoods values into the EA process. EA approaches that have the above properties could ensure the sustainability of ecosystem dependent livelihoods; of which eco-livelihood assessment is one promising EA approach. Eco-livelihood assessment is an EA tool that integrates the tenets of sustainable livelihood approach and ecological assessment, as well as explores TELK in understanding baseline scenario.

4.4. 3 Environmental assessment: emerging issues

The main purpose of EA has been to assist in distributing the benefits of development projects as well as identifying and mitigating adverse environmental consequences. Its purpose is not to prevent development from taking place. More precisely, EA plays a vital role in the stages of determining development strategies and project approval (Lee and George, 2000).

EIA has played a significant role in sustainable environmental management, but the contribution of EIA has limitations whenever quantitative data are required for the assessment of cumulative environmental impacts (Makhdoum, 2002). Furthermore, poor quality and excessive quantitative information found in typical EIS documents have been repeatedly criticised. This criticism is based on the premise that there is too much emphasis on data collection and not enough on the analysis, interpretation and environmental implications of the information generated from many EA studies (McDonnell, 1992). One such criticism is that EIS documents are not focused or written to be useful to decision-makers and stakeholders (Salk, *et al.* 1999). Alton and Underwood (2003), are of the view that it is time for EA professionals to change the focus of writing impact assessments for themselves alone.

In addition, ecological problems have been defined by ecologists in ways that could be easily addressed scientifically (Toth and Hizsnyik, 1998). This is most probably in response to the very complex nature of ecological systems, and because human understanding of ecological systems is presently limited. Such an approach ignores the perceptions of other stakeholders, social issues and ecosystem dependent livelihoods. Therefore it is necessary that environmental issues are resolved in ways that all stakeholders could understand the purpose of the assessment and its findings.

Intra-generational equity is one aspect for which existing EA processes are not as strong as they might be in dealing with the interests of minority and marginalised groups. Conventionally, EAs strongly depend on normal democratic processes to guide decision-makers (George, 1999). This implies that the interests of the electoral majority or the elites are often reflected in environmental statements, at the expense of the interests of the minority or the “voiceless majority”. Although many EA tools make some reference to public participation, the requirements are often very general, which may have resulted in difficulties in their practical implementation (Lee and George, 2000). The most realistic and sincere participation of the public is the use of their knowledge and experiences in EA processes.

Until very recently, environmental problems have often been addressed in a manner of confrontation that has often been initiated by localised environmental incidents. By the late 1990s, there was increasing evidence of a slowly emerging consensus on the importance of local and, increasingly, global environmental issues. Nevertheless, conflicts of interest will continue, but there are indications of the increasing willingness of the various interest groups to communicate with each other and to work towards mutually acceptable compromises. This setting requires methods for conducting responsible negotiations on environmental issues, and for mediating values, perceptions, and priorities of stakeholders (Toth and Hizsnyik, 1998).

Furthermore, McDonnell (1992), reported that it is apparent that although EAs may have met legal requirements they have failed in many instances to provide environmental managers with the required information for the decision-making process. Some of the reasons for this failure may be because of the nature of results from the assessment methodology. This may be an indication that there is a need for EA to be more people focused than merely to meet legal requirements.

Historically, there has been misunderstanding between environmental professionals and decision-makers about the provision and use of scientific information in environmental policy making. For example, in South Korea, large-scale development projects have been carried out without sufficient scientific consideration of the circumstances of the resulting destruction of valuable natural resources and degradation of the environment. This has given rise to: conflicts between the central government and local residents; less efficiency in policy implementation; and indiscriminate destruction of Korea’s natural resources (Kwak, *et al.* 2002).

Environmental professionals have become increasingly frustrated by decision-makers ignoring their results; while policy-makers have complained that environmental professionals do not provide answers to the “*right questions*” (The answers provided by environmental professional may be too technical for policy makers to understand) (Toth and Hizsnyik, 1998). Improved communication between and among stakeholders is a major prerequisite for improvement in the existing EA processes. The EcLA approach may be able to provide an opportunity for better cooperation and understanding between and among stakeholders if the assessment indicators are both ecological and socially relevant.

To many developers, EAs are expensive hurdles that must be surmounted in order to gain planning approval. However, EA could offer benefits to all environmental stakeholders, including developers if appropriately carried out (McDonnell, 1992). Whether EAs are undertaken in aggregate or in detail, an attempt must be made to capture every contributing factor. Every significant aspect of the environment has to be considered, as well as every important component of livelihoods (George, 1999).

Despite progress in controlling point source pollution, there has been a continuous global decline in aquatic biota. Altered water flows in dammed streams and rivers; pollution from non-point sources such as cities, farms; destruction of habitats above and alongside rivers by development or logging; and invasions by alien species have all constituted significant environmental stress on aquatic biota (Karr and Chu, 2002).

Assessment of ecological impacts has been problematic, which may be due to the fact that ecological systems and their responses to anthropogenic impacts are often complex and far from been fully understood (Bojorquez-Tapia, *et al.* 2002). Moreover, EAs may have been limited by the extent and duration of the projects under investigation, which are generally not influenced by ecological considerations such as species migration and rates of recovery / readjustment after natural and, or, anthropogenic stress

EIA approaches and practices vary from country to country (Lee and George, 2000). Despite this variation, EIAs tend to address environmental issues in isolation from social and economic factors (Kirkpatrick and Lee, 1997). When assessments are carried out in aggregate, tradeoffs between different components of the environment may become hidden. A deterioration in the quality of life for some social groups may not become apparent, and potentially unsustainable environmental effects may be undetected (George, 1999).

Climate change and the loss of bio-diversity are two aspects of greatest concern in conducting EA to assess environmental sustainability. In both cases, environmental damage could be serious and irreversible, and so the strong sustainability (precautionary principle) condition, that no loss of natural capital is permissible should apply (George, 1999). Most predictions made in environmental statements are often very general and in some cases over-simplistic. Some of these predictions are rarely checked for accuracy (McDonnell, 1992). Beanlands and Duinker (1983), cite the following examples of general environmental statements:

- The nesting and feeding grounds of water birds may be adversely affected by water flow fluctuations that may arise as a result of the project;
- Direct loss of habitat is expected to negatively affect terrestrial fauna; and
- If oil release took place during the breeding season, it could significantly reduce seal populations.

The above predictions are generic and non-specific and developing appropriate management strategies based on such results may be ineffective at bringing about sustainable livelihoods and environment. It is necessary for EA approaches to be more accurate and specific to goals that could be socially and ecologically relevant.

However, in EA processes it is usually problematic to properly link the ecological and social components of the environment (Sallenave, 1994; Pavlikakis and Tsihrintzis, 2000). The scope of contemporary EA and monitoring approaches are limited to the biophysical components excluding the socio-cultural components of the Study Area (Sallenave, 1994). Generally Pavlikakis and Tsihrintzis (2000) are of the opinion that environmental management systems have often focused on the short-term yield and the economic gain rather than long-term sustainability, and equity (intra-and inter-generational). There is however, hardly any comprehensive EA method that can be suitably used for all assessment scenarios (Sankoh, 1996).

Currently, ecosystem management is a developing approach that integrates human, biological and natural dimensions, aimed at achieving long-term ecosystem protection and sustainability. One of the most difficult tasks in achieving this integration may be to create a framework for research and planning that views science and TK as complementary forms of knowledge (Pavlikakis and Tsihrintzis, 2000),

4. 5 Ecological assessment

Ecological assessment (EcA) is the use of biological indicators in the assessment of anthropogenic consequences or effects of natural variation on the ecosystems. In the context of this thesis, ecological and biological assessment has been interchangeably used to mean the use of biota to assess impact on ecosystems. Biota are the prime witness and victims of environmental change (Karr and Kimberling, 2003). The major difference between EcA and EA is that EcA uses biota as assessment indicator, in contrast to EA that uses abiotic and biotic ecosystem components as assessment indicators.

Many agencies and institutions are shifting to using biota for the direct assessment of anthropogenic impacts on the ecosystems. For example biological and ecological assessments are fully developed and implemented across the USA (Karr and Chu, 1999). In the UK, the ecological impact assessment (EcIA) has been used as a process that could provide scientifically defensible results to ecosystem management (Treweek, 1995).

Biological monitoring and assessment (bio-monitoring), has been used for the evaluation of human induced impacts on biotic resources, and bio-monitoring is gaining widespread acceptance as part of the natural resource manager’s tool kit (Karr, 2003). Furthermore, biological / ecological monitoring is becoming a central component of water resource management throughout the world. The broad perspective offered by biological evaluation and the use of biological criteria has effectively linked human actions to their impacts on the environment. Such an effective link makes ecological assessment better than the use of narrow chemical and physical measures for diagnosing, minimising, and planning the prevention of river degradation (Karr, 1991; Karr and Chu, 2002).

The principal aim of water resource management is satisfying environmental needs and sustaining the ecological values of water-dependent ecosystems (human needs, welfare and livelihoods inclusive). Sustainable water resource management cannot be attained if the natural processes associated with these resources are not properly understood (Al Bakri, *et al.* 1999). Therefore, the link between the biotic functions of water resources and the socio-economic value of these resources should be the primary focus of sustainable water resource management.

4.5. 1 Principle of ecological assessment

Biota reflect watershed conditions better than any chemical or physical measure because they respond to the entire range of biological, geological, and chemical factors in the environment. Protecting the biological integrity of water will thus protect human uses of that water, whether for domestic, agricultural and industrial use, or for livelihood sustenance. Therefore, when the capacity of living rivers to support living things is compromised, these systems may no longer be able to support human welfare (Karr and Chu, 2002). However, the use of biota as assessment indicator in this case does not enhance or favour potable water supply, which may be required if the water is to be supplied for human consumption.

The main goal of biological monitoring is to focus on documenting the effect of changes caused by humans' actions on natural resources. The objective is not to measure every biological attribute, which would be impossible. The goal is to identify those biological attributes that respond reliably to human activities, are minimally affected by natural variation, and are cost-effective to measure (Karr and Chu, 1999). The identification of such attributes will require local ecological knowledge as well as knowledge about the stressor under investigation.

Ecological assessments and monitoring programmes often rely on indicators to evaluate environmental conditions. Ecological assessment indicators are frequently developed by scientists, and target aspects of the environment that scientists consider useful. Yet setting environmental policy priorities and making environmental decisions requires both effective communication of environmental information to decision makers and consideration of the perceived public value of ecosystems or perceived values (Schiller, *et al.* 2001).

4.5. 2 Indicators and ecological assessment

Environmental indicators have been defined by Whitfield and Elliot (2002) as *"physical, chemical, biological or socio-economic measures that best represent the key elements of a complex interpretative framework and have meaning beyond the measures they represent"*. Many investigations aimed at detecting environmental and ecological changes have focused primarily on water quality (Coliforms, nitrates concentrations, or biochemical oxygen demand (BOD) has been used as indicators for water quality assessment) and only a few studies have used associated biota as indicators (For example the use of aquatic plants, invertebrates, birds, and fishes). There is however a growing interest in the use of biological communities to assess the status of water resources, because of its relevance to policy and their sensitivity as indicators of anthropogenic influences (Whitfield and Elliot, 2002).

Bio-indicators can simply be defined as biological responses to environmental stressors that are expressed at multiple levels of biological organisation, from lower to higher levels. The fundamental concept of using bio-indicators to investigate relationships between ecological changes and anthropogenic effects usually become apparent at first at lower levels of biological organisation (These are: biomarkers or molecular; biochemical; and physiological endpoints) before the consequences are realised at higher levels of organisation (Organisms, population, community). The stressor(s) under investigation, must however be of significant magnitude and / or duration to alter the normal balance of the biological system under study (Adams, 2003).

Biological communities are often used as bio-indicators for the assessment of ecological status, because long-term anthropogenic stress on ecological systems could readily be investigated at the community level. The evaluation of the ecological status is however, often a difficult task because of the complexity and variability of ecological systems (OrFandis, *et al.* 2003).

Indicators have been based on the best scientific understanding currently available so that changes detected by these measures can be related to the human activity under investigation. When time-series data for an indicator show a trend, then there is a need to provide some interpretation of the trend and its implications on the environment. Environmental indicators, however, not only help track changes in an ecosystem, they are usually well-understood and can be measured regularly, thus giving valuable information about important aspects of the environment (Whitfield and Elliot, 2002). Numerous initiatives to develop sensitive indicators that could appropriately measure the impacts of developments on the environment have been undertaken. Human development and environmental issues that have livelihood consequences have however, rarely been jointly investigated (Nunan *et al.* 2002). There is therefore a need to develop indicators that reflect the relationships between development, the environment and livelihoods.

Generally, information derived from indicators can be used to inform policy-makers and to highlight both problems and progress (Nunan *et al.* 2002). Expanding on the above understanding of indicators, the major functions of indicators includes:

- Ability to sensitively assess conditions and changes;
- Effective comparison between dissimilar places and situations;
- Appropriate assessment of conditions and trends in relation to management goals and targets;
- Provision of early warning signals that are understandable by all interested stakeholders; and
- Appropriate prediction of future conditions and trends.

(Rigby, *et al.* 2000)

Furthermore, Table 4. 1 shows a summary of the desirable properties of environmental indicators. Environmental indicators, bio-indicators and ecological indicators have been used in the context of this thesis interchangeably to imply parameters used in understanding environmental status. These indicators have been used in understanding environmental status as well as anthropogenic impacts on the environments.

Table 4. 1 Properties of environmental indicators

Properties	Definitions
Specific	Indicators should reflect consequences the project intends to measure, avoiding measures that are largely subject to external influences or natural changes (environmental noise).
Measurable and unambiguous	Indicators should be clearly defined so that their measurement and interpretation is explicit. Data from indicators should be independent of the data collector (replicable) and should be comparable across groups and projects.
Attainable and sensitive	Indicators should be achievable by the project and therefore sensitive to changes the project could potentially cause.
Relevance and easy to collect	It must be feasible to collect data on the chosen indicators within a reasonable time and at a reasonable cost.
Time-bound	Indicators are described by a certain expected changes based on the stressors of interest.
Cost-effective	The cost of the assessment should be reasonable.

(Roche, 1999)

The UN's Agenda 21 emphasised the need to use indicators in decision-making and for sustainable development. It has, however, been difficult to readily apply the developed indicators at project level environmental assessment and in the decision-making process (George, 1999). Good ecological indicators must be specific, relevant to society, and provide information about ecological conditions. Ecological indicators should be able to easily detect anthropogenic impacts on the environment. Sampling activities for indicator measurements should be carefully carried out without significantly affecting the study site (Jackson, *et al.* 2000).

Many groups of organisms have been proposed and used as indicators of environmental and ecological change (Karr, *et al.* 1986). No particular indicator group is preferred by environmental professionals for all assessment situations, although it appears that fish, macro-invertebrates (Larger than microscopic invertebrate animals), birds and plants have received the most attention. Aquatic macro-invertebrates have successfully been used since 1972 by the Stream Monitoring Unit of the New York State Department of Environmental Conservation to monitor the water quality of the State's rivers and streams (NYSDEC, 2005).

Whitfield and Elliot (2002), reported that fish have been used successfully as indicators of changes in environmental quality in a wide variety of aquatic habitats and are relevant to environmental monitoring programmes. The advantages of fish species as eco-indicators are summarised in Box 4. 2. Fish are important for food; serve domestic and commercial uses and are the best known inhabitants of freshwater systems (Giller and Malmqvist, 2001). In addition fisheries have livelihood significance in most rural fishing communities in developing countries which make fish species more relevant in environmental policy-making than invertebrates, plants and birds in areas such as the Central Niger Delta (Tamuno, 2001).

Furthermore, a useful feature of ecological assessment is that direct observation is used which reduces the possibility for errors. Freshwater fish in general have been used widely in North America. Using fish species as biological monitors, however, is not without constraints. Sampling gear is selective and will affect the species richness as would the experience of the field team. The problem of sampling is best minimised by using a wide variety of sampling gear for data collection (Hay, *et al.* 1996).

The use of the ecological assessment protocol assumes that a fish sample represents the entire fish community. Variation in stream size requires different sampling techniques. Each sampling effort must try to obtain a representative sample of all the fish species in the sample area. Seines (seine nest) seem to be the best sample tool for small and relatively simple streams. As streams increase in size and complexity, it is necessary to use more efficient equipment like electrofishing and, in some cases, use of nets.

The use of fishes as eco-indicators, however, does have difficulties. Some of the constraints of using fishes as ecological indicators have been summarised as follows:

- Sampling gear used for fish are selective for certain habitats, fish sizes and species;
- Fish mobility can lead to sampling bias;
- Fish can swim away (migrate) from an area of human impact, hence avoiding localised exposure to pollutants or adverse environmental conditions; and
- Some environments that have been physically altered by human action may still contain diverse fish assemblages, because different fish species respond differently to human stressors.

(Whitfield and Elliot, 2002).

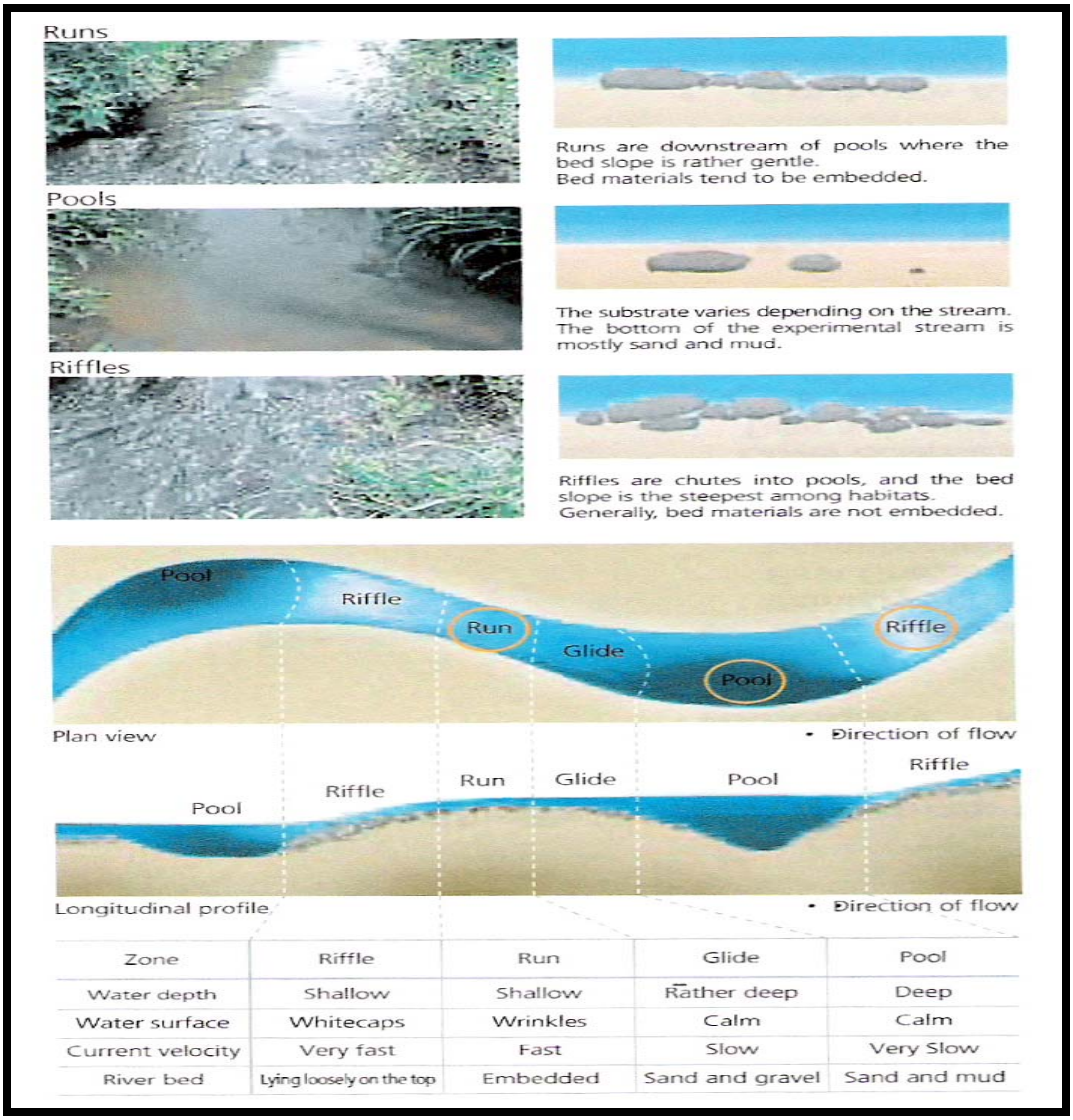
Box 4. 2 Advantages of fish as indicators of ecological status

1. Fish are naturally inhabitants of all aquatic systems, with the exception of highly polluted waters. Listed below are some of the advantages of using fish as eco-indicators:
2. The life-history and environmental response information of most fish species are extensive and available;
3. Fish are relatively easy to identify in comparison to invertebrates. Researchers require relatively little training in fish identification. Most fish species can be sorted and identified at the field site;
4. Fish communities usually include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and include foods of both aquatic and terrestrial origin;
5. Fish are comparatively long-lived and could provide a long-term record of stress on the environment;
6. Fish contain many species and functional roles, hence are likely to cover all components of aquatic ecosystems affected by anthropogenic disturbance;
7. Fish are both sedentary and mobile and hence will reflect stressors within one area as well as wider catchments effects;
8. Severe toxicity and stress effects can be evaluated in the laboratory using selected species, some of which may be missing from the study system;
9. Fish have a high societal awareness value and the public are more likely to relate to and appreciate information about the condition of the fish community than data on invertebrates or aquatic plants;
10. Societal costs of environmental degradation, and cost-benefit analyses, are readily evaluated because of the economic, aesthetic and conservation value of fishes; and
11. Fish are typically present, even in the smallest of streams, in all but the most polluted and degraded waters.

(Whitfield and Elliot, 2002).

Many of the limitations to the successful use of fish as ecological indicators described above are out-weighed by the widespread advantages (See Box 4. 2). In addition, it should be emphasised that a number of these constraints also apply to other taxonomic groups (Invertebrates, birds and plants) that may be used in monitoring the status of the aquatic environment (Whitfield and Elliot, 2002). In addition, the effectiveness of eco-indicators is based on a sampling protocol that is appropriate to the fish community, and the larger geographic area of interest (Karr and Dudley, 1981; Hay *et al.* 1996; Karr and Chu, 1999). The sampling techniques must take account of factors such as the stream's microhabitat, including pools, riffles, margins, and side channels (Karr and Chu, 1999). See Figure 4. 3 for examples of stream microhabitats

Figure 4. 3 Microhabitats of streams



Zone	Riffle	Run	Glide	Pool
Water depth	Shallow	Shallow	Rather deep	Deep
Water surface	Whitecaps	Wrinkles	Calm	Calm
Current velocity	Very fast	Fast	Slow	Very Slow
River bed	Lying loosely on the top	Embedded	Sand and gravel	Sand and mud

Source: (ARRC NEWS, 2005)

Ecologists have long sought concise and cost-effective measures that can characterise ecosystem conditions. With the increased use of indicators, for initiatives aimed at ecological sustainability, and environmental assessments, one key element that emerged repeatedly is the need for effectively communicating technical information from indicators to diverse stakeholders. Effective communication of ecological indicators involved more than simply transforming scientific phrases into easily comprehensible words. Rather, there is the need to develop and use "languages" that are understandable by both scientists and non-scientists. Effective communication on environmental status and trends has significance for the scientific community, decision makers, members of the public, and governmental agencies charged with collecting and reporting such information (Schiller *et al.* 2001).

Therefore, an appropriate indicator must produce results that are clearly understood and accepted by scientists, policy makers, and the public. According to Schiller *et al.* (2001), indicators that has been successfully used in the US for the assessment of ecological status of streams and rivers include:

- Water quality (physico-chemical indicators);
- Microbial metabolism;
- Bird assemblage (community);
- Physical habitat quality;
- Periphyton (A complex matrix of algae and heterotrophic microbes attached and are important indicator of water quality) assemblage;
- Fish Assemblage;
- Fish tissue contamination; and
- Benthic macroinvertebrates assemblage.

Living organisms not only give clear signals about river health, they also attract popular attention, often reaching more diverse groups emotionally. For example, in the areas surrounding Lake Biwa, Japan, aquatic organisms have, for generations, been central to the peoples' daily lives. Although the residents around Lake Biwa are less connected to aquatic organisms today than in earlier generations, they still find biological indices more relevant and appealing than other water status indicators. Signals from the biota are more easily grasped intuitively than are chemical water quality data. Photos of massive fish kill, for instance, present images that have far greater impact than water chemistry data indicating contamination (Karr and Rossano, 2001).

Understanding human impacts on natural resources requires appropriately selected indicators that should provide ecologically sound quantitative information relevant to public policy. Indicators represent diverse dimensions of the system under study, simplify information about complex phenomena to improve communication with interested parties, and are cost-effective (National Research Council, 2000). Identifying indicators that meet the above standards requires a rigorous scientific process beginning with proper study design, including appropriate sampling and analytical methods, and ending with synthesis and communication of study results (Karr and Chu, 1999).

For example, data obtained by using all fishing sampling gear types have been used for the calculation of trophic level category. A high number of pisicivores indicates a healthy trophic composition. Variability in invertebrates assemblage will affect the abundance of invertivores, which reflect changes in water quality, and the use of pesticides will also affect this group (Karr *et al.*1986; Hay *et al.*1996). Invertivore composition reflects the state of secondary productivity of the aquatic systems, whereas the herbivores reflect the primary productivity of the system. Omnivore increase in abundance as specific food needed by specialised feeders becomes less, because omnivores have the ability to change their feeding habit when the food chain is under pressure (Hay, *et al.* 1996).

In summary the advantages of using fish trophic structures as eco-indicators are as follows:

- There is a strong inverse correlation between the abundance of insectivorous cyprinids (A member of the family Cyprinidae, composed of usually small freshwater fishes, which includes the minnows, carps, and shiners) and omnivores, which implies that insectivores reduces as habitat quality declines
- As a site declines in quality, the proportion of fish and other organisms that are omnivores increase; and
- Top carnivores decline or disappear as surface water quality decreases.

Ecological indicators are central to any effort to measure and understand the environmental consequences of human actions. Because ecological indicators trace the status of and trends in living systems, they provide the single most relevant means of evaluating the effectiveness of conservation, cleanup, remediation, and restoration. Such indicators can and should guide policy and direct research (Karr and Kimberling, 2003). Therefore, the selection of the most sensitive indicator is necessary for cost-effective ecological assessment.

4.5. 3 Application of ecological assessment

Environmental variation may be natural or human induced, although the two are invariably intertwined. Natural variation may be: diurnal (daily), seasonal, annual sources, spatial sources (stream size and or channel type). Biological monitoring separates human effects from natural variation by discovering, testing, and using those biological attributes (indicators) that can be precisely measured to provide reliable information about biological condition for the purpose of sustainable management of natural resources (Karr and Chu, 1999). Therefore, carefully designed biological assessment can be used for the rapid and cost-effective exploratory assessment of water resource quality. Where impaired use is suggested, a more comprehensive monitoring programme can be implemented in search of the causative agent(s) (Karr,1981).

Understanding the status of river could provide a holistic view of river condition and facilitate efforts to improve that condition. The use of biological assessment and monitoring has been successfully used by environmental professionals in diagnosing the cause of declining river health and in identifying ways to restore health (Karr and Rossano, 2001). Table 4. 2 summarises some successful applications of ecological assessment. This shows that ecological assessment has been applied in various parts of the world as well as for various purposes, most of which have been for assessments that are of physico-chemical consequences.

Table 4. 2 Summary of the application of ecological assessment

Type of impact	Indicator organism(s)	Location	Researcher(s)
Chemical - Chemical contamination.	Fish	USA	(Karr, et al. 1986; Karr, 1991)
Physical – Flow alteration, land use and urbanisation.	Fish and invertebrate	USA	(Roth, *et al.* 1996; Allan, *et al.*1997; Wang, *et al.* 1997).
Physical – Recreation and logging.	Invertebrates	USA	(Fore, *et al.*1996).
Chemical – Effluents from a bauxite plant.	Fish	Guinea (Africa)	(Hugueny, *et al.*1996)
Physico-chemical - the effects of channelisation and chemical effluents.	Fish	Venezuela	(Gutierrez, 1994 - as cite in Karr and Rossano, 2001)
Physico-chemical - the cumulative effects of channelisation, agricultural runoff, and urbanisation.	Fish	France	(Oberdorff and Hughes, 1992)
Chemical - metal and organic pollution.	Fish	India	(Ganasan and Hughes, 1998)
Physico-chemical - urban point and non-point pollution gradients.	Invertebrate	Thailand	(Thorne and Williams, 1997)
Physico-chemical - urban point and non-point pollution gradients.	Invertebrates	Ghana	(Thorne and Williams, 1997)
Physico-chemical - urban point and non-point pollution gradients.	Invertebrates	Brazil	(Thorne and Williams, 1997)
Physico-chemical – Land use on rivers.	Fish	Mexico	(Lyons, *et al.* 1995)
Biological / physico-chemical – Water pollution, flow modification and introduction of alien species.	Fish	South Africa	(Kleynhans, 1999)

Sceptics of biological assessment argue that the knowledge of the biological condition of rivers alone does not explain the causes behind that condition. The same criticism applies, however, to physico-chemical and habitat monitoring. Water quality assessment does not help understanding the source of any contaminants present, and the existence of physical degradation does not provide any explanation of how or why environmental degradation occurred. Moreover, neither the assessment of chemical water quality nor measures of the quality of physical habitat demonstrates the status of ecological systems. Success in understanding river health is one area in which biological assessment has significantly contributed to protecting life in aquatic resources (Karr and Rossano, 2001). Despite the above criticism of EcA, the results from EcAs could easily be understood by all stakeholders due to the social relevance of assessment indicators

4.5. 4 Ecological assessment: emerging issues

Irrespective of the study approach, bio-monitoring should satisfy several criteria before it can be classified as a valid assessment tool. Some of these criteria have been summarised below:

- The indicator must be biological – assessment indicators should be biota not abiotic ecosystem components;
- Several trophic levels must be investigated – ranging from producers to quaternary consumers;
- The indicator must be sensitive to environmental stress, such as pollution, river flow and habitat degradation – indicators should be able to measure anthropogenic impact at low concentration of stressors or low impact levels, to high level of stressors or high impact levels.
- The response of the indicator must be reproduced over space and time – the demonstrated impact should be able to be replicated under similar circumstances; and
- The range of variability of the assessment indicator must be low – variation in sensitivity of indicator to stressor should be low and consistent. The variation of measure should be a factor on environmental stressor.

(Hay, *et al.* 1996).

Some biological attributes are poor assessment measures, because they are highly variable for use as indicators of ecological status. Examples of such attributes are species abundance, density, and production. However, taxa (a scientifically recognised category or unit of living organisms) richness and relative abundance are more effective than physic-chemical parameters as indicators of biological responses to human actions (Karr and Chu, 1999). The use of fish as indicators of environmental changes has been based on the tenet that fish communities are sensitive indicators (see Box 4. 2) of stress on aquatic systems. Furthermore, biological monitoring is preferred to chemical monitoring because the latter often misses many of the anthropogenic-induced perturbations on aquatic ecosystems (Keeler and McLemore, 1996; Karr and Chu, 1999).

Structurally and functionally, fish communities provide better evidence of water quality, because they incorporate all the local environmental perturbations into the stability of the communities. Hence, fish communities present a viable option for assessing human-induced impacts on freshwater ecosystems (Whitfield and Elliot, 2002). However, the study of large rivers and adequate understanding of how they function for fish and fisheries is fairly recent (Hoggarth, 1999).

The high variability of environmental characteristics between rivers, demand locally-appropriate solutions (Hoggarth, 1999). Biological monitoring and assessment provide the information needed to determine if a water body is impaired, because biological data constitute a useful complement to physico-chemical data (Karr and Yoder, 2004). In the contrary, purely physico-chemical attributes of water are unsuccessful as surrogates for measuring human-induced stressors on biotic integrity (Karr, 1981; Keeler and McLemore, 1996).

The sustainable management of rivers requires a blend of science, public policy, and individual actions (Karr and Rossano, 2001). Society can no longer afford fragmented approaches; neither can society afford seemingly broad yet actually narrow goals. Only by integrating what is known about stream and evaluations of biological conditions can the conservation or rehabilitation goals of rivers be achieved (Wang, 2001; Booth, *et al.* 2004). This requires an appropriate balance between ecological protection and social and economic costs (Karr, *et al.* 1986; Booth, *et al.* 2004).

Biological assessment adds value to the management of surface water resource whenever appropriately designed data collection and analysis are implemented (Doberstein, *et al.*2000). Successful biological monitoring and assessment depend on rigorous quality control, which are invaluable for managing, conserving, and restoring aquatic resources. Successful biological assessment requires environmental professionals and managers to first define the quality of information they require and then to ensure that data collection and analyses meet policy demands. The analytical quality of information obtained from biological assessment outweighs any financial savings that may be associated with cursory data collection and analyses (Doberstein, *et al.* 2000).

There is much for environmental professional to learn from public health professional and medical practitioners in which interdisciplinary team are involved, multiple tests are used in diagnosing and healing disease and controlling epidemics (Karr and Rossano, 2001). Therefore, multidisciplinary approaches as well as multi-test assessment are required if decision-makers are determined to go beyond lip service to the principles of sustainable development.

Establishing causal relationships between anthropogenic impacts and observed environmental consequences is difficult because there is no universally accepted and proven approach for determining such relationships. Several types of approaches or combinations of approaches, each with their own sets of advantages and limitations have been applied in a variety of ecological systems to investigate possible causal relationships between environmental stressors and observed and anticipated effects (Adams, 2003). Below is a brief highlight of common ecological assessment approaches:

- Controlled laboratory studies (including acute and chronic bioassays) – ecological assessments carried under controlled laboratory conditions. There have been commonly used in the assessment of impacts of chemical stressors;
- Experimental field examination – assessments carried out in the field, which involves direct assessment of anthropogenic stressors on ecosystems ;
- Field studies based on synoptic field surveys – a combination of field survey and controlled laboratory experiments;
- Mathematical simulation modelling – uses both biotic and abiotic ecosystems component to illustrate causal relationships between stressors and impacts;
- Statistical associations – statistical tests used to show differences between unimpaired and impaired conditions or quantitative consequences of environmental change(s);
- Various combinations of laboratory, experimental, and field studies – this is a holistic approach that explores the variety of the ecosystem approach used in the assessment of environmental change; and
- The eco-epidemiological approach – this is the study of the causes, distribution, and control of anthropogenic consequences on the ecological system usually based on weight of evidence approach. This approach employs preventive and curative approaches; and take a systematic and holistic approach to diagnosis and treatment) approach.

(Adams, 2003)

Appendix 2 contain a summary the advantages and disadvantages of the respective approaches for ecological assessment. This shows that no single approach is suitable for all ecological assessment scenarios.

Ecological assessment approaches can be useful for identifying anthropogenic impacts. These approaches are however, not designed to identify the causes of environmental consequences. The most common approach for investigating possible causal relationships among environmental factors is to apply a wide variety of statistical procedures such as correlation, logistic, or multivariate regression analysis on field data to test for possible associations between independent (cause) and dependent (effect) variables (Adams, 2003).

In addition, all types of environmental assessment approaches have generally used statistical procedures to check for possible association among and between environmental variables. However, statistical correlation only indicates that variables are associated and not necessarily causally (Cause / effect relationship) related. In complex assessment scenarios, determining causality is not straightforward due to the many potential influential and controlling factors (such as naturalistic mechanisms or synergistic effects caused by several stressors that co-occur or co-vary that could hinder the identification of the true causal mechanisms) that can confound the interpretation of responses in ecological systems (Adams, 2003).

U.S EPA (2000), warns against the use of statistical hypothesis testing (Statistical hypothesis testing has been designed for analysing data from experiments where treatments are independent, replicated, and randomly assigned) in trying to establish causality among observational variables. The application of statistical hypothesis testing to data from observational field studies may lead to erroneous conclusions because observational study treatments are very seldom replicated or randomly assigned to experimental units (Adams, 2003).

One of the difficulties in ecological sampling is the selection of appropriate time, when samples are required to be collected at several times annually, which may however be constrained by time and funds. Natural streams tend to be relatively stable seasonally although exceptions to this generality increase in dry areas. Disturbed areas tend to be more unstable, and thus, the choice of sample times is more critical if ecological assessment is to address the issues of anthropogenic impact on natural systems. Early summer has been identified as the ideal sampling season, because this is the least variable period from year to year (Karr and Dudley, 1981). In addition, Karr, (1981) recommended that ecological sampling of streams be conducted in such a way that:

- Samples should be collected from about 100m long stretch of small streams;
- Selection of several representative pools and riffles (Figure 4. 3) for larger streams may be more appropriate; and
- Larger rivers should be sampled using 1 km units when electrofishing equipment is employed.

The appropriate restoration of biota in aquatic habitat requires baseline data to identify degradation caused by humans and to design appropriate restoration plans; data from long-term monitoring are needed to assess the effects of restoration efforts (Royer, *et al.* 2001). The variation of the inherent characteristics of aquatic systems makes definition and classification of ecological baseline conditions difficult. For example, un-modified headwater rivers generally support fewer species than downstream areas, and warmer streams support more species than colder streams (Karr and Dudley, 1981). Such constraints imply the need of using appropriate approaches for the understanding of baseline scenarios. TK maybe one of such promising approaches (see Chapter 5 for the discussion of the place of TK in environmental assessment).

4. 6 Chapter summary

Ecosystems are highly complex, variable and there is a lack of comprehensive understanding of ecological systems. Humans, human impacts are integral components of this system. The human impacts on this biological system eventually become part of the system's characteristics, but may compromise the biotic integrity of the ecosystem. Ecological systems such as forests and surface water resource are resources that are of common pool / common property value.

People from all over the world earn a living via diverse sources; however, the livelihood components in developing countries are from multiple sources, due to the high level of uncertainty in the macro-economic status of these countries. The sustainable livelihood framework is a flexible and people-centred approach that is aimed at poverty reduction. The dependence of most rural people in developing countries on common pool resources requires an understanding of the link between human effects on this resource and livelihoods.

Environmental assessment was developed and first implemented in the US over thirty years ago with the main purpose of appropriately managing anthropogenic impact on the environment. The EIA is presently a legal requirement all over the world for all projects that may adversely alter the integrity of the environment. Despite the implementation of EIA as a project pre-requisite, and other environmental assessment approaches, the integrity of ecological systems and livelihoods dependent on these resource have not fared any better. The continuous depletion of biotic resources, despite the use of physico-chemical parameters in the assessment of anthropogenic impact on the environment, may have been one of the reasons for the introduction of ecological monitoring and assessment in the early 1980s that focuses on using biota as an indicator of the status of ecosystems.

There is the need for the integration of the tenets of ecological assessment and the principles of the sustainable livelihood framework in assessment of anthropogenic impacts that may be of livelihood significance in areas such as developing countries where there is a high dependence on common pool resource. In the context of this thesis, such integration is termed eco-livelihood assessment. The implementation of such an assessment protocol will require accessing historical data (baseline data). However, most developing countries have been associated with the inadequacy or absence of baseline data. Such a scenario may justify the need to explore the knowledge of those whose livelihood is dependent on the environment. Such knowledge have been recognised as reliable and valid as demonstrated in Chapter 5.

Chapter 5 The place of traditional knowledge (TK) in environmental assessment

This chapter presents a review of traditional knowledge (TK) as an option that could be used in areas where the lack or inadequacies of baseline data is one of the constraining factors to EAs and where the dependence on common pool resources CPRs constitute a major livelihood source. The use of local knowledge for earning or winning livelihood from CPRs has been identified in the context of this thesis as traditional eco-livelihood knowledge (TELK). This chapter also appraises the perceived limitations to the use of traditional knowledge in environmental assessment and management and its place in eco-livelihood assessment.

5. 1 Rural people and traditional knowledge (TK)

Indigenous peoples are identified based on their proximity to and long-standing environmental relationships, and are usually the original and oldest surviving inhabitants of a geographical area (Turner, *et al.* 2000; Nepal, 2002), and are recognised on the basis of their history and culture (Nepal, 2002). Many aboriginal people have a holistic experience and understanding of their environment (Turner, *et al.* 2000). Irrespective of the fact that there is no universally applicable definition of indigenous or aboriginal peoples, but in the context of this thesis, the term “indigenous” or aboriginal has been used interchangeably implying long-term residence in a given area.

The destruction of local environmental resources may have adversely affected local culture and livelihood. Presently, development strategies have been driven by market economies that most often favour national and regional economic growth at the expense of sustaining local livelihood (Turner, *et al.* 2000). However, most of the world’s biodiversity occurs on or adjacent to traditional indigenous territories (Nabhan, 1997), from which some of these indigenous people earn their livelihood (Tamuno, *et al.* 2003b). It is very unfortunate that the concerns, experience and knowledge of local indigenous and traditional peoples have often been ignored in the formulation of environmental and water resource policy; rather most development policies and projects has solely relied on data from “hard science”.

The knowledge of indigenous people about their local environment is adaptive, dynamic and constitutes an integral perspective of the historical resource use pattern and survival strategies, and has been driven by resource availability and local community demands (Warren and Rajasekaran, 1993; Berkes, *et al.* 2000; Olsson and Folke, 2001; Sillitoe, *et al.* 2002; John, 2003a), this interactive knowledge have been accumulated over centuries (Klubnikin, *et al.* 2000). Therefore, traditional knowledge (TK) has been simply defined as a form of logical, systemic and reliable knowledge gained through generations of intimate contact by indigenous peoples with their environment (UNEP, 1998; Huntington, 2000) that has equal status as scientific knowledge (Ellen and Harris, 1996; UNEP, 1998; Berkes, *et al.* 2000). TK is similar to western science because it is knowledge that is acquired by local people through observation, the accumulation of experiences and informal experiments, and through an intimate understanding of the environment in a given socio-geographical context (Warren and Rajasekaran, 1993; Berkes, *et al.* 2000). However, TK is different from science because science is perceived to be concrete, while TK abstract (Berkes, *et al.* 2000). In the context of this thesis, TK has been interchangeably used with indigenous knowledge (IK) meaning local knowledge or the knowledge of indigenous or aboriginal people.

TK is a concept that describe knowledge specific to a given culture, geographical location or society (Warren and Rajasekaran, 1993). The lack of consensus among stakeholders on the meaning of TK is frustrating, particularly for those who advocate or attempt to practically apply this knowledge in management of community based resources. However, TK is generally much more than information which indigenous peoples have about the land and animals with which they have a special relationship. It is an established body of knowledge about life and living close to nature and interdependence on the environment (Bielawski, 1992). The documentation of TK has not in most cases been fragmented rather than holistic.

TK is non-documented, concerned primarily with qualitative observations, and it is based on oral tradition. Gathering both biological data and information about the local socio-political structure can best be accomplished through involving people and participatory observation (Johnson, 2003a). In the words of Forrest (2000), "*aboriginal knowledge is not learnt from a book; it is oral and it is passed on; it is about feeling and it is about studying and it is about learning from each other"*. Furthermore, the understanding of how local people perceive societal issues is a crucial element in the design of projects aimed at encouraging and supporting community-based management regimes to enable rural people to improve their lives and the environment on which their livelihoods depend (Quinn, *et al.* 2003).

Furthermore, TK assumes that humans are connected to the natural world, and that there is no such thing as nature that exists independent of humans and their activities(Pierotti and Wildwat, 2000). Hence, it is customary that most native peoples do not think of nature as an externality but as a home (Pierotti and Wildwat, 2000). TK, however, represents a constantly evolving way of thinking about this home. The essence of traditional beliefs is that these relationships with nature have existed long enough for long-range consequences to affect them and to foresee the effects of potential changes (Pierotti and Wildwat, 2000; Watson, *et al.* 2003).

5.1. 1 The concept of traditional ecological knowledge (TEK)

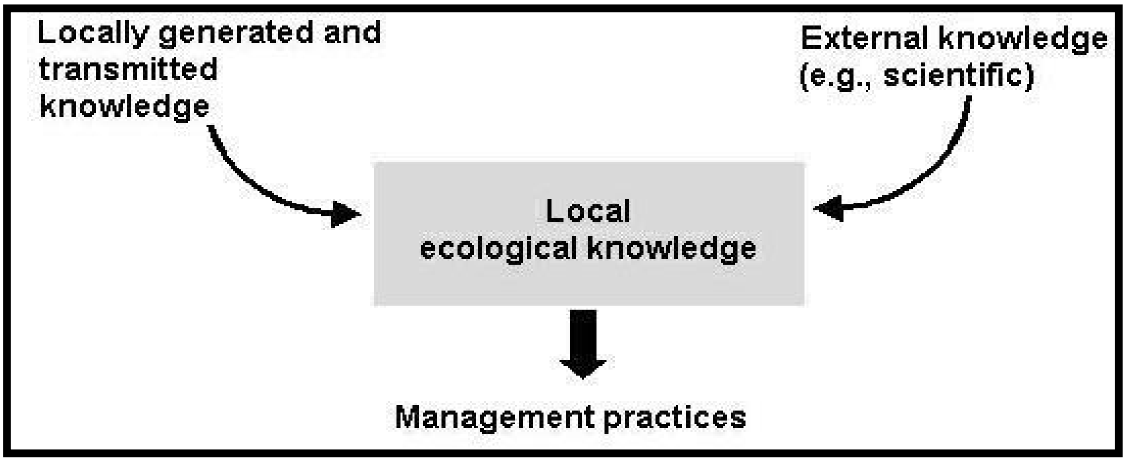
Traditional ecological knowledge (TEK) is a relatively recent area of academic research, the concept and associated theorising and research have been around since the mid-1970s (Berkes, 1999); but the main feature of TEK is indigenous or aboriginal knowledge, which is not a recent concept (Paci, *et al.* 2002). TEK constitutes a cumulative body of knowledge, understanding, practices, and beliefs about the relationships of living beings (human inclusive), to one another and the abiotic components of the environment and is culturally intra- and intergenerational exchanged (Gadgil and Berkes, 1991; Gadgil and Berkes, 1993; Nabhan, 1997; Fernadez-Gimenez, 2000; Olsson and Folke, 2001). TEK represents cumulative experience (CE) of local people about their environment (Fernadez-Gimenez, 2000). In the context of this thesis the concept of TEK refers to the knowledge held by people that are resident in a specific geographical location with a long standing experience, understanding and knowledge about their local environment.

Furthermore, TEK includes a system of classification, a set of practical observations about the local environment, and a system of self-management that governs resource use. The quality and quantity of environmental knowledge in a local community is dynamic and represents a cumulative value of all the experiences of all individuals of that community. TEK is therefore, dependent upon: gender; age; social status; intellectual capability; and people's means of livelihood (Johnson, 2003a).

Huntington (2000), described TEK as the knowledge and insights acquired through extensive observation of an area, which has been successfully used to understand and predict environmental events upon which localised livelihood depends and have been adapted for centuries for survival in marginal areas. Interest in TEK has been growing since the early 1990s, partly in recognition that such knowledge can contribute to the conservation of biodiversity, rare species, and ecological processes (Gadgil, *et al.* 1993; Berkes, *et al.* 2000). Although the value of TEK in scientific research, environmental assessment, and conservation monitoring has become more apparent and accepted, wider application of TEK-derived information is still perceived to be elusive (Huntington, 2000).

TEK is a blend of knowledge generated locally through practice and experience, and external source of knowledge, such as scientific knowledge and or knowledge from other geographical location (Tengö and Belfrage, 2004). Therefore, experiences, skills and locally adapted knowledge acquired by professionals such as fishermen, hunters and farmers that have been acquired by living in close contact with the environment could be regarded as TEK. Figure 5. 1 illustrates the concept of TEK as an integration of locally developed knowledge based on localised experience and knowledge and external knowledge source for the purpose of managing the environment.

Figure 5. 1 Representation of the components of TEK



Source: (Tengö and Belfrage, 2004)

The difference between TK and TEK is that TK generally the knowledge of indigenous people, while TEK is specific knowledge of local people about their environment. Based on the concepts of TEK, this author has coined the term traditional eco-livelihood knowledge (TELK). TELK has been simply defined as the environmental knowledge of indigenous people that have either been used in earning or winning livelihoods or in livelihood sustenance in rural communities. The features described in the succeeding section are quite applicable to TK, TEK and TELK. TELK has been explored in the context of this research in the eco-livelihood assessment of inland river dredging in the Study Area, Nigeria, where there is a high dependence on CPRs for livelihoods and baseline data is scarce, inadequate or unavailable.

5.1. 2 Features and use of TK

The characteristics of traditional knowledge (TK) presented in the sub-sections below are not exhaustive, but are aimed at highlighting the main features of TK that is applicable to traditional ecological knowledge (TEK) and traditional eco-livelihood knowledge (TELK). These characteristics show that the knowledge of indigenous people constitutes a viable option for use in knowledge transfer and application in environmental assessment and management.

5.1.2. 1 Localised and descriptive

TK is characteristically locally embedded and represents a set of experiences generated by people living in a specific geographical area that have been tested over centuries (Ellen and Harris, 1996; Berkes, *et al.* 2000; Sillitoe, *et al.* 2002). Furthermore, the knowledge of indigenous people represents a system of collectively held descriptive knowledge that has been used for communal survival in the face of environmental challenges (Berkes *et al.* 2000; Kurien, 2000; Paci, *et al.* 2002).

For example, the relationship of the Dene of Northern Canada with their environment have been in existence for centuries and has helped the Dene in earning a livelihood through hunting, and fishing. The experiences and knowledge of the Dene people have endowed them with a wealth of knowledge of the geography and resources that have sustained them for generations and still remain central to their lives (Johnson, 2003b). The cost (financial and time cost) for the collection and documentation of such knowledge scientifically would in addition require specialised expertise, but on the contrary such geographically specific information could otherwise be easily accessed via the knowledge of these local residents.

5.1.2. 2 Historical information

The knowledge of indigenous people has been gathered over generations by indigenous or local people whose livelihood depends on such information (Berkes, 2000). For example, in British Columbia, it has been estimated that the gillnet fisher had a collective experience (CE) of approximately 270 fishing years (Mackinson, 2001). The implication of this is that such longstanding experiences represent historical information and trends that may be used to develop a database that may not be able to be captured by any scientific database.

Furthermore, TK has been recognised as a form of logical and reliable knowledge developed through generations of intimate relationship of native peoples with their environment (UNEP, 1998). Irrespective of the fact that indigenous people have sometimes caused species extinctions and degraded their local environments, these people have often persisted for millennia in their territories by using their adaptive knowledge for the equitable exploitation of their environment (Mauro and Hardison, 2000). The knowledge of traditional people has existed for a long time, long enough to serve as a rich reservoir of quality local knowledge, which may not have a substitute in environmental assessment and management of CPRs.

TK constitutes a body of knowledge that is dynamic. For example, old adaptive practices have been reviewed in response to, climate change and new diseases as well as the incorporation of recent findings in agricultural science into farm management. Local networking have also significantly influenced the knowledge of indigenous people in Tanzania (Tengö and Belfrage, 2004). This may be an indication that the knowledge of indigenous people that has been acquired over centuries could be relevant in addressing contemporary environmental issues that may be of livelihood consequences. Some studies, such as Woodhouse (2000), see this dynamism in TK as a fundamental critique of using "traditional" or "indigenous" to describe this knowledge. Whilst acknowledging the strength of this argument which might affect how the terms TK, TEK and TELK are understood, there is nevertheless value in the use of such terms. These terms are therefore used in this thesis.

5.1.2. 3 Modes of transmission

TK is typically orally inter- and intra-generationally transmitted (Ellen and Harris, 1996; Capp and Jorgensen, 1997; Forrest, 2000). The knowledge of indigenous people is not taught in abstract context, but culturally acquired by observation and participation (Capp and Jorgensen, 1997; Turner, *et al.* 2000). In addition, this knowledge system attempts to holistically understand ecosystems and the interactions between ecosystem components (Capp and Jorgensen, 1997).

TK is locally-based knowledge and the possession of this type of knowledge by indigenous people has been an issue of pride and cultural identity. Most of this knowledge is acquired unconsciously by living in close contact and harmony with nature and in the process of making a living from CPRs (Forrest, 2000). The highest level of learning and teaching at which TK is transmitted is via the elder-apprentice relationship (Paci, *et al.* 2002) and the documentation of such knowledge is a new area that scientists are presently exploring (Becker and Ghimire, 2003). However, the non-documentation of TK makes it difficult to readily access by researchers and other interested groups or individuals. As such, the maintenance of such knowledge should be supported, with the involvement of elders in documenting community knowledge for the purpose of maintenance of cultural identity and sustainable management of natural resources (Paci, *et al.* 2002).

For example, Baines (2003), reported that the local knowledge of fisheries and other aquatic biota in the Marovo area of the Solomon Island, is primarily behaviour oriented, focusing on information required to find and capture. This knowledge is based on first-hand observation and experience of fish in the fishing grounds, which has accumulated through generations. Most of the inherited knowledge is retained and the less relevant to fishing and survival of the culture of the Marovo people often fade away in response to new development in the local environment. There are however factors that have constrained the successful use of TK, some of which have been discussed in the succeeding sections.

5. 2 Limitations and constraints of TK usage

The value and existence of TK has never been in doubt, however, there are constraints to its use in environmental assessment and management. Perhaps, these constraints have been limiting the usage of TK and associated concepts in the management of natural resources. Like Western science, TK has its own limitations. Unfortunately, some researchers tend to be excessively critical of TK and see nothing good about this system of knowledge that has been in existence for centuries. Other researchers are of the view that TK is inferior to their “superior” knowledge.

5.2. 1 Scientific bias

Most “educated experts” find it difficult to accept that local and impoverished farmers understand better than they do about local environmental issues or problems; that they could have anything to learn from these rural uneducated people; or recognise that there is a parallel system of knowledge to their own which could be complementary. Most of these “educated experts” seldom accept that TK is logical and in some aspects (such as in the aspect of wealth of historical information that has accumulated over centuries of experience) or equal to their own (Mackinson, 2001). Most probably, this bias of scientists may be on the presumed premise that the knowledge of indigenous people is subjective, non-quantitative, and unscientific.

Western scientists are largely sceptical of TK. Much of this scepticism is based on the belief that, although the knowledge of local people may have been impressive in its earlier forms. TEK is being irreversibly eroded by the assimilation of aboriginal peoples into Western culture and by the failure of elders to pass on their knowledge to the younger generations. However, both social scientists and aboriginal peoples confirm the continued vitality of traditional cultures and note that TK is evolving, not dying (Osherenko, 1988).

In Western science, intellectual achievements of its members are usually judged based on a rigidly defined set of institutional standards. As Nakashima (1990), pointed out, that University degrees, journal publications, conference presentations and years of post-qualification experience have been used as milestones on which knowledge has been assessed. Guided by these inflexible norms, environmental professionals have rejected the knowledge of native people as unreliable, non-quantitative and immethodical.

Furthermore, most scientists are often sceptical of the value of TK unless it has been recast in scientific terms (Mauro and Hardison, 2000). Generally, environmental professionals and researchers have preference and rely primarily on “hard” scientific based data. This view has been increasingly challenged from within even the scientific community, as purely based on prejudice since the early 1990s (Sallenave, 1994). However, Barsh (1997), argues that TK is essentially scientific because it is gathered through methods that are empirical, experimental, and systematic.

However, scientists continue to be reluctant to accept TK as valid because of its spiritual base, which have been regarded superstitious. What these environmental professionals often fail to recognize is that spiritual explanations rarely conceal functional ecological concerns and conservation strategies. Furthermore, the spiritual aspect of some concepts embedded in TK does not necessarily detract local people from making appropriate decisions about the rational use of resources. Spirituality merely indicates that the system exists within an entirely different cultural experience and set of values, one that presents no more and no less valid a picture of reality than the scientific system of knowledge (Johnson and Ruttan, 1991).

There is the claim that spiritual explanations of environmental issues may conceal conservation measures in most cases. For example, methods to improve fishing or hunting in Northern Canada that focus on appeasing the spirits or counteracting the effects of sorcery may divert attention from protecting threatened species as well as from the real problem of resource depletion (Johnson, 1992). The issue of spiritualism should be as much as possible be investigated and excluded in natural resource management if the authenticity of opinion based on such perceptions are not validated.

5.2. 2 Subjectivity and validity

TEK, like other knowledge systems (including science), could sometimes be wrong. Such errors may be due to misinterpretations made by both observers (such as informants or holders of TK) or by collectors of information (e.g. environmental professionals and researchers) (Huntington, 2000). Therefore, the collection and use of TEK in natural resource management should explore multiple informant sources for the purpose of triangulation of the information acquired.

There is a distinct difference between what indigenous people interpret as “significant” impacts and what environmental professionals and policy-makers regard as significant impacts. This poses an obstacle on both the effective monitoring of impacts and the possible incorporation of TK into the EIA and other EA processes (Sallenave, 1994). Each indigenous person has unique economic, practical, political, and historical relationships to his and her community, which implies that even within indigenous societies, TK is not homogenous. For example differential knowledge among women and men in areas of aquatic and terrestrial resource management is common (Turner, *et al.* 2000). The consultation of a wide range of socio-economic groups within communities under investigation may be able to reconcile the difference in opinion to arrive at a resultant representative of cultural norms or experience.

5.2. 3 Location-specific traditional knowledge (TK)

The importance accorded to TK for understanding environmental processes and designing sustainable management of natural resources has grown in recent years. However, variation in indigenous experiences and practices, both within and across cultures, has not been given much attention in resource management nor in developing scientific understanding of the ecological status of key resources (Ghimire, *et al.* 2004).

It is often difficult to generalise about practices that function in resource and ecosystem management in the specific aboriginal context. In addition a given experience that has been documented about one social group may be exclusive to that group alone and may not be useful outside its social and political contexts (Sallenave, 1994; Berkes, *et al.* 2000). Furthermore, TK has been maintained by the coexistence and co-relationship of people and environments, but may not be easily communicated to those of a different language, culture or in documentary forms (Paci, *et al.* 2002). The restrictive application and usage of TK may make collection and acquisition of this type of knowledge less cost-effective.

There are cultural barriers between aboriginal and non-aboriginal researchers, methodological barriers exist between social and natural scientists. The traditional anthropological methods of interviewing and participant observation are often perceived by natural scientists as lacking scientific rigour in their analyses (Johnson, 2003a). TK cannot be properly understood if it is analyzed out of the socio-cultural (the social perspective of TK includes the way people perceive, use, allocate, transfer, and manage their natural resources) and political context it exists in. Nevertheless, it is essential that TK research is undertaken in a multi-disciplinary dimension, and involving people with appropriate backgrounds, such as those that have background in biology, ecology, resource management and people with social science skills (Johnson, 1992).

In addition, TK is revealed through stories and legends that are difficult for outsiders to understand and appreciate these experiences. For example, even within communities, the younger community members may be unfamiliar with all of the subtleties and sophisticated terms of the aboriginal language. Consequently, these younger members of the community may not know how to ask the proper questions to obtain specialised indigenous knowledge of the ecology, medicines, and spiritual matters (Colorado, 1988; Johnson, 1991). Similarly scientific knowledge may be difficult for non-scientists to understand.

5.2. 4 Dynamic livelihoods and values

TK is a constantly evolving way of thinking about the world and should not be regarded as a dogmatic or static system of knowledge (Anderson, 1992). The viability and applicability of this knowledge system depends on the expansion of academic norms and social and scientific inquiry to acquire and document the dynamic culture of indigenous people. However, not all members of a given community are TK holders (Paci, *et al.* 2002).

Globally, the knowledge base of TK and associated concepts is threatened, and so are the possibilities for continued expression and reproduction of this type of knowledge (Turner, 2000). One of the major reasons for the rapid disappearance of TK is the death of elders and lack of resources to document it as well as the decline in the availability of CPRs (Johnson, 1992).

The decline in CPRs may also be responsible for a decline in the interest in TK, among the younger generation. This decline in interest may be *"reinforced by a modern largely "bookish" system of education"* (Gadgil, *et al.* 2000). However, younger people should be encouraged to take advantage of the recordings and demonstrations of indigenous knowledge system within their community as a way of adding value to their lifestyles (CSIR, 2005). In any case, whenever this knowledge is used for livelihood sustenance, even the death of elders or the depletion of CPRs may not adversely affect the continual existence of TK, because livelihood sustenance will definitely continue as long as life on earth persists.

5.2. 5 Harmonisation and usage

Most environmental professionals, government officials, and aboriginal peoples are of the opinion that, given the multi-cultural and multi-socio-economic nature of modern society and the ecological interdependence among nations, there is the need for the integration of TK and Western science in established decision support systems for sustainable natural resource use and management. Despite much discussion on the need to integrate these two systems, there are a few attempts to establish co-management institutions. The effective use of TK in decision-making is yet to be fully tested and established (Wolfe, *et al.* 1992).

The scientific approach to knowledge management is the deliberate analytical fragmentation of data in order to understand whole and complex phenomena. The scientific approach views social and natural phenomena as separate components, and humans are believed to be superior to other biotic ecosystem components (Johnson, 1992). On the contrary TK adopts a holistic approach to the acquisition and management of information about the environment, with humans viewed as an integral component of the ecosystem.

Respect for cultural diversity and the treatment of TK as coequal and complementary to hard scientific knowledge is fundamental to the integration and harmonisation of these knowledge systems into decision support systems. Indigenous peoples are requesting that their knowledge be respected and supported by scientists and environmental professionals because the use of TK has been vital for cultural survival, and ecosystems integrity (Nabhan, 1997). The rapid disappearance of TK has been associated with the absence of established documentation system for this knowledge system. It is only through documentation and the cooperation of all residents of rural areas that the usefulness of TK can become apparent and fully appreciated (Johnson, 2003a).

For example the comparison between western science and the knowledge of the Denes (An aboriginal group in Northern Canada) showed that it was evident that both knowledge systems require thoughtful and systematic observation to understand ecological processes and that both seek to utilise resources in an ecological sustainable manner. The main difference between the two systems appears to be: the different types of information gathered; the way this information is interpreted and expressed, and the approaches to resource management (Johnson, 1992). Scientists employ quantitative measures in the presentation of their findings while results from TK systems are generally qualitative and descriptive information.

Furthermore, in Canada, there are significant problems with the attempts to integrate the knowledge of indigenous people into EIA. However, the Canadian Environmental Assessment Agency (CEAA) currently undervalues TK (Paci, *et al.* 2002). Some holders of TK, on their part, were sometimes reluctant to share information, because of disputes over the ownership, use and control of TK that sometimes arise (Huntington, 2000). Some researchers argue that efforts to integrate TK with science serve to interpret TK in scientific terms, thereby taking it out of context while benefiting scientists and managers rather than holders of indigenous knowledge

(Cruikshank, 2001). Therefore, the use of TK by environmental professionals have not been collaborative, but merely exploitative (Nadasdy, 1999).

The design of an institutional arrangement that recognizes the validity of both TK and Western science are prerequisite for the successful implementation of co-management regimes, particularly in rural areas of Developing countries. Co-management regimes represent an attempt to integrate TK and Western science. A co-management regime is an institutional arrangement in which government agencies with jurisdiction over resources and user groups enter into agreement covering a specific geographic location and procedures for making collective decisions affecting all stakeholders (Osherenko, 1988). The integration of TK and Western science in resource management has been affected by the deliberate subordination of TK to Western science to the displeasure of most indigenous people (Johnson, 2003a).

5. 3 The place of TK in environmental assessment and management

TK has been recognised among environmental professionals for its value to contemporary environmental management, as well as its usage in the management of natural resources (Johnson, 1992). For example, the Canadian Arctic Resources Committee (CARC) advocated that the incorporation of TK in decision making will help to implement principles of sustainable development adopted by the federal and territorial governments and enshrined in various international agreements of which Canada is a party (Fenge, 1997). Hence, TK as a knowledge source is an integrated method of resource and ecosystem management, which is adaptive to environmental complexity and the dynamic environmental attributes.

5.3. 1 Information

Scientists have much to learn from rural people that have historically been able to identity issues that are important to them but which “outsiders” (such as environmental professionals) may not be able to see as such. TK provides an avenue of exploiting relevant information for the improvement of scientific research. A typical example is that the knowledge of traditional fishers in Northern Canada has been compiled over generations and found to provide essential information to environmental managers (Mackinson, 2001).

Indigenous communities routinely make common property decisions based on the premise of equity to all stakeholders. Such management system offers insight for environmental conservation (Becker and Ghimire, 2003). This may not be the case in all situations, particularly in areas where there are class domination. The incorporation of local knowledge and practices in the process of scientific research, have given rise to new hypotheses that have been relevant to contemporary environmental management (Ghimire, *et al.* 2004).

The analysis of TK and local management practices in Nepal shows that the vast body of knowledge possessed by the local people, particularly the specialist users, on the biology and ecology has great implications for developing appropriate biological and ecological research for the purpose of resource management (Ghimire, *et al.* 2004). Moreover, there are economic and political incentives for attaching importance to public perceptions and support, because public funds generated through national and local taxation are used for the management of natural resources. Hence, it is justified for environmental managers to seek the active co-operation of the public for many policies and decisions that may affect them (Tunstall, 2000).

5.3. 2 Localised livelihoods and ecological data

Local ecological understanding also appreciates the possible negative consequences of anthropogenic consequences such as large-scale logging, mining, and commercial fishing. Indigenous people with a historical continuity of resource use practices have acquired a deep knowledge base about the complex ecological systems with which they interact and most often rely on for livelihood sustenance. This knowledge is largely community / locality specific and descriptive (Kurien, 2000). In the Solomon Islands, much discussion in the Marovo community is about environmental trends and the relationships between rural people and their environment and how it affects their livelihoods. Specifically, resource depletion and scarcity have been easily identified by the Marovos (Baines, 2003).

For thousands of years, aboriginal people around the world have used knowledge of their local environment to sustain themselves and to maintain their cultural identity. However, only in the past decade, have this knowledge been recognized by the Western scientific community as a valuable source of ecological information. Today, a growing body of literature attests not only to the presence of a vast reservoir of information called TK that informs the local ecosystem; as well as the existence of effective indigenous strategies for ensuring the sustainable use of local natural resources (Watson, 2003).

The benefit of integrating TK into a broad-based system of knowledge is the ability to access a large amount of information and experience that has been previously ignored, thereby enhancing the effectiveness of baseline data required for environmental management (Pierotti and Wildwat, 2000). There is no substitute to the perception and experiences of local / indigenous people in the evaluation of local natural resources, particularly in situations where the resources are used for livelihoods sustenance.

Historically, the field of knowledge utilisation has been developed as a way to find solutions to the unsolved environmental problems to which existing knowledge and information has been applied and still remain unresolved (Castilo, 2000). In most rural communities in sub-Sahara Africa (SSA), rural ecological or environmental knowledge are usually linked to livelihoods, which has been rarely explored and used in environmental management. The neglect of TK continues irrespective of the fact that the present global scientific understanding of the environment is incomprehensive and inadequate to fully understand the environment as well as the dynamic nature of anthropogenic impacts on these systems.

5.3. 3 Traditional knowledge as a complement to Western science

Although there is a growing body of literature on the value of TK, only in recent years have researchers seriously examined the potential of using this knowledge in conjunction with Western science to study the impacts arising from development projects on the environment (Sallenave, 1994). The knowledge of rural people and their experiences, coupled with scientific understanding and ideas could provide the best means of ensuring that data gaps are filled, problems solved, and opportunities exploited (Chambers, 1978). Therefore, the use of TK offers one way of bridging gaps in perspective and understanding, especially when used in conjunction with knowledge derived by scientific method (Stevenson, 1996; Huntington, 2000).

Increasingly, the published scientific literature and the convening of conferences and workshops reflect the growing awareness that there is a legitimate field of environmental expertise known as TK (Freeman, 1992). The value of TK is becoming recognised by environmental professionals, managers, and policy-makers, and has been an evolving subject in national and international law (Anaya, 1996). Therefore, Mauro and Hardison, (2000) advocated that there is the need for scientists and the scientific community to:

- Increase their support for TK research in partnership with communities;
- Support the development and sustenance of indigenous management institutions;
- Make provision for the full and effective participation of indigenous communities in policy, research, and management; and
- Ensure transparency in research, and data management and support cultural revitalisation efforts and the continuous use of TK.

The multi-dimensional structure inherent in TK makes it relatively easy for knowledge and insights gained through TK to be communicated among members from different academic background, leading various stakeholders to negotiate more effectively with one another through shared conceptual framework (Pierotti and Wildwat, 2000). Therefore, the synergy between scientific knowledge and TK systems can play a positive role in sustaining biodiversity and nature's services, as well as sustain the cultural norms of indigenous communities (Becker and Ghimire, 2003).

Johnson (2003a), summarises the benefit of incorporating TK to Western management system as follows:

- TK can offer new biological and ecological insights into environmental research and investigations;
- TK when appropriately applied is relevant to the sustainable management of natural resource;
- TK could be used for conservation education, especially where the local communities derive benefits from the protected areas;
- TK can be used by development agencies and governments in providing more realistic evaluations of natural resources and their multi-user status; and
- TK could be used as a very valuable resource in holistically assessing the social and environmental impacts of proposed development projects.

Since the 1970s, the global environmental crisis has led to a belated acknowledgment that man is part of nature (see Figure 4. 2 for the traditional concepts of the ecosystems of which humans are an integral ecosystem component), a new paradigm challenging biological and ecological research, which has, in the past, tended to consider natural objects as totally independent of any social or political sphere. The 1992 Earth Summit in Brazil, through the Convention for Biological Diversity (CBD), acknowledges the role that TK could play in biodiversity conservation. Since then, academics and decision-makers have emphasized the value of local knowledge in determining the co-viability of social and ecosystem dynamics and in informing the design of people-centred resource management approaches (Ghimire, *et al.* 2004).

TK has gained international recognition through such documents as the *World Conservation Strategy* and *Our Common Future* (IUCN, 1980). Both reports (the CBD and IUCN report) emphasized the need to use the wealth of environmental knowledge of rural people in managing natural resources. Both reports stressed that sustainable management of natural resources could only be achieved by developing an environmental management system based on the priorities of local people and a blend between traditional and modern management approaches to addressing localised environmental problems (Fenge, 1997; Johnson, 2003a). The call for the preservation and recognition of TK as a tool for equitable development was further reiterated at the World Earth Summit on Sustainable Development in Johannesburg 2002 (United Nations, 2002).

In addition, international organisations, such as the United Nations and World Bank, are continually placing emphasis on bridging the implementation gap between the inclusion and exclusion of indigenous communities in public policy (Paci, *et al.* 2002). For instance, the World Intellectual Property Organisation (WIPO) has agreed to intensify efforts to protect TK as an attempt to improving sustainable resource use and management, but this has not been reflected in concrete commitment in the form of an international treaty (Kapp, 2003).

An understanding of local peoples' perception of their communities may be a crucial element in the design of projects aimed at encouraging and supporting community-based management regimes to enable people to improve their livelihoods and CPRs (Quinn, *et al.* 2003). For example, the neglect of the culture and social organisation of local communities may be one of a number of reasons for the failure of the resource management strategy imposed by central legislature between 1945 and 1958 in Tanzania (Kikula, 1999). The increasing recognition in the UK and elsewhere of the significance of public awareness, and attitudes towards environmental resources for equitable management has been a welcome development (Tunstall, 2000).

5.3. 4 Knowledge about seasonal variability and trends

The scale and duration of development projects under EAs often serve as the criteria for the scope of the assessment, hence, making the evaluation of the cumulative consequences of long-term projects difficult to ascertain with any certainty during snapshot EA processes (Paci, *et al.* 2002). For example, comprehensive scientific studies in Northern Canada are expensive and rare; data are often limited to the last ten to twenty years, making it difficult to establish trends over long periods. Migration patterns and sites aggregation are typically variable, thus scientists may not obtain reliable results from seasonal observations during a one- or two-year study (Fenge, 1997). Indigenous people, on the other hand observe wildlife habits throughout the year, during all seasons, night and day, and has done so for many generations (Sallenave, 1994). This may be an indication that TK has more to offer in the EA processes than its present status in resource management.

Furthermore, TK could be viewed as a "library of information" that has been developed in response to coping with dynamic changes in complex ecological systems. The knowledge of indigenous people may help connect the present to the past. Building ecological knowledge to understand qualitative changes in complex systems has been a means for improving the chances of survival of indigenous people and environmental sustainability (Berkes, *et al.* 2000). A local knowledge system is “traditional” because of its firm roots in the past, with a specific origin in indigenous culture and the local environment. Tradition is often unwritten, based not only on what each generation learns from the elders but also on what that generation is able to add to the elders’ knowledge. For example, the Marovo people’s knowledge and understanding of their environment is a complex system that has evolved over centuries (Baines, 2003).

5. 4 Emerging issues

TK constitutes a valuable resource for assessing the social and environmental impacts of development projects and environmental change. It is necessary that indigenous peoples are involved in the design and implementation of environmental management strategies through their participation with equal authority as Western scientists under appropriately established legal standing (Johnson, 1992). A potential shortcoming that may constrain the method of pooling knowledge is the possibility of having pieces of knowledge from different experts that may be inconsistent or even conflicting (Mackinson, 2001). Even, among Western scientists, there are disagreements between social and natural scientists regarding the most appropriate methods to use in the documentation and integration TK (Johnson, 2003a).

Furthermore, Johnson (2003a), identified the issues listed below as the reoccurring reasons for the difficulty in the integration of TK into scientific management system, these are:

- The disappearance of TK as a result of the unavailability of resources to document it;
- There are practical problems in reconciling two different world views and the attempt in trying to translate ideas and concepts from one culture into another; and
- Attitude problems, which has been characterised by cultural barriers and misunderstanding that has prevented western scientists and aboriginal people to acknowledge the value of each other’s knowledge system.

Nevertheless, the importance of TK in environmental monitoring, or for understanding ecological processes, has received much attention in resource management (Berkes, *et al.* 2000; Huntington, 2000; Olsson and Folke, 2001). International agencies such as the World Wildlife Fund (WWF) and UNESCO, in the context of their joint program, have promoted research on the knowledge of rural people, as well as integration of people’s perceptions and practices in resource management at the local level. Therefore, the incorporation of TK into biological and ecological studies of local resource use patterns and of the social and institutional background that guides the relationships between people and nature, has led to a greater understanding of the relationship between social and ecological dynamics (Ghimire, *et al.* 2004).

However, most aboriginal peoples are often reluctant to accept Western science because of what appears to be its fundamental need to control and interfere with nature. Nevertheless, in some instances, the Western scientific knowledge system may be able to provide information that is otherwise unavailable through TK (For example, the ability to view phenomena at the microscopic level or over large distances are beyond the scope of TK). The involvement of indigenous people through appropriate consultation and collaboration could lead to the break down of cultural barriers between environmental professionals and local people (Johnson, 2003a).

The difference between traditional and scientific perceptions is understandable since reactions of a society or culture to development cannot be understood outside the context in which it exists. Moreover, the continued exclusion of indigenous peoples and their knowledge from decision support systems in environmental management only makes the situation of sustainable resource management difficult to attain. To bridge the gap of exclusion of indigenous people is to develop a meaningful dialogue among all parties, with indigenous people playing a greater role in EAs process (Sallenave, 1994; Castillo, 2000). Therefore, an effective knowledge management system must be developed for the collection and classification of native knowledge, particularly with respect to local culture as well as applicable in other social contexts without losing the essential value of such knowledge source (Hobson, 1992).

Among scientific branches, ecology has been given particular responsibility for finding solutions to environmental problems by involving resource users in effective resource management (Castillo, 2000). Some Western scientists are still unable to accept indigenous knowledge as valid in itself. Most often, TK is translated directly into English without examining whether or not the scientific terminology accurately reflects the indigenous concepts being described. Scientific terminology may not be able to capture the concepts expressed in the local languages; hence, some of the insight from TK may be lost through translation (Johnson, 1991).

Interest in TEK has been growing in recent years, partly due to the recognition that the participation of traditional people and the application of their knowledge could help resolve ecological problems, such as loss of biodiversity and restoration of degraded ecological systems (Berkes, *et al.* 2000; Turner, *et al.* 2000). TK offers rich ecological insights, and it allows indigenous and other local communities to participate more effectively and equally in resource management, thereby supporting sustainable and more equitable development policies. The use of TK confers numerous benefits from the narrowly technical and scientific to the broadly cultural and political (Huntington, *et al.* 2002). In the Asian and Pacific context, the importance and relevance of TK for ecosystem sustainability has been well documented (Kurien, 2000).

Scientists should recognise that TK could be used to understand and predict environmental consequences and the risk posed by environmental changes. This type of knowledge is embedded in socio-cultural contextual norms and does not function in isolation. The structure and dynamics of institutions are critical for implementation of management practices based on ecological understanding in any society (Berkes, *et al.* 2000). The application of TK in environmental management and the longer-term study of the environment in general require building linkages between communities (and individuals within these communities) that are the holders of TK with other environmental stakeholders.

Researchers and environmental managers should be aware that neither TK nor Western science should be judged for its worth according to a rigid set of rules and generalizations or a static image of the past. The knowledge system of any culture is constantly changing through the "*assimilation of 'outside' knowledge and synthesis and hybridization with existing knowledge*" (Mulvihill, 1988). Ultimately, both approaches have their strengths and limitations in solving environmental problems and both knowledge systems are somewhat interlinked (Johnson, 1991). Nevertheless, the sharing of existing knowledge may not be necessarily sufficient; hence, the gathering of new information should be collaborative to create trust and a sense of shared ownership among those involved.

In contrast to Western science, TK is more holistic than reductionist, subjective rather than objective, and experiential rather than positivist. It is often difficult to transmit ideas and concepts from TK to those who do not share the tradition and the experience, because it is culturally based. For example, aboriginal hunters may have developed their concepts through their own experience as well as shared and familiar experiences with other members of the community. Any instruction they had received would be oral instruction from another person and rarely from a recorded source. Consequently, hunters may find it difficult to describe their observations and ideas to someone versed in scientific explanation and unfamiliar with the local cultural and cognitive system (Wolfe, *et al.* 1992). Table 5. 1 contains a summary of a comparison between TK and Western science knowledge systems.

Table 5. 1 Comparison between TK and knowledge based on Western Science

S/No.	Traditional knowledge system	Western scientific knowledge system
1	All elements of matter are viewed as interconnected and cannot be understood in isolation.	This system operates under a deliberate system that breaks down data into smaller elements to understand whole and complex phenomena
2	Intuitive mode of thinking emphasising emotional involvement and subjective certainty of understanding	Analytical and objective thought, emphasises abstract reasoning. Observations have to be replicable to be acceptable.
3	Mainly qualitative detailed qualitative knowledge about the environment is gained through ongoing intimate contact with the resource.	Mainly quantitative; Western scientists gather quantitative information to build mathematical models.
4	Based on data generated by resource users. As such, it is more inclusive than Western science	Western science is collected by a specialized group of researchers who tend to be more selective and deliberate in the accumulation of facts and information
5	TK is based on diachronic data (long time series of information on one locality)	Western science is largely based on synchronic data (short time series over a large area)
6	TK is rooted in a social context that sees the world in terms of social and spiritual relations between all life-forms. Relations are based on reciprocity and obligations toward both community members and other life-forms and communal resource-management institutions are based on shared knowledge and meaning.	Western science is hierarchically organized and vertically compartmentalized. Managers become distinct from harvesters; authority becomes centralized and flows from the top down. The environment is reduced to conceptually discrete components that are managed separately.
7	TK explanations of environmental phenomena could be spiritual and based on cumulative, collective experience. It is checked, validated, and revised daily and seasonally through the annual cycle of activities	Western science employs methods of generating, testing, and verifying hypotheses and establishes theories and general laws as its explanatory basis

(Wolfe, *et al.* 1992)

There are however, exceptions to the above generalizations in Table 5.1. For example, the result from the work of Feit (1986), with sub-arctic beaver trappers indicates that TK could be quantitative. Berkes (1977), also reported that the Cree fishermen of the sub-arctic are perfectly capable of carrying out controlled field experiments. In terms of recording and transmitting the traditionally oral knowledge, aboriginal researchers are now experimenting with the use of film, audio and the written word.

For many aboriginal peoples, however, TK is at the heart of their cultural identity and remains a viable aspect of their way of life. For the rest of the world, apart from the ethical imperative of preserving cultural diversity, TK is important for many tangible and practical reasons (Becker and Ghimire, 2003). Such as in northern Sudan, where elders have provided useful information to forestry scientist and managers based on their experience (Barker and Cross, 2003). This is an indication that there has been tremendous untapped knowledge among indigenous people that could be of benefit to environmental professionals.

Despite over two decades of efforts towards involving indigenous peoples and the need to use TK in environmental management (Klubnikin, 2000), there is hardly any evidence that indicates the actual involvement of indigenous people in the management of their environment (Nepal, 2002). One way of addressing the issues of neglecting indigenous knowledge could be the inclusion TK in the educational curriculum. This suggestion has been based on the premise that TK is equal to Western scientific knowledge and that this knowledge system can be taught and learned in formal schools (Forrest, 2000).

Much TK has been severely eroded by national and international development policies and interaction with western cultures. However, the two sources of understanding have some common ground: both knowledge systems rely on direct observation; experience; experimentation; and interpretation. Western science offers TK a broader appreciation of the context beyond the local level that may favour local sustainability and, thus, cultural survival. On the other hand TK offers western science depth experience in a local context and a window to cultural interpretations that may be logical, unique and rich. These knowledge systems can be complementary, therefore, viewing either of these knowledge systems as purely negative is not productive for biodiversity conservation or for ecologically sustainable development (Becker and Ghinire, 2003).

However, in Marovo, in the Solomon Islands, TK is starting to fade particularly among younger residents who spend long periods at school away from Marovo and away from rural subsistence activities that are dependent on CPRs. Nevertheless, TK is still widely possessed, by those who remain actively involved in traditional subsistence activities, including many people of the younger generations (Baines, 2003). In addition, for many centuries, African communities have generated knowledge necessary for their day to day living. Despite suffering ridicule and repression as well as not being widely documented, indigenous knowledge has survived (CSIR, 2005).

Critics of TK often deliberately ignore the significant changes that are occurring within Western science. Over the past 20 years, the fundamental tenets of Western science is becoming increasingly interdisciplinary in approach in response to today's world that is highly interconnected, in which biological, psychological, and social dimensions are recognized as belonging to an interdependent system (Capra, 1982). Since the early 1990s, the tenets of ecological management and the concept of sustainable development have found many parallels with TK (Booth and Jacob, 1990; Johnson, 1991; Wolfe, *et al.*1992).

Reed *et al.* (1967), acknowledges that despite the fact that local fishermen in Northern Nigeria may not have had the privilege of attendance of formal educational institutions, their knowledge about their environment constitutes a wealth of knowledge (particularly about the local fisheries resource) that many years of expensive formal education could not have given. Therefore, fisheries workers and managers should not neglect the great fund of information of these rural fishermen. Though, this has been reported over forty years ago, the experience of Nigerian fishers about fisheries may still be relevant to today's environmental managers.

Barker and Cross (2003), conducted a survey between 1989 and 1990 in eight Sahelian countries (These are: Burkina Faso; Chad; Ethiopia; Mali; Mauritania; Niger; Senegal; and the Sudan) with the aim of documenting TK, to improve cooperation between holders of indigenous knowledge and authorities responsible for the management of local natural resources, for the purpose of project planning and implementation. The findings of the authors' survey are summarised below:

- The elderly tend to play a very dormant role in most long-term environment projects, based on the premise that these are too frail for hard, voluntary work and economically less productive;
- Despite the neglect of the elderly in these countries, the elderly are very much honoured and respected by members of their communities;
- Most development projects fail to benefit from the knowledge and experience of the elderly in these countries;
- Social change such as improved access to formal education may have contributed to the loss of cultural continuity;
- TK has been increasingly regarded as out-of-date;
- That the documentation of TK could rescue it from extinction as well as demonstrate its value to the younger generations and outsiders;
- That recent environmental and economic pressures in these regions have created social unrest, which Western scientific description and illustrations of these changes have failed to capture the subjective aspects of these unrests; and
- That TK has a place to play in the understanding of the social context of environmental and economic problems as well as in addressing these issues.

There is increasingly the recognition of the vital role of the knowledge of indigenous people in the sustainable management of the environment and as a suitable alternative to management systems based solely on Western science. The change in perspective has resulted in a shift away from theoretical studies to more applied research in Canada. Recent emphasis in applied research has been on understanding the ecologically sound practices that contribute to sustainable resource use among indigenous peoples and ways that this knowledge can be successfully integrated with the Western scientific resource management strategies (Brody, 1981; Gunn, *et al.* ; Johnson, 1991).

TK has been widely applied in various areas of human endeavour. For example, the knowledge of the Akha people of Northern Thailand have been applied and successfully used in the area of traditional medicine, nutritional knowledge, animal husbandry, handicrafts, agriculture, water resources management, and forest management. Agricultural knowledge includes an understanding of soils, natural fertilizers, and traditional cash crop and forest products. The knowledge of water resources includes an awareness of underground currents, the location of water sources in areas of scarcity, and the hydraulic principles of water systems. The Akhas' forestry management knowledge is substantial, even in heavily deforested areas. This forest belt serves both economic and ecological interests. It is a source of medicine, food for both people and animals, and protection for some animals (Von Geusau, 2003).

There is a growing body of literature that attests not only to the presence of a vast reservoir of information regarding plant and animal behaviour but also to the existence of effective indigenous strategies for ensuring the sustainable use of local natural resources (Johnson, 2003a). In addition, until quite recently, many inland river fisheries in Africa have been managed by traditional systems, which had evolved within local communities based on indigenous knowledge. Therefore, the presence of traditional fisheries management systems could have important implications for fisheries policy in Nigeria and other West African countries (Neiland, *et al.* 2000).

5. 5 Ecological assessment (EcLA) and traditional eco-livelihood knowledge (TELK)

The ecosystem approach and the concept of sustainable development are examples of environmental philosophies among modern ecological movement that has drawn inspiration from TK (Johnson, 1992). In the context of this research the eco-livelihood approach has been derived from the concepts of ecological assessment and the sustainable livelihood framework. Chapter 6 presents a vivid illustration of an attempt at using social research tools to access TELK and Western scientific approach to identify ecological consequences of in-land river dredging. This integration of approaches represents an attempt at using eco-livelihood assessment in a developing country setting where the dependence of CPRs has been a major livelihood component and baseline data are unavailable or inadequate.

Eco-livelihood assessment as an environmental assessment tool is an attempt at addressing the issue of inequitable distribution of the benefits of development projects in a rural setting in a developing country. This approach explores TELK in understanding environmental trends and seasonality. Therefore, the eco-livelihood assessment approach as applied in this research context is people focused and aimed at addressing the issue of the equitable distribution of the benefits and negative consequences of development projects.

5. 6 Chapter summary

Indigenous people have a long-standing relationship with their environment and their knowledge has been used to their benefit for survival and in the sustainable exploitation of their local environment. TK is the broad concept encompassing: TEK which implies indigenous knowledge specifically about the environment; and TELK that is knowledge about the local environment that is used for livelihood sustenance.

The application of TK and its associated concepts however has its limitations, such as: bias from the Scientific community; perceived subjectivity of TK; localised in content and application; dynamic livelihoods and localised perceptions; and the constraints of harmonisation and usage of TK. However, TK has been identified to contribute to the quality of research as well as broadened the applicability of scientific research by: providing long-term (historical) information that may not be able to be accessed by environmental professionals; provided localised livelihood data and information; providing information about seasonal variability which complements science where and whenever science has not be able to adequately address environmental issues. TK should not be ignored just because it is not recorded like Western science, because oral traditions are often very reliable.

TK is presently recognised by many International and national governmental organisations as an invaluable source of knowledge. The knowledge of indigenous people have been successfully used in research in many countries such as Canada, Nigeria, Ecuador, Mexico, the Solomon Islands and eight Sahelian Sub-Saharan countries as well as being increasing recognised elsewhere as in the UK and Tanzania. Therefore, it may be necessary to invest in documenting and exploring TK and its associated concepts in assessing anthropogenic impact, particularly in rural communities in developing countries.

Chapter 6 The Study Area and field work

6. 1 Background

This Chapter contains background information of the Study Area, as well as the approaches that has been used to investigate the research hypotheses. The research hypotheses are as shown below:

- ***Eco-livelihood is a significant livelihood component in the Central Niger Delta (specifically the Study Area) and in similar areas in most developing countries;***
- ***Traditional eco-livelihoods knowledge (TELK) can provide useful baseline data for EA especially where eco-livelihood is a major livelihood source and baseline data are inadequate and or unavailable;***
- ***Fisheries can be used as good indicators in the retrospective assessment of the impacts of inland river dredging on the ecosystems that are of livelihood significance; and***
- ***Eco-livelihood assessment (EcLA) is an appropriate EA tool in areas where the dependence on the ecosystem is a major livelihood component.***

The research methodology has been divided into two major aspects; these are the social and ecological surveys. The field work was carried out between January 2004 and August 2004 in four communities in the Study Area in the Ogbia local government area (LGA) (Ogbia LGA is one of the eight LGAs in the Central Niger Delta (Bayelsa State). The Central Niger Delta is presently administratively made up of eight (8) LGAs, these are: Southern Ijaw (SILGA), Ogbia OGBALGA), Yenagoa (YELGA), Ekeremor (EKELGA), Sagbama (SALGA), Nembe (NELGA) and Brass (BALGA) LGAs.

6. 2 Study Area

Nigeria has rich, underdeveloped but developable and navigable inland waterways. The appropriate exploitation and development of these waterways could result in benefits to all stakeholders (Wolf, *et al.* 2005). The Niger Delta is located in the southernmost part of Nigeria, with about 30, 000 km^2 of wetland. The Delta is ecologically fragile but rich in biodiversity and characterised by a network of rivers, creeks and swamps that has historically maintained a dynamic balance between saline, estuarine and freshwater systems (Abam, 2001).

Bayelsa was created on October 1996 from the old Rivers State, and it is presently one of the six states of the Niger Delta region and one of the 36 states in Nigeria. The name **Ba- Yel - Sa** is an acronym derived from the three parent LGAs that were part of the old Rivers State. These three LGAs were combined to form a Senatorial district for the purpose of elections into the Upper Federal Legislative Chamber (House of Senate) in 1979 and 1983 (Alagoa, 1999). **Ba** represents BALGA for Brass LGA; **Yel** represents YELGA representing Yenagoa LGA; and **Sa** representing SALGA for Sagbama LGA. In the present day Bayelsa State, BALGA has been divided into three LGAs (Brass, Nembe and Ogbia LGAs), YELGA into three LGAs (Yenagoa, Kolokuma / Opokuma and Southern Ijaw LGAs), and SALGA into two LGAs (Sagbama and Ekeremore LGAs). Table 6. 1 shows the major languages spoken in the Central Nigeria Delta.

Table 6. 1 Major languages spoken in the Central Niger Delta

Local government area (LGA)	Language(s) spoken
Brass (BALGA)	Nembe
Ogbia (OGBALGA)	Ogbia
Nembe (NELGA)	Nembe
Yenagoa (YELGA)	Epie-Atisa, Okordia, Zarama, Biseni, Ijaw
Southern Ijaw (SILGA)	Ijaw
Kolokuma Opokuma (KOLGA)	Ijaw
Ekeremor (EKELGA)	Ijaw
Sagbama (SALGA)	Ijaw

6.2. 1 Geography and ecology

Bayelsa is located in the Central Niger Delta region of Nigeria (Alagoa, BSEDPA, 1998; 1999), at Longitude 6 degrees east, and Latitude 4 degrees 30 minute north and covers an area of about 12, 000 square kilometres about 70% of which is riverine (Alagoa, 1999; Angaye, 1999). The Central Delta have the longest coastline among the maritime states in Nigeria, measuring approximately 200 km (Sikoki and Otobotekere, 1999). The Ramos River marks the boundary between Bayelsa State and Delta State in the west and north, the Santa Barbara serves as the border between Bayelsa and Rivers State in the east, and the Atlantic ocean represent the southern perimeter (Alagoa, 1999).

The Niger Delta is the fourth largest wetlands on earth, and the largest in Africa, it encompasses over 20,000 square kilometres, characterised by high biodiversity with many unique fauna and flora (World Bank, 1995b; HRW, 1999; Ohimain, 2004). The Niger Delta is a vast floodplain with four major ecological zones, these are: coastal barrier islands; mangroves; fresh water swamp forests; and lowland rainforest, the boundaries between the ecological zones are transitional (See Section 4.2.1 for the description of ecosystem boundary) and vary according to seasonal flooding patterns (HRW, 1999). Figure 6. 1 shows the ecological zones of the Niger Delta. The Study Area is between the Nun and Orashi Rivers in the Niger flood zone. However, the environmental issues that have been associated with the Delta have compromised the age-long ecological attributes of this vast wetland.

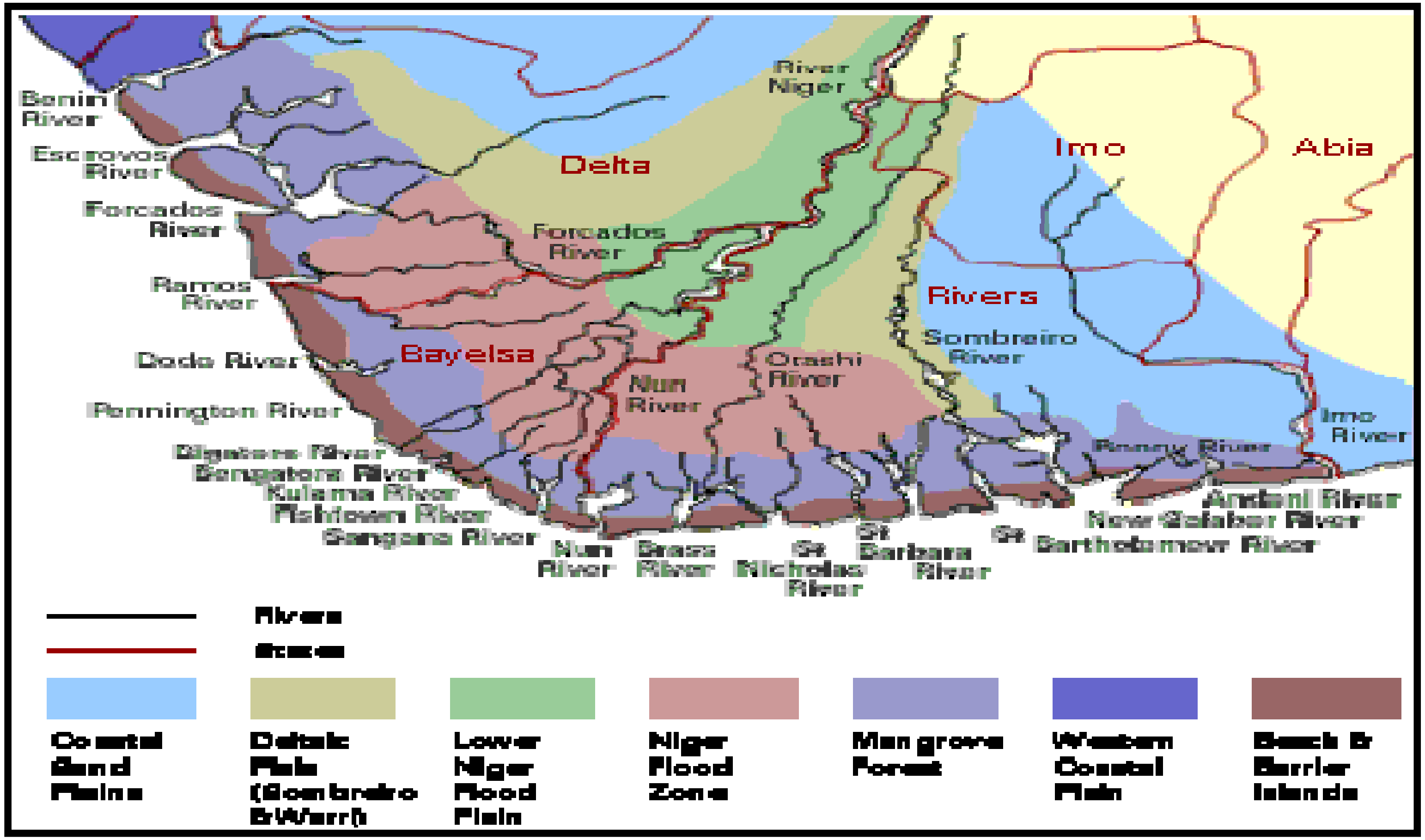
The World Bank (1995b) coordinated a stakeholders' workshop in the Niger Delta in 1995 and the findings of the workshops have been summarised in Table 6. 2 that shows the common environmental problems of the Niger Delta, which are all common problems in the Central Delta (the priority ranking has been based on best available information). All the listed environmental issues may have in one way or the other compromised the biodiversity of the Niger Delta. However, the order of priority of these environmental issues has been criticised by Tamuno (2001) as elitist, because most of the participants in the stakeholders' workers are resident in Port Harcourt, Lagos and Warri (these are bigger cities and towns in Nigeria and not rural areas where most of these environmental problems occur). For example, some of these issues (such as oil pollution and gas flaring) are generally regarded as among the major environmental issues in the Niger Delta by residents of rural communities contrary to the outcome in Table 6. 2. The above opinion notwithstanding, the outcome of the World Bank participatory workshop provides the most comprehensive list of environmental issues in the Niger Delta. Inland river dredging has been reported as one of the factors responsible for fisheries depletion. In this thesis five of the environmental issues of high priority and one of moderate priority have been re-echoed by the respondents of this study (see Table 7. 20).

Table 6. 2 Ranking of environmental issues in the Niger Delta

Category	Ranking		
	High priority	Moderate priority	Low priority
Land resource degradation	Agricultural land ; degradation; and Flooding (Moderate high)	Coastal erosion; and Riverbank erosion	Sea level rise
Renewable resource degradation	Fisheries depletion; Deforestation; Biodiversity loss; and Water hyacinth expansion	Fisheries habitat degradation	Mangrove degradation; and Nypa palm degradation
Environmental pollution	Sewage; Emission from Vehicles; Municipal solid waste; and Toxic and hazardous waste	Oil pollution; Industrial effluent; Industrial air emission; and Municipal solid waste	Gas flaring

(World Bank, 1995b).

Figure 6. 1 Ecological zones of the Niger Delta

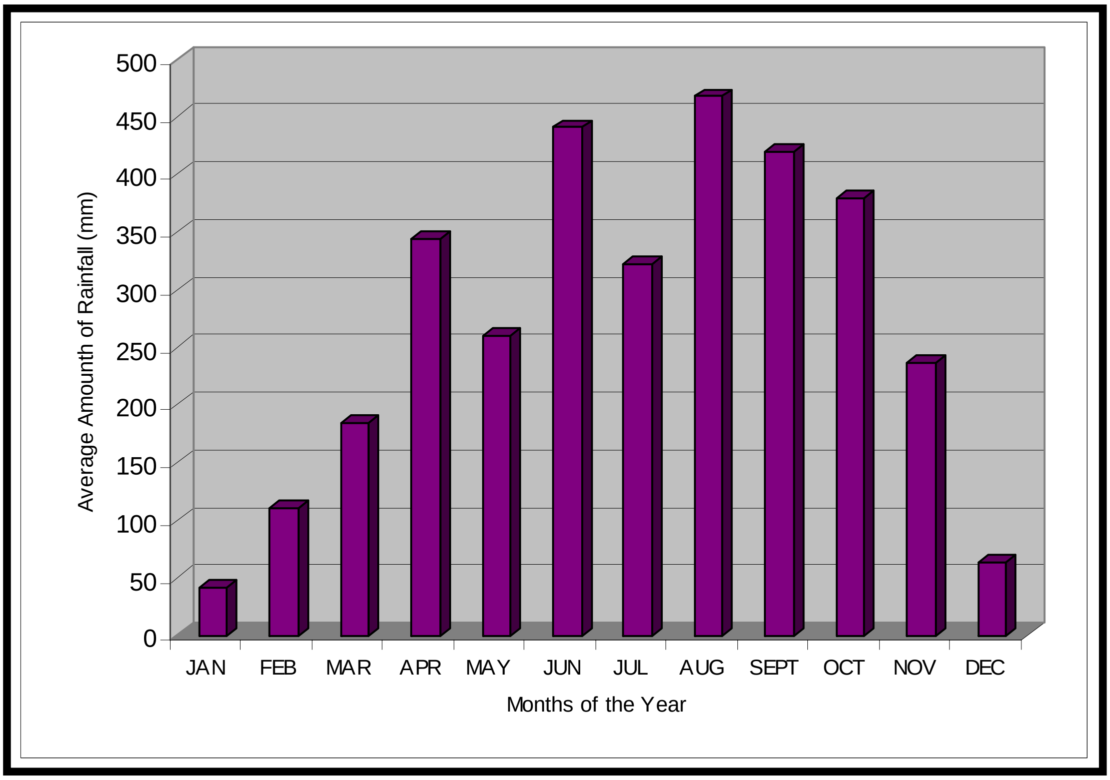


Source: (SPDC, 2000)

6.2. 2 Rainfall and drainage pattern

The Central Delta has a humid semi-hot equatorial climate (Oyegun, 1999). The mean annual rainfall ranges from between 2,000 and 4,000 mm and spreads over eight to ten months of a typical year between the months of March and November. The duration of the dry season is comparatively shorter, beginning from December and extending to February, but there are however, occasional rainfall and storms during the dry seasons (Abam and Akagbue, 1986). Figure 6. 2 show the average rainfall pattern at the Peramabiri rice farm in the Central Delta. About 45% of the rainfalls are precipitated between August and November, which has been identified as the flood season (Tamuno, 2001).

Figure 6. 2 Average rainfalls at Peramabiri between 1948 and 1992



Source: Modified from (NDBDA, 1992)

About 40% of the total aquatic region of the Niger Delta is made up of freshwater, that are contained in rivers, creeks, floodplain swamps and lakes, and a greater proportion of the Niger Delta's fresh water area lies within the Bayelsa area. The characteristics of the fresh water ecosystem are dynamic and dependent on the annual flood pattern (Sikoki and Otobotekere, 1999).

Bayelsa is mainly a low-lying wetland environment, with interconnected rivers and creeks, which are linked to national and international waterways outside of the Niger Delta region, and the land surface of the Central Niger Delta slopes gently in a north-south direction towards the Atlantic ocean (UNCSD, 1997; Sikoki and Otobotekere, 1999). Larger rivers in Bayelsa like the Nun, Brass, St. Nicholas and Santa Barbara have channels often in excess of 500 meters even at their more northerly reaches. Some of the medium sized creeks like the Apoi, Seibiri, Sagbama and Taylor creeks are more than 100 meters in width. There are about 6 kilometres of channel length for every square kilometre of land space in the Central Delta (Oyegun, 1999). Table 6. 3 contains a summary of the lengths and widths of major rivers and creeks in Bayelsa State with Kolo Creek and Otuoke Creek (in the context of this thesis Elebele / Otuoke Creek) highlighted (The major drainage channel in the Study Area is the Kolo Creek). Furthermore, Figure 6. 3 shows the drainage pattern in the Ogbia LGA of which Kolo Creek is one of the major rivers.

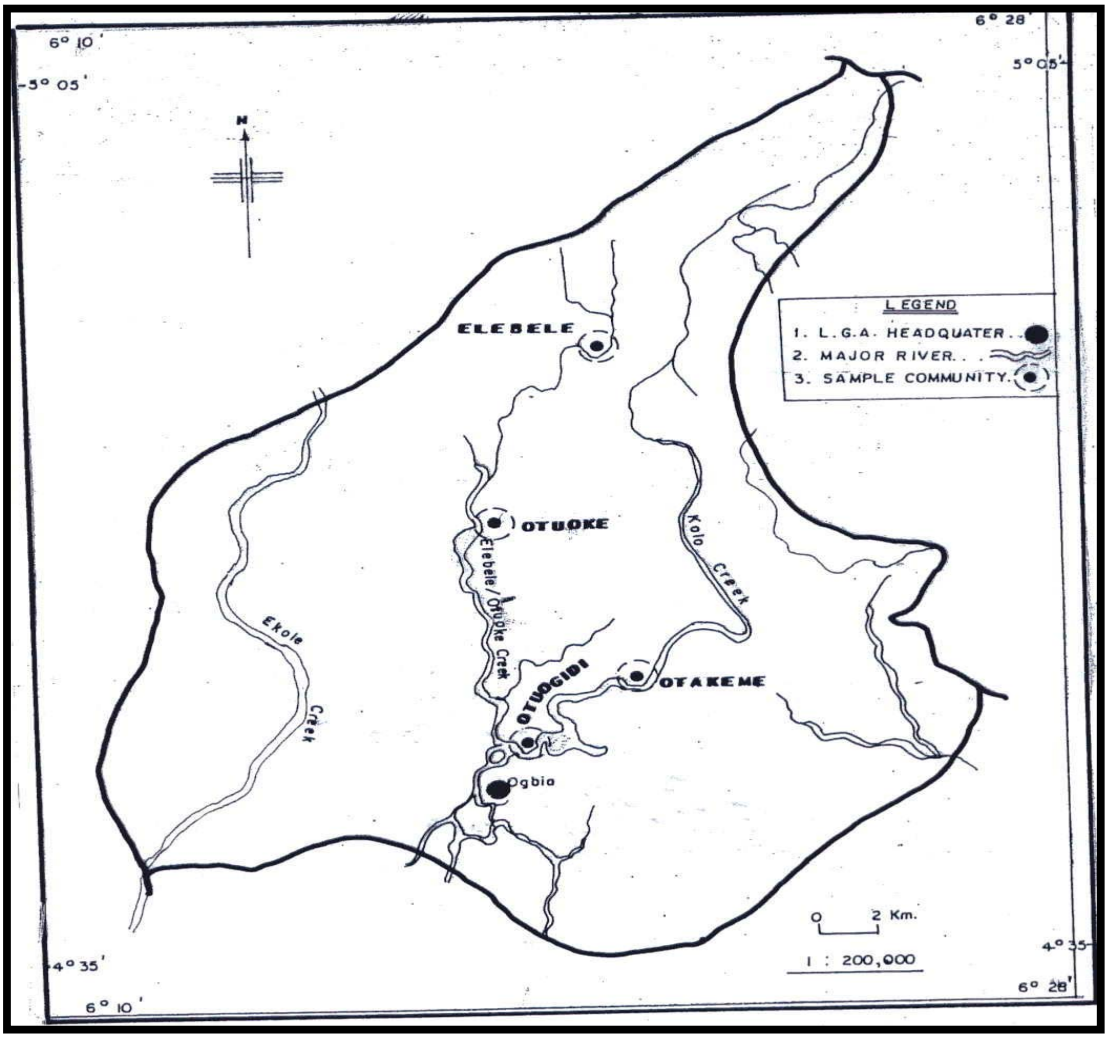
Table 6. 3 Major rivers and creeks in Bayelsa State

S.No.	Names of Rivers or Creeks	Length in Km	Average Width in m
1	Nun River	195	370
2	Taylor Creek	95	ND
3	Ekole Creek	78	150
4	Epie Creek	35	ND
5	Kolo Creek	85	ND
6	Otuoke Creek*	33	ND
7	Egbedi Creek	38	190
8	Egbebiri Creek	41	100
9	Diebu Creek	51	ND
10	Bassa Creek	9	ND
11	Ologaga-Abylabiri Creek	24	ND
12	Ogubiri Creek	26	325
13	Osiama Creek	55	140
14	Polobobou Creek	10	ND
15	Okolomabiri Creek	21	ND
16	Sangana River	50	315
17	Ikebiri Creek	55	60
18	Seibiri Creek	54	180
19	Olugboboro Creek	44	230
20	Kugbogbene Creek	43	ND
21	Sagbama Creek	39	210
22	Brass Creek	40	ND
23	Apoi Creek	82	50

Source: Modified from The (NDBDA, 1980). ND No Data

***** Elebele / Otuoke Creek (in the context of this thesis)

Figure 6. 3 Map of the Study Area and drainage pattern



Source: Author's map

6.2. 3 Population

The total population of the Central Delta based on the 1991 census was 1,121,693, 52.1% of which are males and 47.9% females (NPC, 1997). Table 6. 4 contain the projected population of the LGAs in the Central Delta. This projection is based on a 3% growth rate and on the assumption that emigration and immigration is always equal (NPC, 1997; UNCSD, 1997). Table 6. 4 shows the population distribution of Bayelsa State as projected for 2004 based on the result of the Nigerian 1991 Census figures. This population distribution has been arranged in descending order with Ogbia LGA highlighted.

Table 6. 4 Projected 2004 population of Bayelsa State by LGA

	LGA	Total Population	Male Population	Female Population
1	Southern Ijaw (SILGA)	392, 643	205, 332	187, 311
2	**Ogbia (OBGALGA)**	**234, 039**	**134, 311**	**99, 728**
3	Nembe (NELGA)	225, 891	106, 068	119, 824
4	Brass (BALGA)	186, 375	96, 101	90, 274
5	Ekeremor (EKELGA)	182, 508	94, 922	87, 586
6	Sagbama (SALGA)	175, 870	91, 288	84, 582
7	Yenagoa (YELGA)	152, 817	80, 114	72, 703
8	Kolokuma/Opokuma (KOLGA)	97, 092	48, 191	47, 432
	Total	**1, 647, 244**	**857, 796**	**789, 448**

Source: Modified from (NPC, 1997).

The average population density of the Central Delta was 122 per square kilometres (based on 1991 census figures), and this sparse population density may be as a result of the very difficult terrain of this area. As a matter of fact the majority of the LGAs in Bayelsa lie in the lower Niger Delta that is characteristically flooded all year round. On the other hand, the two most populous LGAs (SILGA and OGBALGA) are located in the Upper Niger Delta where the lands are relatively drier when compared to the lower Niger Delta (Akpoghomeh and Okorobia, 1999). As at 1991 OBGALGA is the most densely populated LGA with 272 persons per square kilometre. However, based on the author's personal experience the situation may have changed based on the premise that Yenagoa is now the capital of Bayelsa State; this may have resulted in the migration of rural people to Yenagoa town. Therefore, YELGA may most likely presently be the most populous LGA in the Central Delta.

About 50% of the population of Bayelsa is made up children below 15 years, while 4.7% of the population are above 65 years, and the remaining 47.3% constitute the working age population (between 15 and 65 years). The dependency population are those below 15 and those above 65 years, which puts the dependency ratio of Bayelsa at 1.2. The dependency age ratio is therefore an indication of the burden on the working age population. The implication of this is that an average of 100 persons in the productive age range (15 - 65) have to support about 112 people as regard education, health, food, shelter, and general support (Akpoghomeh and Okorobia, 1999). Such a dependency ratio represents a relatively high economic vulnerability in the Central Delta. In the context of this research the target population are those that are twenty years and above. Twenty years has been used as the base year because the average age of school leavers in the Central Delta is eighteen and an adjustment of two years has been used so that the target population represent those that are expected to have a livelihood source. (See section 6.3.4.1 for the selection criteria for respondents that participated in the social survey).

6.2. 4 Livelihoods

This section contains an appraisal of the major livelihoods pattern, as well as an overview of the general outlook of the socio-economic situation in Bayelsa. The World Bank (1995a), reported that the Gross National Product (GNP) per capita of Rivers State (old) was at 1995 below the Nigeria national average of US$280. This low GNP may be attributed to the high dependency ratio in the Central Delta of 1.2 (see section 6.2.3).

The numbers of the poor is increasing and unacceptably high in the Niger Delta region, especially since available natural capital stocks such as fisheries, tropical forest and biodiversity are fast depleting. In addition, as at 1991, the unemployment rate in Bayelsa State was the highest in the country and about three times that of the national average (NDES, 1997; Akpoghomeh and Okorobia, 1999). The Nigeria average unemployment rate was 28% (NPC, 1997).

Fisheries, agriculture and forestry, are the major livelihood source in Bayelsa State, with over 65% of the people earning their livelihood from this economic sector. In addition, rotational cultivation of food and cash crops, and rearing of domestic animals are also common agricultural practices (Allison-Oguru, *et al.* 1999).

6.2.4. 1 Farming

Farming is one of the major livelihood sources in the Central Delta. The meander belt, part of the mangrove belt, on the soils of the flood or alluvial plains and non-flood plains or dry lands are presently used for farming in the Central Delta. The major crops cultivated in the flood and alluvial plains include cassava, sugar cane, rice, cocoyam, and yam, Table 6. 5 contain a summary of the farming calendar of major crops cultivated in Bayelsa.

The size of a typical farm household in the Central Delta, ranges from between 2 and 25 people, which is made up of the husband or the farm head, his wife / wives and children. Such a large farm household size reduces the demand for hiring labour from non-family sources. The bush fallow system is predominantly practiced in the Central Delta. The bush fallow farming system entails a practice in which lands are cleared, cultivated for between 1 and 3 years and left to fallow from 4 up to 10 years. This type of farming system favours the regeneration of farmland.

However, in recent years, rapid population growth have increased the pressure on land and fallow periods have being reduced resulting in gradual deforestation and declining crop yields (Allison-Oguru, *et al.* 1999).

Table 6. 5 Farming calendar of major crops cultivated in Bayelsa State

Crop	Planting time	Harvesting time
Plantain	All year round except periods of very high rainfall and drought	All year round
Cassava	All year round except during periods of very high rainfall and drought	All year round
Yam	December – March	May – August
Maize	December – March	April – July
Cocoyam	All year round except during periods of very high rainfall and drought	All year round
Melon	December – February	April – July
Rice	June – September including Nursery establishment	August – December

Source: (Allison-Oguru, *et al.*1999), pp 289

6.2.4. 2 Fishing

The entire coastline of Bayelsa State is lined with fishing villages, which are either temporary or permanent fishing settlements. In 1985, the population of full and part-time fishermen in Rivers State (old) was 23,590, and 17,240 respectively, and considering the fact that Bayelsa occupies two third of the coastline of old Rivers State. It would therefore be logical to infer that two third of the above population represents fishers from Bayelsa State. By 1994 the population of fishers in the Old Rivers State rose to about 33,598 and 25,036 full and part-time fishers in Bayelsa State respectively. These figures represent 12.7% of full-time and 12.96% of part-time fishers in Nigeria. Furthermore, as at 1998, the fishery sub-sector represented a high foreign exchange earner, generating about 20 million US dollars annually as well as providing secondary employment to more than one million Nigerians. Specifically, fishing and related means of livelihoods are the main base of the rural economy in most communities in the Central Delta (Sikoki and Otobotekere, 1999).

The period between July and mid-September usually experiences low fishing activity due to "rough" waters (flood season). During this period, fishermen engage in gear mending and preparation for the next fishing season (flood recession season). Traditionally operated fish ponds are estimated to yield 300 to 500 kg/ha, while small-scale fishponds can yield 1 ton/ha/yr (Satia, 1990). Table 6. 6 summarises the major fish species in different habitats of the Central Delta.

Table 6. 6 Commonly occurring fishes in the catch by fishers in Bayelsa State

Fish Species	Habitat Types		
	Inland River	Floodplain	Swamp / Lake
Pellonula leonensis	X		
Parailia pellucida	X		
Heterotis niloticus		X	X
Mormyrus rume	X		
Gymnarchus niloticus		X	X
Brycinus Macrolepidotus	X		
Distichodua spp	X	X	X
Citharinus citharus	X		
Labeo spp	X		
Heterobranchus spp	X	X	X
Synodontis spp	X	X	X
Parachanna spp		X	X
Oreochromis niloticus	X	X	X
Tilapia zilli	X	X	X
Clarias spp	X	X	X

Source: (Sikoki and Otobotekere, 1999), pp 318

From Table 6. 6, it could be seen that about 80% of the fish species caught by fishers in the Central Delta are from inland rivers. This implies that inland rivers serve as a considerable source of income as well as food in Bayelsa State. Table 6. 7 shows the 14 most caught fish species by inland river fishers, based on which *Tilapia spp.* constitute about 12% of the total fish catch in the Central Delta.

Table 6. 7 Inland river fish catch records for 1991 and 1992 in the Central Delta

Species	Catch (kg)		
	1991	1992	Average use
*Tilapia spp**	2,309.53	2,419.38	2,364.45
Parachanna spp	1,759.64	1,857.13	1,808.39
Citharinus spp	1,541.69	1,621.05	1,581.37
Clarias spp	1,484.70	1,534.96	1,509.83
Gymnarchus nloticus	1,429.69	1,528.80	1,479.26
Heterobranchus spp	1,429.17	1,528.80	1,478.99
Papyrocranus afer	1,374.73	1,452.83	1,413.78
Distichodus spp	1,266.74	1,294.85	1,280.80
Heterotis niloticus	1,209.26	1,288.69	1,248.98
Lates niloticus	1,154.77	1,212.79	1,183.78
Alestes spp	1,099.77	1,130.69	1,115.23
Chrysichthyes spp	1,044.80	1,130.69	1,087.75
*Synodontis spp***	939.79	1,044.59	992.19
Hepsetus odoe	783.07	820.85	801.96
Total	**18,827.35**	**19,866.10**	**19,346.73**

* Includes all cichlids ** Includes all Mochochidae

Source: Modified from (Sikoki and Otobotekere, 1999) pp 319

Appendix 3 contains a summary of the main fishing gear types used by fishers in Nigeria. Generally, set-and-wait, chasing, barrier, and hovering gears are commonly used gears for fishing in tropical inland freshwater. A brief description of these major fishing gear types are presented below:

- Set-and-wait gears are set and hauled after a few hours, and catch fish when they are feeding or moving around the floodplain, examples of this type of gear are gill nets, portable traps and baited hooks;
- Chasing gears involve more active pursuit of fish by fishers, such as drag nets, push nets, some types of seine nets, cast nets and spears;
- Barrier gears are set more permanently than set-and-wait gears to catch fish during seasonal migrations. Barrier gears may be set both in the main river (where it is narrow enough), or in the secondary channels where fish migrate off the floodplain when waters fall. They may also be complete barriers (e.g. suspended trawl nets, bamboo barricades) or only partial barriers, which do not span the full width of the channel (e.g. Lift nets);

- Hovering gears are used in the dry season to catch fish stranded in pools and river channels (e.g. fish drives, electric fishing, and - most dangerously – poison and dewatering).

(Hoggarth, 1999).

Inland freshwater fishery in Nigerian is practised predominantly at the artisanal level. Artisanal fisheries'' imply small scale, labour based fishing that is carried out by subsistence fishers that are unable to acquire large industrial fishing boats (such as trawlers and purse seines) and sophisticated mechanized fishing gear, and therefore have to make do with dugout/planked canoes with simple fishing gear. The productivities and incomes derived from such fisheries are generally low and lack infrastructural backing and credit facilities. Despite this low scale of operation, artisanal fisheries production accounts for over 45% of the world fish catch and constitutes over 40% of the total world supply of food fish. In addition, artisanal fisheries accounts for about 85% of the national total fish production from the inshore waters in Nigeria (Moses, *et al.* 2002).

Fishing in the Central Delta has been carried out in either marine / brackish waters or inland freshwaters. Marine water fisheries is an all-year-round affair, with fishers taking advantage of favourable fishing seasons, such as moon phases; ocean current; fish migratory pattern. However, fishing activities in brackish water are usually high during the rainy season. The most important gear types used in brackish and coastal waters are Gill nets and Cast nets, while other commonly used are Long line, Fish fences, Tidal filter traps and hand nets (Sikoki and Otobotekere, 1999). These fishing gears have been successfully used by fishers in fish harvest in the Central Niger Delta.

As at the early 1980s freshwater fisheries account for about 40% of the total fish catch in Nigeria (Bosseche and Bernaseck, 1990). However, data on the inland fisheries of the Central Delta remain scanty (Otobo, 1995). Inland freshwater fisheries are basically at subsistence level, involving many people, and different fishing gears are usually used in exploiting the resources in rivers, creeks, floodplains, swamps and swamp lakes. Full-time fishers are few in inland waters compared to marine waters and most inland freshwaters fishers combine fishing with other means of livelihoods to supplement their income (Sikoki and Otobotekere, 1999). This implies that multi-livelihoods have been used by fishers in Bayelsa state as a means of living in a vulnerable area, such as the Lower Niger floodplain.

Despite the Nigeria 1992 inland fisheries decree, that puts the ownership and management of fisheries resources on the government. The management of fisheries resources is still under community control. Fishing is intensified and confined to the river channels in the dry season or low water period, but shifts into the inundated floodplain at the high water flood period. At this period the river channels are abandoned due to the fast flow of the flood water and take advantage of the lateral movement of fish into the floodplain (Sikoki and Otobotekere, 1999). Therefore, the favourable fishing seasons in inland rivers in the Central Niger Delta are: the dry season and the flood recession season, while the unfavourable fishing season are the rainy and flood seasons.

6.2.4. 3 Commerce

The people of the Central Delta are involved in several commercial activities, which range from canoe carving, manufacturing of ceramics, decorative materials, distillation and marketing of locally brewed gin, as well as a retinue of formal and informal commercial activities (Alagoa, 1999). Therefore, petty trading is a common livelihood component in the Central Delta, while middle scale commercial activities are presently represented by supermarkets, palm oil processing and operators of commercial land and riverine transport services.

6.2.4. 4 Formal economic sector

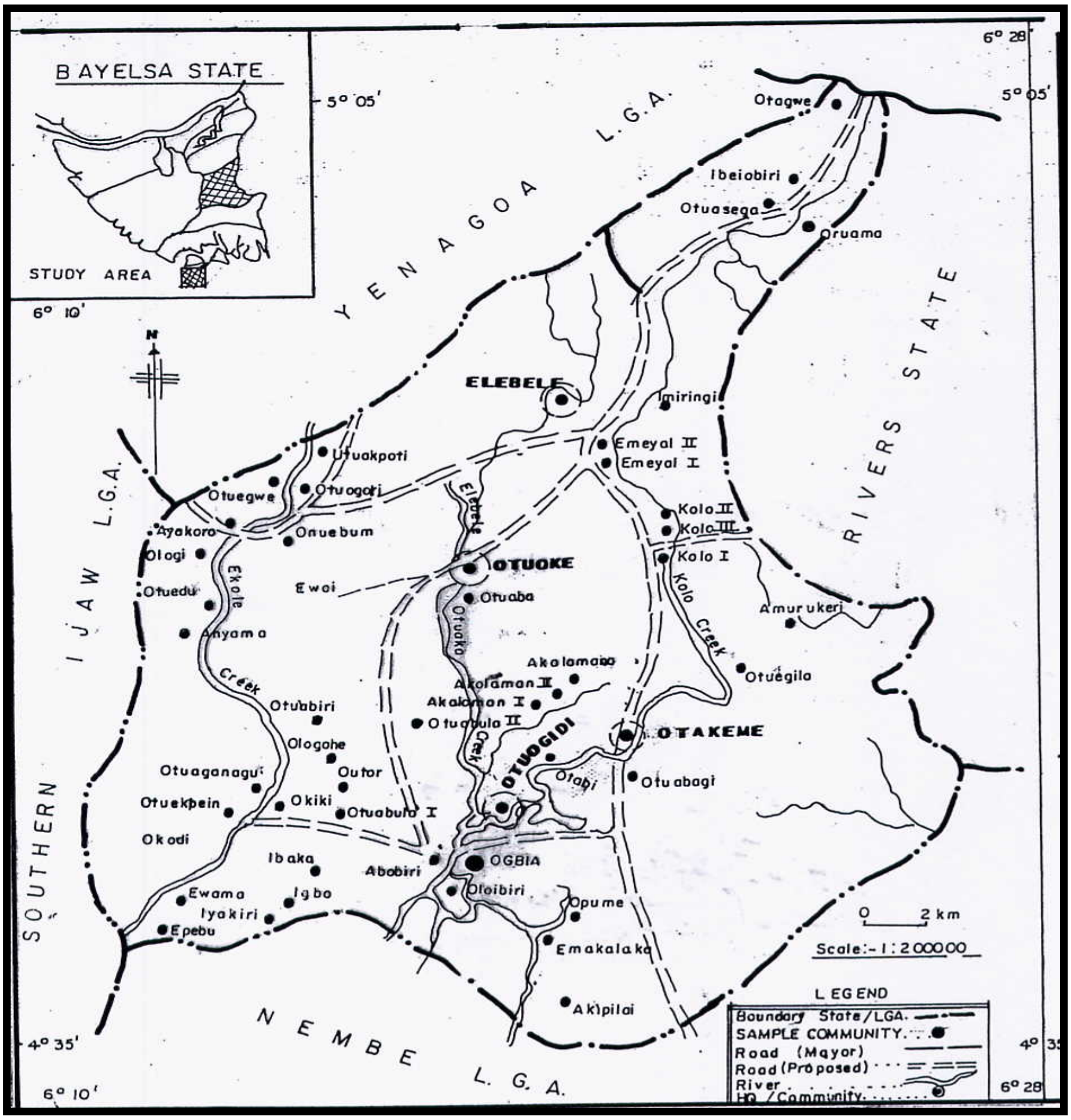
It is widely believed that the Bayelsa State government is the major employer of labour in the formal economy sector of the Central Delta. This statement has been buttressed by the report of Oyadongha (2001), that the major employer of labour in the Central Delta, is the State government. However, with the creation of Bayelsa State in 1996 and the present spate of development in Bayelsa State, there has been an increase in the proportion of those employed by construction companies, commercial banking institutions, as well as departments and parastatals of the federal government of Nigeria (FGN).

6. 3 Field work

The field work has been designed to investigate the validity or otherwise of the research hypotheses in the Study Area as outlined in section 1.2. The Study Area has been identified as a geographical area within the Ogbia LGA. Social and ecological surveys have been used as the major research tools for this study. The field work was carried out in the Study Area between January 2004 and August 2004, after a preliminary survey that was done between November and December 2003.

Figure 6. 4 show that the Central Delta falls within three ecological zones (the Barrier forest, the Mangrove Swamp and the Freshwater swamp), while all the communities in the Study Area fall within the Freshwater swamp zone. Figure 6. 4 show the map of Ogbia LGA with the sample communities in Ogbia LGA in the Study Area respectively. The Test communities (Otuogidi and Otuoke) are both located down stream of their respective reference communities (Otakeme and Elebele). Table 6. 8 contains the 2004 estimated population of the sample communities based on projection from the 1991 National Population census figures (Based on a 3% growth rate).

Figure 6. 4 Map of the Central Delta showing the sampling communities in Ogbia LGA



Source: Author's map

Table 6. 8 Projected populations of sample communities

Community	Male 2004	Female 2004	Total 2004
Elebele	1,540	1,592	3,132
Otuoke	1,903	2,078	3,981
Otuogidi	2,197	1,997	4,194
Otakeme	2,519	2,372	4,890
Total	**8,159**	**8,039**	**16,198**

Source: Modified from (NPC, 1997).

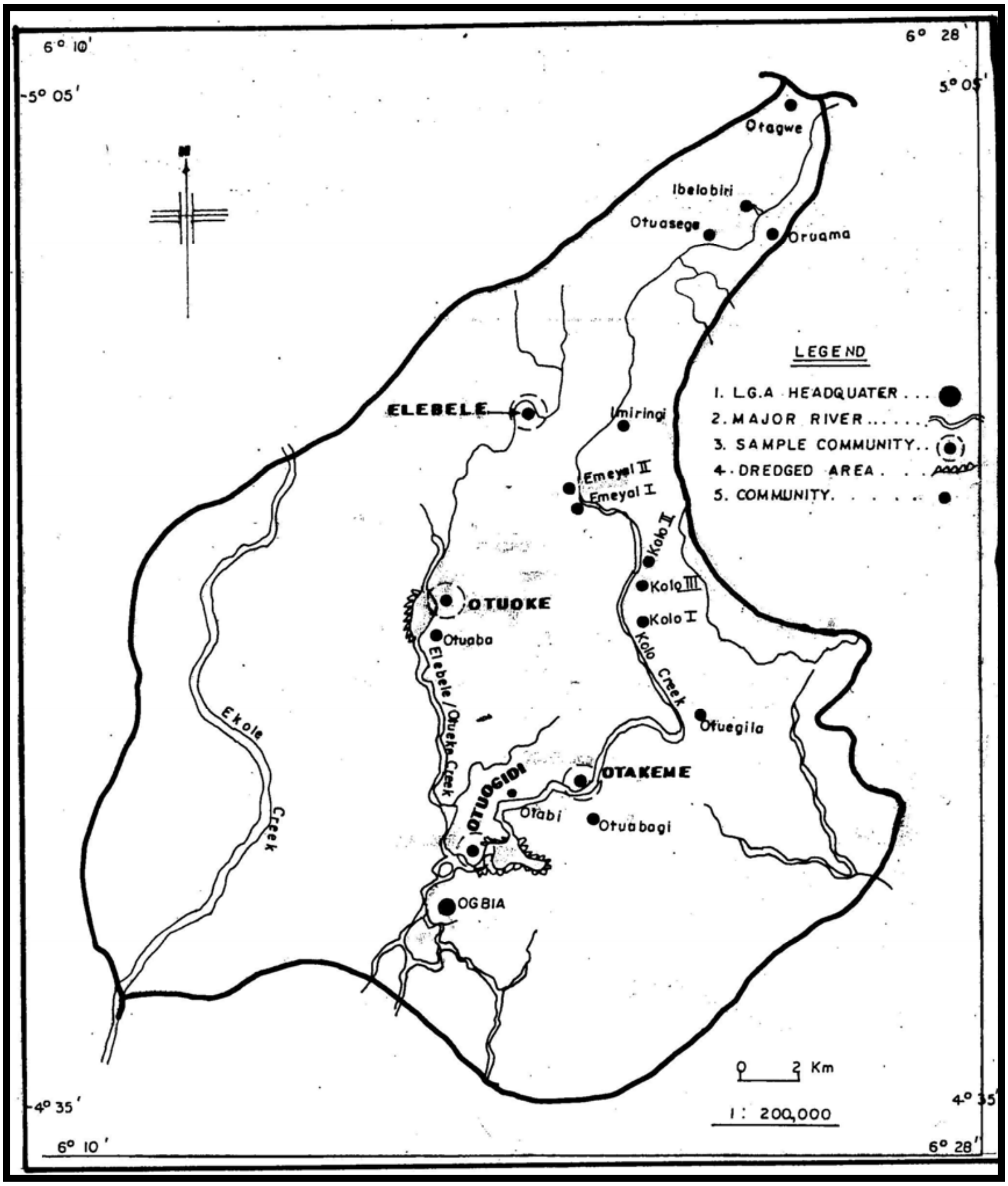
6.3. 1 Selection of sample communities

The four sample communities have been selected for this study based on the criteria listed below:

- All communities are expected to have similar ecological features, and be within inland freshwater catchment of the Central Delta;
- All communities should have as much as possible experienced similar environmental stressors. This helps the understanding of all environmental consequences that may have affected the research results;
- All four communities should be accessible (physically and cost-effectively accessible) during the sampling periods (between November 2003 and August 2004);
- Fishing should be one of the major livelihoods source in all sample communities; and
- Members of the sample communities should be willing to participate in the ecological and social surveys.

The only difference in criteria for selecting Test and Reference communities is that river section(s) along Test communities must have been dredged, while those along Reference communities must not have been dredged. Royer *et al.* (2001), recommended that reference sites should be as much as possible representative of unimpaired condition, or area in which the anthropogenic action of interest has not occurred, while Test sites are impaired locations as a result of anthropogenic stressor(s) under study. Figure 6. 5 show the dredged sections in the Study Area.

Figure 6. 5 Map of the Study Area showing dredged locations



Source: Author's map

6.3. 2 Survey tool and approach

Interview questionnaires constitute the social survey tools. These questionnaires have been administered to willing respondents from the sample communities that are twenty years of age and above. Cast nets (See Appendix 3 for the description of Cast nets) and dug-out canoes have been used for sampling fish species in the river stretch of both the Test and Reference communities, with the help of experienced fishermen from the respective communities. Experienced in the context of this thesis refer to fishermen that are regarded as renowned or respected (respected based on their fishing prowess) fishers by other fishers and other respondents of the respective sample community. The ecological survey has been carried out in three out of the five fishing seasons. The fishing seasons are: Rainy season (June – August), Flood season (September and October), Flood recession season (November and December); Dry season (January – March); and Early rainy season (April and May) that has been identified from the preliminary survey. The ecological survey was executed during the Dry, Early rainy and Rainy seasons. Figure 6. 6 show a Cast net that has been hung to dry after a fishing expedition in the Study Area, while Figure 6. 7 shows a Fisher throwing a Cast net from a dug-out canoe.

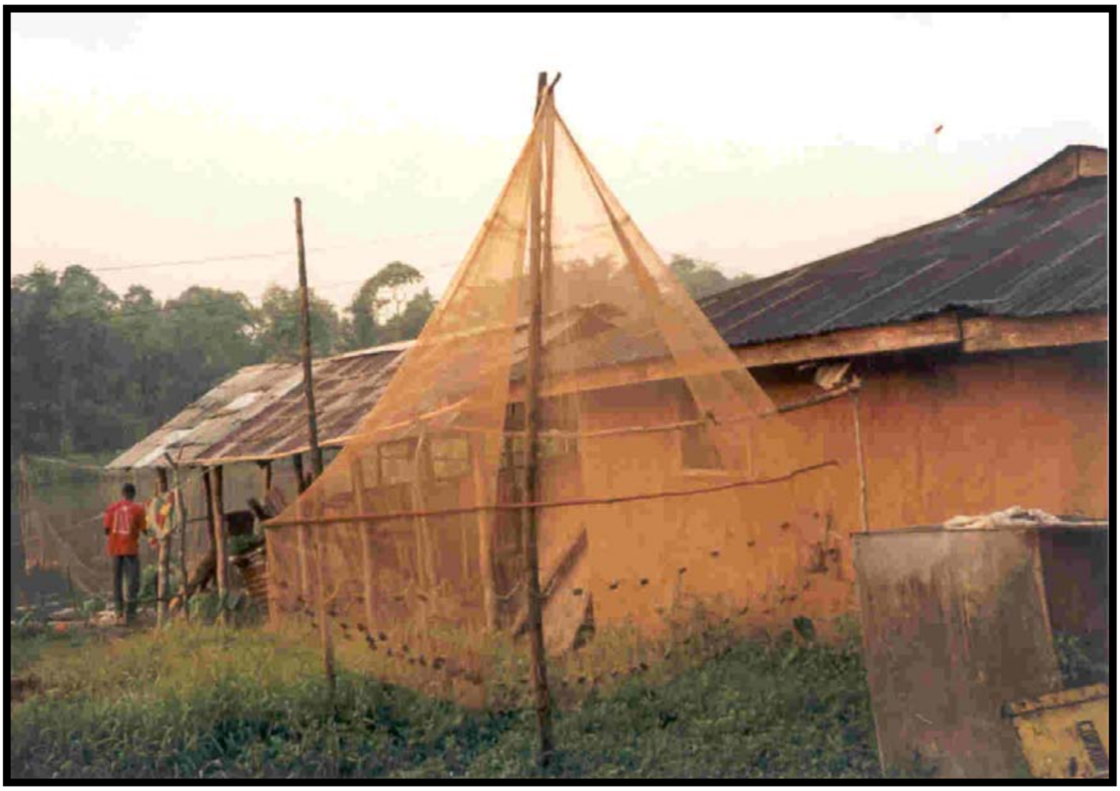


Figure 6. 6 A Cast net hung to dry in Otuogidi

6.3. 3 Ecological survey

The aim of the ecological survey was to identify the ecological consequences of inland river dredging that may be of livelihood significance in the Study Area. Fish diversity, abundance and trophic structure have been investigated in the sample communities to identify the consequences of dredging on the ecological system that may be of livelihood significance in the Test communities. Fisheries has been used as the indicator community for this study because fisheries are of livelihood significance in the Study Area (for details see Section 6.2.4.2) and have inherent ecological significance because fish occupy various trophic level as well as reasons that have been summarised in Box 4. 2.

The dredging projects that have been carried out along the Kolo and Elebele / Otuoke Creeks have been for the purpose of land reclamation and the sands used for road construction. The projects have been conducted between the years 1999 and 2000 along the Otuogidi section of the Kolo Creek, and 2002 along the Otuoke section of the Elebele / Otuoke Creek, by The Ballast Ham Dredging and the Global Seaways Dredging respectively (both are private companies).

Figure 6. 7 A Fisher throwing a Cast net in the Kolo Creek

6.3.3. 1 Sampling seasons and procedure

The seasonal abundance of fisheries is affected by the length of dry season and the height and duration of flood (Hoggarth, 1999). In addition ecological variation may be because of natural causes such as seasonality or as a result of anthropogenic actions. Therefore, natural variation may make it difficult to establish the relationship between observed effects and human impact on the environment (Karr and Chu, 1999; Adams, *et al.* 2000). Sampling across seasons may help to reduce error that could arise as a result of natural ecological variation. Therefore, the ecological survey of this research has been carried out to represent as much as possible seasonally with the purpose of isolating the eco-livelihood impacts of dredging from natural variation and environmental noise (other environmental issues that may affected the indicator community that have not been investigated). Table 6. 2 contain some of the other environmental stressors that have occurred in the Study Area.

The ecological survey has been conducted in duplicates (Two sampling days per season) between 06:00 hours and 19:00 hours during the Dry season (in February), Early rainy season (April), and Rainy season (between June and July). Table 6. 9 contains a summary of the ecological survey, which shows that sampling have been carried during three of the five fishing seasons identified above The colour codes have been used to represent sampling season, these are: Yellow for Dry season; White for Early Rainy season; and Green for Rainy season. Furthermore, (T) has been used to represent Test community, while (R) for Reference community. Similarly, Whitefield and Paterson (2003) used such sampling protocol in which samples were collected (using Seine nets) in all 40 sample locations in the Eastern Cape estuaries, South Africa, over two consecutive days during the months of January, May, July and October in 1999.

Similarly, in the River Benin, Nigeria routine sampling of fish from the study site was conducted on a fortnightly basis at night only (23.00 - 04.00 hours) from May to December 1990 and 1991. in this case the author conducted sampling at night because the preliminary survey revealed the absence of *B. Zongiunalis* (which was the target species of this study) in the daytime catch in the River Benin (Ikomi, 1996).

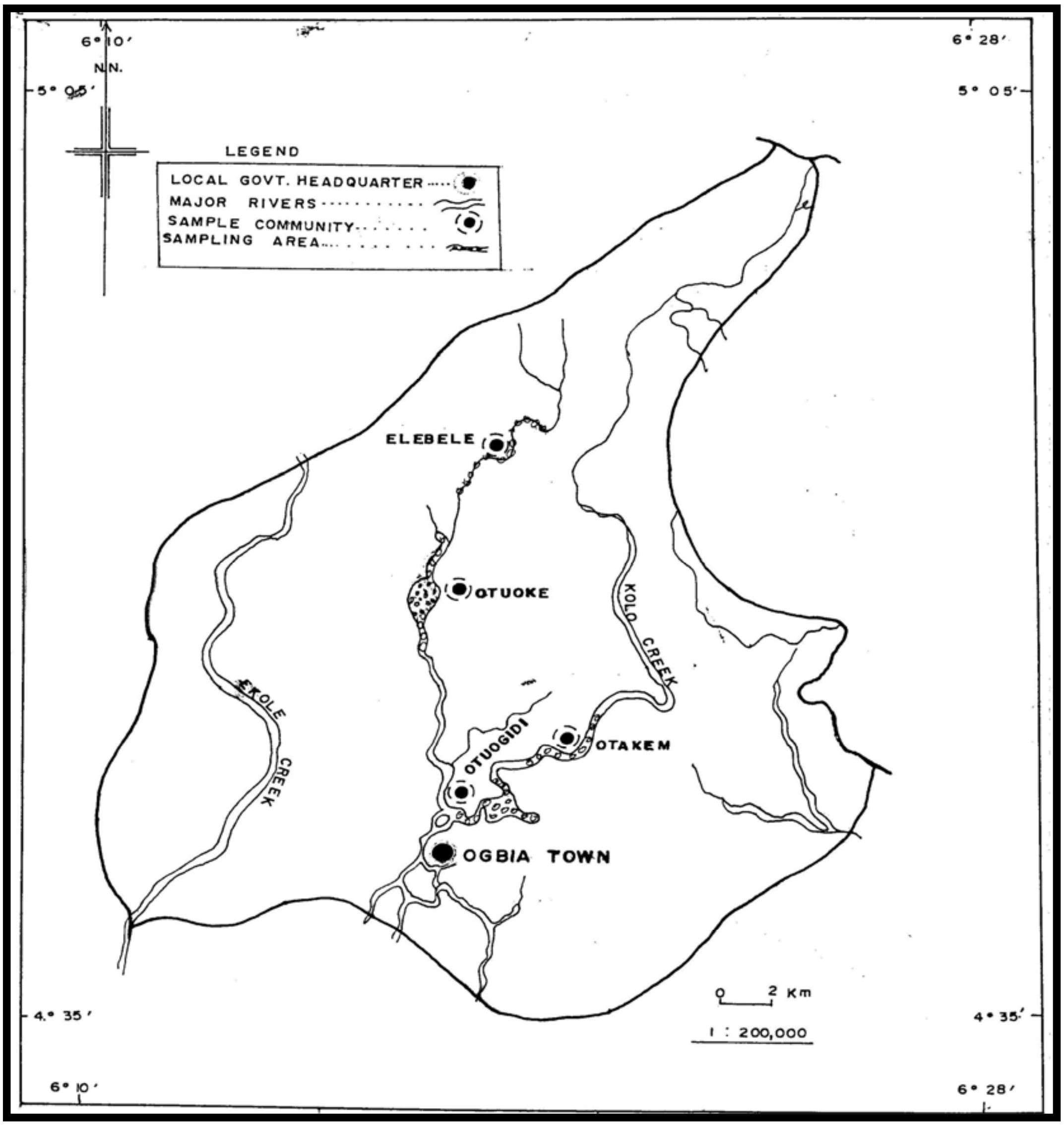
In the case of this research, there has been a deliberate avoidance of night sampling due to the risks (a twenty-eight year old fisher and indigene of Otuogidi lost his life during a fishing expenditure along the Otuogidi section of the Kolo in January 2004) that may be associated with night sampling using traditional fishing equipment. Moreover, the reason why sampling has not been done during the Flood season is the risk that may be posed by the high flow and height of flood waters. The ecological survey was conducted during the Flood recession season because the pre-ecological survey (Identifying sample communities, sampling locations and survey personnel) and the preliminary survey were done during this season. The preliminary survey involved the author travelling to all prospective sample communities along the dredged channels and checking if the selection criteria highlighted in section 6.3.1 have been met. In addition the general relevance of fishing as a means of livelihood was cursory investigated.

The sampling has been done across all river habitat (See Figure 4.3 for details of microhabitats of stream that are applicable to rivers and creeks) and fishing grounds in all four sample communities, which has been based on the professional knowledge and experience of the respective fishers that were involved in the ecological survey. Figure 6. 8 show the sampling sections of the Kolo and Elebele / Otuoke creeks. The use of localised knowledge in the design of the ecological survey has been advocated (Karr and Chu, 1999). Furthermore, Karr and Chu (1999), had reported that optimal sampling period varies from region to region and advocated that the use of local or regional knowledge could enhance the efficiency of the sampling protocol.

Table 6. 9 Summary of ecological survey sampling

Community	Sampling season	Day	Date	Time	Duration (Min.)
Elebele (R)	Dry season	1	24th February 2004	13:40 – 17:56	256
Elebele (R)	Dry season	2	28th February 2004	10:18 – 13:04	166
Elebele (R)	Early rainy season	3	22nd April 2004	15:15 – 17:28	133
Elebele (R)	Early rainy season	4	23rd April 2004	15:15 – 17:48	153
Elebele (R)	Rainy season	5	9th June 2004	15:17 – 1805	168
Elebele (R)	Rainy season	6	12th June 2004	11:16 – 14:47	211
Average duration - Elebele					181
Otuoke (T)	Dry season	1	18th February 2004	10:19 – 14:46	267
Otuoke (T)	Dry season	2	20th February 2004	07:34 – 11:08	214
Otuoke (T)	Early rainy season	3	29th April 2004	07:38 – 10:09	151
Otuoke (T)	Early rainy season	4	1st May 2004	09:35 – 12:56	201
Otuoke (T)	Rainy season	5	15th June 2004	11:50 – 15:29	219
Otuoke (T)	Rainy season	6	17th June 2004	10:56 – 13:12	136
Average duration – Otuoke					198
Otakeme (R)	Dry season	1	12th February 2004	15:00 – 17:15	135
Otakeme (R)	Dry season	2	13th February 204	07:00 – 10:40	220
Otakeme (R)	Early rainy season	3	7th April 2004	06:45 – 10:08	203
Otakeme (R)	Early rainy season	4	9th April 2004	07:37 – 10:13	136
Otakeme (R)	Rainy season	5	1st July 2004	09:51 – 15:58	367
Otakeme (R)	Rainy season	6	3rd July 2004	09:27 – 14:35	308
Average duration – Otakeme					228
Otuogidi (T)	Dry season	1	4th February 2004	08:15 – 10:55	160
Otuogidi (T)	Dry season	2	7th February 2004	10:00 – 16:26	386
Otuogidi (T)	Early rainy season	3	14th April 2004	16:10 – 18:45	155
Otuogidi (T)	Early rainy season	4	16th April 2004	14:40 – 16:55	135
Otuogidi (T)	Rainy season	5	8th July 2004	07:41 – 10:50	199
Otuogidi (T)	Rainy season	6	9th July 2004	07:23 – 11:48	245
Average duration - Otuogidi					213

Figure 6. 8 Map of the Study Area showing the ecological sampling sections



Source: Author's map

Figure 6. 9 show the author returning from a preliminary survey visit along the Kolo Creek. The personnel used have been one fisherman and a boat-rower, except in the case of Otakeme in which the fisherman doubled as the boat-rower, with assistance from the author.

6.3.3. 2 Fish species documentation and identification

The fish caught per throw (catch per unit effort CPUE) during sampling have been recorded, as was the duration of each survey expedition. Photographs were also taken and the fish species identified by their local names by fishers in the field. Community level triangulation of the names of these fishes has been done with the help of other fishers in the respective study community. The FishBase (An on-line data base and catalogue of fish) edited by Forese and Pauly (2005) and the book titled "Fish and fishes of Northern Nigeria" by Reed, *et al.* (1967) have been used for confirmatory identification of the fishes.

Figure 6. 9 Author in a dug-out canoe after a preliminary ecological survey

6.3.3. 3 Limitations of the ecological survey

Table 6. 10 contain a summary of the limitations of the ecological survey.

Table 6. 10 Limitations of the ecological survey

Issues	Description
Sampling time	The sampling for this study has been restricted to day-time, which may have given rise to a result that could be criticised as not be representative of all fish species (particularly nocturnal fish species). In addition, sampling was not done in two of the five identified fishing seasons, thereby giving rise to a result that may not be representative of these seasons. However, the choice of three of the five fishing seasons has provided useful assessment information.
Sampling tool	No single fishing gear may be appropriate for every habitat; therefore multiple sampling gears would be most appropriate. However, this approach would have been difficult, due to cost and may be very impractical to use all fishing gears. The use of Cast nets as the only sampling tool in this study may have restricted the benefits of using other fishing gears, but Cast nets has been reported as very appropriate to access more fish species than most other fishing gears. See Appendix 3 for a description of all other fishing gears used in the Central Delta.
Sampling protocol and personnel	The time between the dredging projects and the time of the study is between two and three years and most of the consequences (particularly the physico-chemical consequences) of the projects may have been lost with time due to the progress of natural re-adjustment that may have occurred. In addition, the use of different fishers (a total of four different fishing teams per community) may be criticised as a non-biased (varying experience and knowledge of fishers may have affected the result of the survey). However, no single fisher in the Study Area would have had localised experience or knowledge of all fishing grounds in all the sample communities. Hence, the justification for the sampling protocol used for this study.
Finance	The number of sample communities (Test and Reference alike) has been restricted due to financial constraints. Due to financial constrains the number of sampling visits per seasons has been reduced to two visits per season. An increased number of visits may have increased the statistical validity of the result from the ecological survey. However, the quantity of data collected during this survey has been demonstrated to be statistically representative (see Chapter 7 for part of the result analyses).

Source: Author

6.3. 4 Social survey

The objectives of the social survey have been to gain an understanding of:

- Livelihood characteristics;
- Livelihoods patterns and CPRs;
- The relationship between livelihood and river use pattern and seasonal variation;
- Inland river fishing as a livelihood component;
- Present status of fish abundance, diversity and economic significance of inland river fishery resources;
- Inland river fishing and seasonality;
- Specific environmental consequences that may have favoured or constrained inland river fishing;
- Environmental issues that have been associated with the sample communities (that may have contributed to environmental noise which may have affected the difference between Test and Reference communities.);

- Perception of dredging as an environmental issue in the Test communities; and
- Preferences for good dredging practices by residents of Test communities.

Questionnaires have been designed to obtaining the above listed information from the residents of the sample communities. Furthermore, the information from the social survey has been used as a basis of gaining information about environmental trends as well as accessing localised eco-livelihood information.

6.3.4. 1 Selection of respondents and sampling process

Residents of the sample communities that are at the time of the fieldwork (year 2004) of the age of twenty years and above have been identified as the target population. Similarly, Tamuno (2001) used twenty years as the base age for selecting respondents for a study conducted in the Central Delta in 2001 in investigating appropriate flood mitigation options for the Central Niger Delta.

The questionnaire has been administered to a total of 418 respondents in the social survey (by simple random sampling), of these: 81 were from Elebele; 103 were from Otuoke; 108 were from Otuogidi; and 126 were from Otakeme. The above sample population represents 5% of the target population (those that are twenty years old and above as at the time of the fieldwork) from these communities. 5% of the target population has been used, for the purpose of making the survey as cost-effective as possible without compromising the target of accessing the TK of a fair representation of the target population. Obtaining the perceptions of more respondents across the socio-economic segment of the sample communities tends to reduce the degree of subjectivity, as well as improve the statistical validity of the outcome of the social survey. A total of 418 respondents is above the minimum of 350 recommended by Perry (2002) as statistically valid when a quantitative survey is conducted for a PhD research. Table 6. 11 contain the population of the sample community and the target population of the social survey.

Table 6. 11 Population of sample communities and the target population

Community	Male 2004	Female 2004	Total 2004	Target Population 2004	5% Target Population
Elebele	1,540	1,592	3,132	1,613	81
Otuoke	1,903	2,078	3,981	2,050	103
Otuogidi	2,197	1,997	4,194	2,160	108
Otakeme	2,519	2,372	4,890	2,518	126
Total	**8,159**	**8,039**	**16,198**	**8,342**	**418**

Source: Modified from (NPC, 1997).

Residency in the sample communities has been used as an additional respondent selection criterion. The target respondents have been divided into: specialist groups and non-specialist groups. In the context of this study, inland river fishers have been used as the specialist group to obtain information based on their knowledge and experience. This type of experience and knowledge constitute traditional eco-livelihood knowledge (TELK). This is based on the premise that this research is focused on assessing the ecological consequences of inland river dredging that may be of livelihood significance in the Study Area. All other respondents belong to the non-specialist group. Hence, two types of questionnaires have been used for the purpose of this study for each group.

The questionnaire designed specifically for inland river Fishers was for the purpose of obtaining information about fisheries, fishing seasons and environmental consequences that may have favoured or constrained fishing in the sample communities. The second questionnaire has been used for Non-fishers, and intended to obtaining generic information such as environmental issues, livelihood issues and perception about dredging in the Test communities.

Similarly, Ghimire *et al.* (2004) had conducted an ethno-ecological field study in the Himalayas of Nepal between 1997 and 2003, in which respondents has been categorised into specialist and non-specialist groups. In the study by Ghimire *et al.* (2004) the specialist respondents were those for whom the National Park is a major component of their life, while the non-specialists are those for whom the National Park are not an important component of their life, but who may occasional use the National Park.

All respondents (Fishers and Non-fishers alike) gave their consent to participate in the social survey and the respondents were informed that the survey is purely for an academic research purpose. The two questionnaires contain a mixture of open and closed questions. The closed questions have been for the purpose to ease the analyses of the results, while the open questions were meant to making the process of administering the questionnaires more interactive. Hence, the open questions gave respondents the opportunity to express their opinions / experiences and enabled the researcher obtain as much information as possible from the respondents without constraints. Both qualitative and quantitative data were collected by the use of the questionnaires. See Appendix 4 and Appendix 5 for samples of the questionnaires used for the Fishers and Non-fishers respectively.

The questionnaires have been administered face-to-face to respondents from the sample communities. Face-to-face questionnaires have been found to be useful in eliminating no-responses from respondent and reliable for direct observation of the authenticity of responses (Budds, 1999). Furthermore, Roche (1999) reported that face-to-face interviews using questionnaires have been conducted in a number of case studies in the Book "*Impact Assessment for Development Agencies, Learning to Value Change*" which were generally very useful in obtaining community perceptions. By and large, questionnaires administered face-to-face make the data collection process very interactive, and informal.

The English language and or "Pidgin English" (this is a colloquial form of English language, generally spoken and understood by majority of the people from different ethnic background in southern Nigeria) have been used in administering the questionnaires. In some cases the questionnaire has been administered through an interpreter (Ogbia is the native language spoken in all the sample communities). Furthermore, the consents of respondents were sought for the discussion to be recorded with a microcassette recorder. The recordings of the discussion have been done in conjunction with the direct filling out of the response from respondents by the author in the course of administering the questionnaires. Figure 6. 10 show the author administering a questionnaire.

6.3.4. 2 Constraints of the social survey

Some of the constraints of the social survey are: accessing prospective respondents, particularly female respondents; likely memory failure; respondents' expectations and loss of information due to interpretation. Despite these limitations the author has explored the strength of the eco-livelihoods approach in this study.

During the day (Monday through Saturday), most prospective respondents are usually at work, while at the evening they may be so tired to be involved in the social survey. This constrain has been surmounted by administering the questionnaires mostly on Sundays. Accessing female respondents have been more difficult than male respondents; this may be because of the demand of domestic chores, language barrier (the proportion of literate females is less than that of males), as well as the fact that women are more reserved than males. However, the author also involved local interpreters during the survey. These interpreters helped in encouraging more female respondents to participate in the survey.

Another issue that may have compromised the results from the survey is the non-documentation of the knowledge and experience of local people. This may have resulted in some respondents not being able to accurately remember specific dates and specific events. Loss of respondents' memory may have given rise to conflicting perceptions. In addition, interpretation may have given rise to loss of information. Consulting with more respondents may help reduce the impact of such memory loss as well as loss of information due to interpretation. An option the researcher had explored by administering the questionnaires to 5% of the target population.

One of the issues the author had to contend with is the question of "*what will be our benefits to be involved in your research?"* Most residents of the Test communities are of the opinion that they have "suffered" much from the consequences of inland dredging and a study of such an environmental issue should bring them some benefits. On the contrary, this research has been designed for academic purpose. This has been explained to all prospective respondents, but the respondents were guaranteed that their participation would be acknowledged and this research would give them an opportunity to say their own side of the "story".

Figure 6. 10 Author administering questionnaire

6. 4 Chapter summary

The social survey has been used to gain localised information about the Study Area, such as: livelihoods characteristics, livelihoods pattern, environmental characteristics (seasonal and annual variation in environmental status), fisheries status and trends, and perception about the eco-livelihood consequences of inland river dredging in the Test communities in the Study Area. The ecological survey has been executed to compare the status of fishery (Fish diversity, abundance; and trophic structure) between the Test and the Reference communities. The discussion of the results of the ecological survey has been done in the light of the background information from the social survey.

The data from the social survey served as baseline data for the ecological survey. Generally, the social survey provided both qualitative and quantitative information, while the ecological survey provided quantitative scientific information. The social survey has been used to present local contextual information of the Study Area, as well as in the discussion of the ecological results. The integration of these approaches, have been intended to test if TELK has a place in "hard science" environmental assessment in areas where baseline data are inadequate or unavailable such as in the Study Area. Table 6. 12 contain a summary of the relationship between the research methodology and the research hypotheses.

Table 6. 12 Research hypotheses and methodology

	Hypotheses	Ecological Survey	Social Survey
1	To demonstrate that eco-livelihoods (livelihood dependent on the ecosystem) is a major livelihood component in the Study Area and in similar areas in developing countries.		X
2	To show that traditional eco-livelihood knowledge (TELK) can provide useful baseline data for environmental assessment (EA) especially where livelihoods are dependent on CPRs.		X
3	To show that fisheries (in the light of other ecological indicators) are good indicators for the retrospective assessment of the impacts of in-land river dredging on the ecosystem that are of eco-livelihood significance.	X	
4	To show that eco-livelihood assessment (EcLA) is an appropriate environmental assessment approach in areas where the dependence on the ecosystem is a major livelihood component.	X	X

Source: Author

Chapter 7 Eco-livelihoods baseline of the Study Area

7. 1 Background

This Chapter contains the assessment baseline scenario of the Study Area. The baseline scenario has been based on the social survey (one of the components of the fieldwork) carried out in the Study Area between January and August 2004. The information collected from the social survey includes TELK, which has been used to build a baseline scenario of the Study Area as well as understanding the eco-livelihoods consequences of inland river dredging in the Study Area. The baseline scenario has been categorised as: livelihood characteristics; river use profile; fishery characteristics; and eco-livelihoods issues that have been associated with the Study Area.

This chapter has been structured in the light of research hypotheses (specifically hypotheses one and three). See Table 6.13 for details of the research hypotheses and the tools employed in the data collection process for the investigation of these hypotheses. The research analyses have been done using the Statistical Package for Social Sciences 11 (SPSS for windows version 11) and Microsoft Office spread sheet (Excel). Box 7. 1 contains a brief summary of all statistical tests that have been used in the analyses of the research data.

Statistical analyses of the results from the social survey have been used to understand the eco-livelihoods baseline scenario in the Study Area in the Test: Otuoke (T); and Otuogidi (T), and Reference: Elebele (R) and Otakeme (R) communities to establish eco-livelihoods consequences of inland river dredging in the Study Area. (T) and (R) have been subsequently used in this thesis to represent Test and Reference communities.

7. 2 Sample and sampling

Simple random sampling has been used in the administration of face-to-face questionnaires to 418 respondents representing 5% of residents of the respective sample communities. The respondents have been divided into the specialised and non-specialised groups: the inland river fishers represent the specialised group; and the all other residents make up the non-specialised group. The respondents represents various age ranges, as well as all socio-economic / livelihoods strata in the sample communities. Table 7. 1 and Table 7. 3 contain the profiles of all respondents and the profile of inland river fishers. Table 7.2 shows that fishers (specialist groups in the context of this research) cut across all age groups as well as fishing activities across the sample communities. Appendices 6 to 17 and Appendices 18 to 33 contain detail of the profiles of respondents of the respective sample communities and fishers in the sample communities respectively. In addition, Table 7.3 contains a comparison of the inland rivers fishers and all respondents from the sample communities.

Box 7. 1 Statistical tests used in analyses of research data

Kolmogorov-Smirnov (K-S Test) Test for normality – This test has been carried out on all parameters / metrics. This test has been used to identify distributions that are parametric and non-parametric. A significant value of 0.05 has been used as the borderline between parameters / metrics that are normally distributed (parametric) and those that are not normally distributed (non-parametric). Normally distributed indicates parameters having values that correspond to a Normal distribution curve, about the mean, which is symmetrical. Significant values of greater than 0.05 imply that the parameters / metrics are normally distributed; in contrast significant values of less than 0.05 are not normally distributed. The K-S Test for normality has been used to determine the type of further analyses required;

.**Correlation Tests** - Correlation is a measure that show linear relationships between metrics / parameters. Correlation does not show causality but it indicates both the strength and direction of relationship (Bryman and Cramer, 2005; Field, 2005). Pearson (r) correlation analyses have been carried out on parametric metrics / parameters, while Spearman's rho (r_s) and Kendall's tau (τ) on parameters that are non-parametric. In addition Kendau's tau (τ) has been performed when non-parametric metrics / parameter size are less than 100, while Spearman's rho (r_s) on those with size greater than 100. Kendall's tau (τ) is more sensitive for smaller size non-parametric data(Field, 2005);

Student t-test – The Student t-test has been used to test for the statistical significance between parametric variables. The independent sample t-test compares the mean from two different groups. This test has been used to show statistical relationships between parameters / metrics in the context of this research. Significant values greater than 0.05 imply that the test variables are statistically significantly similar, while significant values less than 0.05 imply that the test variables are statistically significantly different;

Non-parametric Tests – The Mann-Whitney and the Kolmogorov-Smirnov Z (K-S Z) Tests have been used to test for relationship between means of two independent non-parametric variables. The Kolmogorov-Smirnov Z (K-S Test) tends to be more sensitive than the Mann-Whitney Test when the sizes are less than 25 per group (Field, 2005). In addition the Kruskal-Wallis H Test has been used to compare the means of three or more independent non-parametric group of variables. The statistical boundary between significantly similar and significantly different variable is the same that used as for the Student t-test (0.05).

ANOVA – The analysis of variance (ANOVA) has been used in the comparison of parametric assessment variables / parameters / metrics. One-way ANOVA has been used in this thesis to compare a Test parameter against a Reference parameter.

Source: Author

Table 7. 1 Profile of respondents

Description	Percentage respondents			
Gender	Elebele (R)	Otuoke (T)	Otakeme (R)	Otuogidi (T)
Male	64.2	75.5	66.7	65.7
Female	35.8	24.3	33.3	34.3
Educational Qualifications				
None	21.0	10.7	6.3	13.0
First School Leaving certificate	46.9	31.1	31.7	28.7
Secondary School Certificate	28.4	47.6	53.2	52.8
National Diploma / NCE	2.5	8.7	4.8	4.6
Degree / HND	0.0	1.9	3.2	0.9
Higher Degree	1.2	0.0	0.8	0.0
Age (In years)				
20 – 29	13.6	32.0	49.2	37.0
30 – 39	33.3	32.0	27.0	27.8
40 – 49	27.2	19.4	11.9	15.7
50 – 59	17.2	6.8	6.3	12.0
60 years and above	8.6	9.7	5.7	7.4
Years resident				
Less than 5 years	2.5	1.9	7.1	2.8
Between 5 and 19 years	28.4	19.4	29.4	29.6
Between 20 and 34 years	27.2	44.7	44.4	37.0
Between 35 and 49 years	24.7	20.4	13.5	18.5
50 years	17.3	13.6	5.6	12.0
Livelihood option				
None / Unemployed	1.2	1.9	4.0	1.9
1 Livelihood source	23.5	18.4	20.6	21.3
2 Livelihood sources	45.7	43.7	44.4	45.4
3 Livelihood sources	27.2	30.1	25.4	26.9
4 Livelihood sources	2.5	5.8	4.8	3.7
5 Livelihood sources	0	0	0.8	0.9
Livelihoods and common pool resources (CPRs)				
Unemployed	1.2	1.9	4.0	1.9
Highly dependent on CPRs	29.6	48.5	49.2	45.4
Moderately dependent on CPRs	22.2	25.2	15.1	21.3
Dependent on CPRs	79.0	72.8	73.8	81.5
Neutrally dependent CPRs	43.2	46.6	47.6	44.4
None dependent on CPRs	1.2	1.9	2.4	0.9
None dependent on CPRs and stable	35.8	28.2	19.8	19.4

Source: Author

Table 7. 2 Fishers in the sample communities

Description	Percentage respondents			
Gender	Elebele (R)	Otuoke (T)	Otakeme (R)	Otuogidi (T)
Male	77.8	87.5	97.2	83.3
Female	22.2	12.5	2.8	16.7
Category of fisher				
Full-time	5.6	28.1	22.2	23.3
Part-time	94.4	71.9	77.8	76.7
Livelihood option				
None / Unemployed	0.0	0.0	0.0	0.0
1 Livelihood source	0.0	0.0	2.8	3.3
2 Livelihood sources	44.4	31.3	27.8	20.0
3 Livelihood sources	55.6	56.3	58.3	66.7
4 Livelihood sources	0.0	12.5	8.3	10.0
5 Livelihood sources	0.0	0.0	2.8	0.0
Livelihoods and common pool resources (CPRs)				
Unemployed	0.0	0.0	0.0	0.0
Highly dependent on CPRs	100.0	100.0	100.0	100.0
Moderately dependent on CPRs	16.7	18.8	16.7	36.7
Dependent on CPRs	77.8	87.5	69.4	83.3
Neutrally dependent on CPRs	27.8	28.1	50.0	36.7
None dependent on CPRs	0.0	0.0	0.0	0.0
None dependent on CPRs and stable	33.3	21.9	22.2	20.0
Years fishing				
Less than 5 years	0.0	0.0	2.8	6.7
Between 5 and 19 years	44.4	68.8	50.0	46.7
Between 20 and 34 years	50.0	25.0	38.9	36.7
Between 35 and 49 years	0.0	3.1	5.6	6.7
50 years and above	5.6	3.1	2.8	3.3
Days fishing per week				
Between 1 and 2 Days	11.1	18.8	25.0	20.0
Between 3 and 4 Days	33.3	56.3	52.8	50.0
Between 5 and 7 Days	55.6	25.0	22.2	30.0
Hours fishing per week				
Between 0 to 3 hours	27.8	34.4	11.1	53.3
Between 4 and 6 hours	61.1	53.1	83.3	46.7
Between 7 and 9 hours	11.1	12.5	5.6	0.0

Source: Author

Table 7. 3 Specialised group in the context of all respondents

Description	Percentage respondents	
Gender	Community	Fishers
Male	68.1	86.5
Female	31.9	13.6
Educational Qualifications		
None	12.8	18.7
First School Leaving certificate	34.6	32.5
Secondary School Certificate	45.5	40.6
National Diploma / NCE	5.2	4.7
Degree / HND	1.5	2.9
Higher Degree	0.5	0.7
Age (In years)		
Between 20 and 29 years	33.0	19.7
Between 30 and 39 years	30.0	29.7
Between 40 and 49 years	18.6	27.5
Between 50 and 59 years	10.6	12.8
60 years and above	7.8	10.4
Years resident (in years)		
Less than 5 years	3.6	6.1
Between 5 and 19 years	26.7	17.5
Between 20 and 34 years	38.3	38.4
Between 35 and 49 years	19.3	22.3
50 years and above	12.1	16.0
Livelihood option		
None / Unemployed	2.3	0.0
1 Livelihood source	20.9	1.5
2 Livelihood sources	44.8	30.9
3 Livelihood sources	27.4	59.2
4 Livelihood sources	4.2	7.7
5 Livelihood sources	0.4	0.7
Livelihoods and common pool resources (CPRs)		
Unemployed	2.3	0.0
Highly dependent on CPRs	43.2	100.0
Moderately dependent on CPRs	20.9	22,2
Dependent on CPRs	76.8	79.5
Neutrally dependent on CPRs	45.5	35.6
None dependent on CPRs	1.6	0.0
None dependent on CPRs and stable	25.8	24.4

Source: Author

On the average 68% of the respondents are male compared to 32% female. This is due to the fact that it has been easier meeting and administering the questionnaires to men than for women. The results from Nigeria's 1991 census show a 55.3 to 44.7% male to female population in Ogbia LGA (NPC, 1997). The Study Area is situated in the Ogbia LGA, and a comparison of the above data shows a statically significant linear relationship ($p = 0.01$) between the 1991 census results and the male, female proportion of the respondents of this study (SPSS Output 7. 1). However, there is gender bias in the proportion of respondents, which constitutes one of the limitations of this study. There were more male than female respondents for the reasons given in section 6.3.4.2.

SPSS Output 7. 1 Relationship between genders based on (Census and social survey)

Correlations

			Gender (Census Result)	Gender (Social Survey)
Kendall's tau_b	Gender (Census Result)	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	.	.
		N	2	2
	Gender (Social Survey)	Correlation Coefficient	1.000**	1.000
		Sig. (2-tailed)	.	.
		N	2	2

**. Correlation is significant at the .01 level (2-tailed).

Table 7. 4 show a section of the percentage of individuals in various age ranges from the 1991 census figure and age classes used in this study. K-S Test for normality on age distribution from both sources shows that these variables are normally distributed ($p > 0.05$; $df = 10$) Conducting Pearson (r) correlation analyses shows that there is a significant linear relationship between the age classes used in this study and that from the Nigeria's 1991 census result for the Old Rivers State ($r = 0.94$ p (two-tailed) < 0.05). In addition, ANOVA shows that there is no significant difference between the age distribution from the social survey and the Nigeria 1991 census results of the Old Rivers State ($p = 0.98$; $df = 9$). The analyses imply that the social survey is unbiased based on age classes of respondents when compared to demographic information from the 1991 census results.

Table 7. 4 Comparison of age distribution

Age range (in years)	Percentage (Census)	Percentage (Social survey)
20 to 29 years	34	33
30 to 39 years	24	30
40 to 49 years	17	19
50 to 59 years	12	11
60 years and above	13	8

Source: Author and modified by the Author

7. 3 Livelihood patterns and distribution

The sustainable livelihoods framework has generally been represented in the context of a pentagonal structure with five basic interconnected and inter-dependent components, these are: human capital, social capital; natural capital; physical capital and financial capital (Carney, 1998; DFID, 2000; Neefjes, 2000). The interaction of these capital stocks holistically describes the livelihoods structure in any setting; however, natural capital stock (as represented by CPRs) and human capital (as represented by level of educational qualifications) have been explored in describing the pattern and distribution of livelihoods in the Study Area. Similarly, human capital, natural capital stocks and technical skills acquired from the non-formal educational sector have been used in livelihoods description in the Central Niger Delta (Tamuno, 2001; Tamuno, *et al.* 2003b).

The livelihoods characteristics have been described in the context of gender, age, years resident, level of educational attainment, livelihood options and source of livelihoods as it relates to common pool resource (in this case the surface water resource). The livelihoods characteristics have been presented below.

7.3. 1 Livelihood characteristics

An understanding of years resident in the Study Area have been presented in the context of this thesis as one of the key issues that determines the quality of TK. Educational level of respondents have been presented as a major livelihoods characteristics that determines the stability and viability of livelihoods. In furtherance of livelihoods characteristics, livelihoods options of resident have been presented to show the livelihoods structure in the Study Area.

7.3.1. 1 Years resident in the Study Area

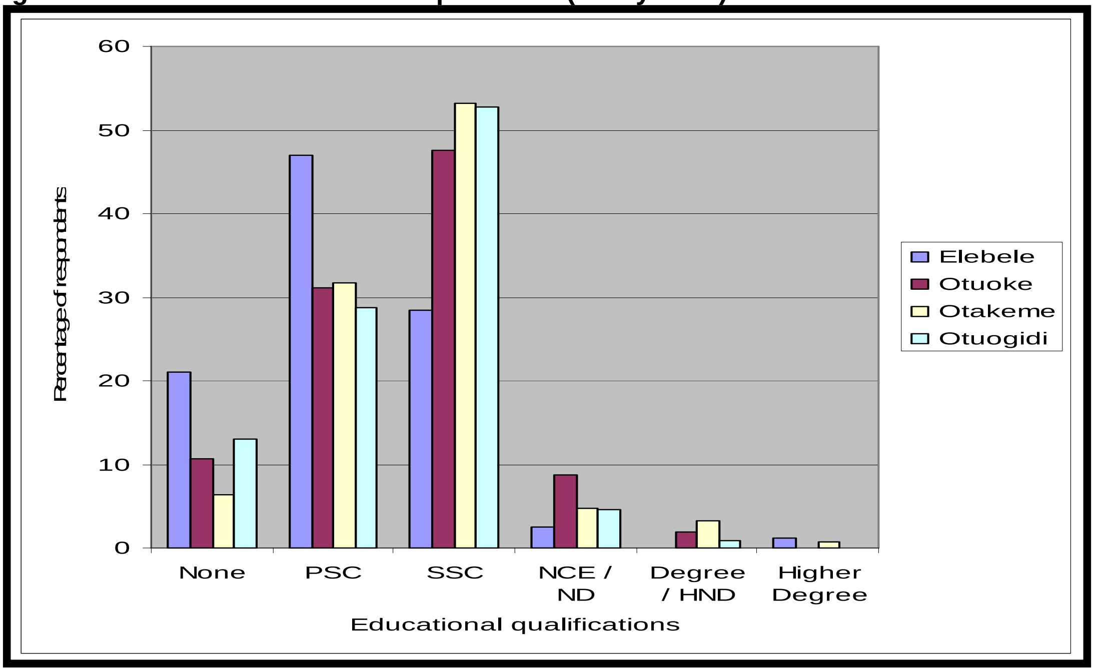
An average of 31.4% of respondents has lived in the Study Area for 35 years or more. See Table 7. 3 for the arrangement of respondents into age classes. People that have lived in a community know a lot about their communities as well as most likely to remember historical environmental and other localised issues (Kolsky, 1998; Tamuno, 2001). Similarly, in the middle Majakam Peatlands, East Kalimantan, Indonesia, Chokkalingam *et al.* (2005) choice of respondents for their study have been based on those with long-term knowledge of the local ecosystem in the their study that investigated the effect of fire on livelihoods and local environment. In addition, in the Navachiste-San Ignacio-Macapule lagoon complex, Sinaloa, Mexico, respondents that participated in a study to investigate mangrove usage and changes over several decades have also been arranged into groups based on their age (the age classes are: 30 to 40 years, 40 to 50 years, 50 and 60 years, and 60 to 70 years) (Hernández-Cornejo, *et al.* 2005).

Therefore, the involvement of 31.4% of the respondents that have resided for a minimum of 35 years in the Study Area shows that it is most likely the TK accessed in this study is of relatively high quality.

7.3.1. 2 Educational level of respondents

An average of about 93% of respondents have educational qualifications that are not higher than secondary school certificate (See Figure 7. 1: PSC – Primary School Certificate; SSC – Secondary School Certificate; NCE – National Certificate of Education; ND – National Diploma; and HND – Higher National Diploma). This implies that a considerable proportion of the residents in the Study Area are low income earners in the formal economic sectors, because salary and remuneration is based on educational qualifications and employee experience. See section 7.3.1.5, for discussion of the relationship between educational level and other livelihood parameters.

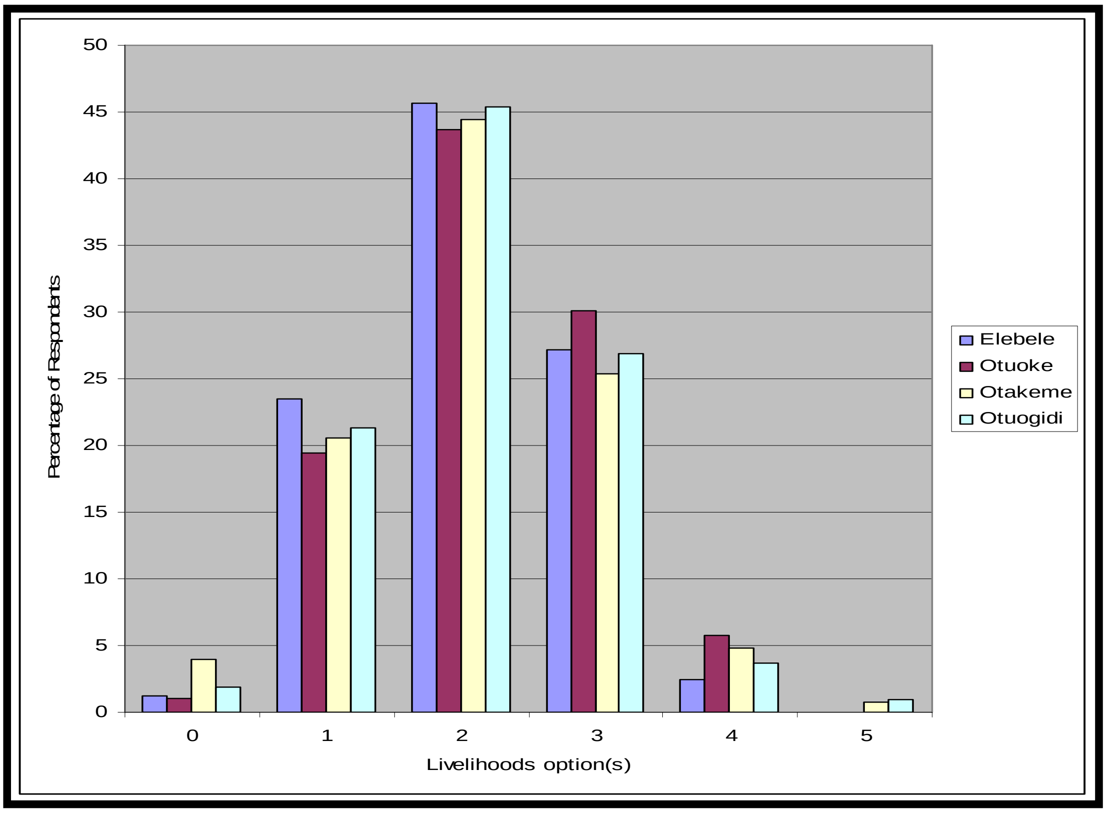
Figure 7. 1 Educational level of respondents (Study Area)



7.3.1. 3 Livelihood options

An average of about 45% of the respondents have two or more livelihood sources (multiple livelihood sources, see Figure 7. 2). About 2% of the respondents from this study are unemployed which is contrary to the report that the Old Rivers State has an unemployment rate of 12.6%, which was the highest unemployment rate in Nigeria as at 1997 (national average unemployment rate is 4.7%) (NPC, 1997). Employment as reported by the NPC (1997) may be regarded as only those engaged in the formal economic sector. Multiple livelihood sources is common in developing countries, which has been an adaptation to reducing the risks associated with living near subsistence (Farrington, *et al.* 2001). See section 7.3.1.5 for a discussion of livelihoods and common pool resources in the Study Area.

Figure 7. 2 Livelihood options of respondents (Study Area)



<u>7.3.1. 4 Fishing as a livelihood option in the Study Area</u>

In the context of this research, fishers constitute the specialist group of this study, and a summary of fishing patterns and livelihoods properties of fishers based on 116 Fishers in the Study Area shows that: 86% of fishers are male compared to 14% female; 92% of fishers have the secondary school certificate as their highest educational qualifications (19% do not have any formal educational qualifications); 51% of fishers are forty years and above; 38% of fishers have been resident in the Study Area for forty years and above; 98% of fishers have more than one livelihoods source; 45% of fishers have been involved in fishing for a minimum period of twenty years; 81% spend a minimum of three days per week fishing; 68% spend between four and nine hours daily fishing; and 80% are part-time fishers. These figures are based on data from the four sample communities Similarly, a household survey of eight provinces in Cambodia, shows that 30% and 70% of the fishers are full-time and part-time fishers respectively (Van Zalinge, *et al.*

1998). The succeeding section presents and discusses the comparison between sample communities in the Study Area.

7.3.1. 5 Relationship between livelihood properties

A K-S Test for normality for gender, age of respondents; number of years respondents have resided in their respective community; qualifications of respondents and livelihoods options shows a deviation from normality ($p < 0.05$). Spearman correlation coefficient r_s have been conducted on the relationship between the above variables except gender. SPSS Output 7. 2 contain the correlation result. The results indicate that there is no significant relationship between level of educational attainment and livelihood options. However, there are significant negative correlations between level of educational attainment with age of residents and duration of residence in the sample communities. It implies that younger residents have higher education qualifications than the older residents of the Study Area. This compares favourably with the literacy level of the Old River State, which shows that the average literacy rates are 81.7% (age range 20 to 39 years) and 57.9% (age range 40 years and above) (NPC, 1997).

In addition, there is a strong positive correlation between age of residents and years of residence ($r_s = 0.65$ (2-tailed) $p < 0.01$). Due to such a strong positive linear relationship, it implies that number of years of residency could be appropriately substituted for age of residents, in situations where respondents do not really know their actual age, or are reluctant to divulge their actual age. There is a strong positive correlation between the age of residents and livelihood options ($r_s = 0.18$ p (2-tailed) < 0.01). Similarly there is a strong positive correlation between duration of residency in the Study Area and livelihood options ($r_s = 0.15$ (2-tailed) $p < 0.01$). Therefore, older residents have multiple livelihood sources and have low level of educational qualifications (an average of 93% of the residents have low educational level, see Figure 7. 1).

SPSS Output 7. 2 Relationship between livelihood properties (Study Area)

Correlations

			Educational Qualification	Age in Years	Years Residency	Livelihood Options
Spearman's rho	Educational Qualification	Correlation Coefficient	1.000	-.264**	-.237**	.037
		Sig. (2-tailed)	.	.000	.000	.446
		N	418	418	418	418
	Age in Years	Correlation Coefficient	-.264**	1.000	.654**	.182**
		Sig. (2-tailed)	.000	.	.000	.000
		N	418	418	418	418
	Years Residency	Correlation Coefficient	-.237**	.654**	1.000	.155**
		Sig. (2-tailed)	.000	.000	.	.001
		N	418	418	418	418
	Livelihood Options	Correlation Coefficient	.037	.182**	.155**	1.000
		Sig. (2-tailed)	.446	.000	.001	.
		N	418	418	418	418

**. Correlation is significant at the .01 level (2-tailed).

Kruskal Wallis H Test shows that there is no significant difference ($p > 0.05$) between all four sample communities on gender and livelihoods options. There is, however, significant difference ($p < 0.05$) between sample communities on the issue of level of educational qualifications, age and the duration of residency in the Kolo Creek (See SPSS Output 7. 3. Community ID imply sample communities). The implication of this output is that multiple livelihood is common practice in the Study Area, irrespective of difference in educational level, age, and duration of residency of respondents in the Study Area. Similarly, the comparison of livelihood properties across the both creeks, are as shown in SPSS Output 7. 4 and SPSS Output 7. 5 show that there is no significant difference in livelihood sources and years resident in between communities along the Elebele / Otuoke Creek and the Kolo Creek.

SPSS Output 7. 3 Livelihood property (Study Area)

Test Statistics[a,b]

	Gender	Educational Qualification	Age in Years	Years Residency	Livelihood Options
Chi-Square	3.718	21.475	27.463	12.280	1.401
df	3	3	3	3	3
Asymp. Sig.	.294	.000	.000	.006	.705

a. Kruskal Wallis Test

b. Grouping Variable: Sample Communities

Further analyses have been carried out using the Mann-Whitney Test to compare livelihoods properties across communities along the Elebele / Otuoke Creek and the Kolo Creek respectively. SPSS Output 7. 4 and SPSS Output 7. 5 shows that there is a no-significant difference ($p > 0.05$) in gender, duration of residency of respondents in the sample communities; and livelihoods options in communities along both creeks. Nonetheless, significant differences ($p < 0.05$) in age of respondents in communities along both creeks have been observed. In addition, there is non-significant difference ($p < 0.05$) and a significant difference ($p > 0.05$) in level of educational attainment in communities along Elebele / Otuoke Creek and Kolo Creek respectively.

SPSS Output 7. 4 Livelihood properties (Elebele / Otuoke Creek)

Test Statistics[a]

	Gender	Educational Qualification	Age in Years	Years Residency	Livelihood Options
Mann-Whitney U	3690.500	2968.000	3214.000	4161.000	3812.000
Wilcoxon W	7011.500	6289.000	8570.000	9517.000	7133.000
Z	-1.700	-3.575	-2.757	-.030	-1.070
Asymp. Sig. (2-tailed)	.089	.000	.006	.976	.285

a. Grouping Variable: Sample Communities (Elebele / Otuoke Creek)

SPSS Output 7. 5 Livelihood properties (Kolo Creek)

Test Statistics[a]

	Gender	Educational Qualification	Age in Years	Years Residency	Livelihood Options
Mann-Whitney U	6741.000	6282.500	5763.500	5952.000	6697.500
Wilcoxon W	12627.000	12168.500	13764.500	13953.000	14698.500
Z	-.149	-1.114	-2.133	-1.739	-.220
Asymp. Sig. (2-tailed)	.882	.265	.033	.082	.826

a. Grouping Variable: Sample Communities (Kolo Creek)

Fishers constitute the specialist group used in this study. Educational qualifications, gender, age of fishers, duration residency in the Study Area, livelihoods option, years fishing, average day(s) per week in which respondents are involved in fishing and number of hour(s) per day fishing is carried out are variables that have been used in comparing livelihoods properties of fishers. A K-S Test for normality on these variables shows a deviation from normality ($p < 0.05$) on all of these parameters.

Spearman rho correlation coefficient (r_s) has been conducted on the above variables except gender and category of fisher. The result is shown in SPSS Output 7. 6. The implication of the above analyses is that multiple livelihood sources of fishers is positively significantly related to age of fishers, duration of residency in the Study Area, number of years fishing, and time invested in fishing (fishing days per week and fishing hours per day). Furthermore, older Fishers have more fishing experience which may have been acquired over the years as well as investing more time in fishing. The strong relationship between fishers' level of educational qualifications is not contrary to that represented by respondents from the Study Area. The implication of this strong correlation is that fishers with higher education qualification have the opportunity of earning a livelihood from the formal economic sector compared to their counterparts with lower educational qualifications.

Kruskal-Wallis Test, have also been conducted on the livelihoods properties (educational qualifications, gender, age of fishers, duration residency in the Study Area, livelihoods option, years fishing, average day(s) per week in which respondents are involved in fishing and number of hour(s) per day fishing) across all sample communities. The result shows that there is no significant difference ($p > 0.05$) between communities on: gender; qualifications of fishers; livelihoods option, years fishing, category of fisher and number of days per week in which fishing is carried out. A significant difference ($p < 0.05$) has been observed in the number of years fishers have been resident in the Study Area and numbers of hours spent fishing, however a comparison of age of fishers falls on the borderline between significant difference and non-significance difference ($p = 0.05$) (Table 7.5). The results of Table 7.5 show that fishing as practised as a livelihood source is non-dependent on educational qualifications, that fishing is a "Man's Business", that multiple livelihood sources are common among fishers, and that fishing is predominantly practiced on a part-time basis in the Study Area. Generally there is no significant difference in fishing practices across all communities.

Furthermore, Mann-Whitney Tests have been performed to compare the above variables between communities along the Elebele / Otuoke Creek, Kolo Creek, among Test and Reference communities. The Mann-Whitney Test shows that there is no significant difference in all variables ($p > 0.05$) in the Elebele / Otuoke Creek (see Table 7.6), and no significant difference ($p > 0.05$) in all variables in the Kolo Creek except numbers of years fishing and fishing hours per day ($P < 0.05$). See Table 7.7 for the above result. Furthermore, the average educational level is low and multiple livelihood sources are common among fishers of the Study Area. The succeeding section (7.3.2) contains a comparison of the livelihood sources in the Study Area in relation to level of dependence on CPR.

Section 7.3.1 has demonstrated that the Test and Reference communities are representative of communities in the Study Area in livelihood properties which shows that residents are engaged in multiple livelihood sources. In addition, number of years resident in the Study Area can be appropriate used as surrogate for age, if the age of a respondent is not known. Although respondents were representative, there was a gender bias, with a majority of male respondents.

SPSS Output 7. 6 Relationship between livelihoods properties of fishers (Study Area)

Correlations

			Educational Qualification [Fishers]	Livelihood Option [Fishers]	Age in Years [Fishers]	Years Residency [Fishers]	Years Fishing	Fishing (Day/Wk)	Fishing (Hrs/Day)
Spearman's rho	Educational Qualification [Fishers]	Correlation Coefficient	1.000	.327**	-.310**	-.332**	-.152	-.218*	-.060
		Sig. (2-tailed)	.	.000	.001	.000	.103	.019	.523
		N	116	116	116	116	116	116	116
	Livelihood Option [Fishers]	Correlation Coefficient	.327**	1.000	-.021	-.024	.071	-.053	-.045
		Sig. (2-tailed)	.000	.	.825	.802	.448	.570	.635
		N	116	116	116	116	116	116	116
	Age in Years [Fishers]	Correlation Coefficient	-.310**	-.021	1.000	.679**	.604**	.238*	.077
		Sig. (2-tailed)	.001	.825	.	.000	.000	.010	.409
		N	116	116	116	116	116	116	116
	Years Residency [Fishers]	Correlation Coefficient	-.332**	-.024	.679**	1.000	.633**	.217*	.027
		Sig. (2-tailed)	.000	.802	.000	.	.000	.019	.774
		N	116	116	116	116	116	116	116
	Years Fishing	Correlation Coefficient	-.152	.071	.604**	.633**	1.000	.228*	.205*
		Sig. (2-tailed)	.103	.448	.000	.000	.	.014	.028
		N	116	116	116	116	116	116	116
	Fishing (Day/Wk)	Correlation Coefficient	-.218*	-.053	.238*	.217*	.228*	1.000	.211*
		Sig. (2-tailed)	.019	.570	.010	.019	.014	.	.023
		N	116	116	116	116	116	116	116
	Fishing (Hrs/Day)	Correlation Coefficient	-.060	-.045	.077	.027	.205*	.211*	1.000
		Sig. (2-tailed)	.523	.635	.409	.774	.028	.023	.
		N	116	116	116	116	116	116	116

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Table 7. 5 Kruskal Wallis H of the livelihood properties of fishers (Study Area)

Property	df	Asymp. Sig. (2-tailed)
Gender	3	0.155
Educational qualification	3	0.071
Livelihood option	3	0.415
Age of fishers (years)	3	0.050
Years residency	3	0.029
Years fishing	3	0.514
Category of fisher	3	0.311
Fishing (Day / Week)	3	0.119
Fishing (Hours / Day)	3	0.005

Table 7. 6 Mann Whitney test of livelihood properties of fishers (Elebele / Otuoke Creek)

Property	Asymp. Sig. (2-tailed)
Gender	0.373
Educational qualification	0.146
Livelihood option	0.184
Age of fishers (years)	0.107
Years residency	0.165
Years fishing	0.125
Category of fisher	0.058
Fishing (Day / Week)	0.052
Fishing (Hour / Day)	0.750

Table 7. 7 Man Whitney test of livelihood properties of fishers (Kolo Creek)

Property	Asymp. Sig. (2-tailed)
Gender	0.052
Educational qualification	0.389
Livelihood option	0.687
Age of fishers (years)	0.239
Years residency	0.040
Years fishing	0.893
Category of fisher	0.915
Fishing (Day / Week)	0.459
Fishing (Hour / Day)	0.000

7.3. 2 Livelihoods and common pool resource (CPR)

Table 7. 8 shows a summary (by percentage of respondents) of the livelihood sources in the Study Area arranged by community and based on dependence on CPR (in this case surface water resource). Fishing, palm cutting, farming, trading and commerce, pension, and formal economic sectors are major livelihood sources in the Study Area and have been defined in the context of this research based on dependence on CPR (others in Table 7. 8 represent the other minor livelihood sources in the major six categories). In addition, a summary of other livelihoods other minor livelihoods in the respective sample communities have been summarised in Table 7. 9, while Appendix 11 to Appendix 17 contains detail of the livelihood sources in the respective sample communities.

Table 7. 8 Summary of livelihood sources in the Study Area

	Source of livelihoods (percentage of respondents)						
Community	**Unemployed**	**Highly dependent on CPR Fishing**	**Moderately dependent on CPR Palm cutting**	**Dependent on CPR Farming**	**Neutrally dependent on CPR Trading and Commerce**	**Non-dependent on CPR Pensions**	**Non-dependent on CPR and stable Formal economic sector**
Elebele (R)	1	22	19	79	42	1	36
Others	0	7	4	0	1	0	0
Total	1	30	22	79	43	1	36
Otuoke (T)	2	39	15	73	43	2	28
Others	0	10	11	0	4	0	0
Total	2	48	25	73	47	2	28
Otakeme (R)	4	38	10	74	43	2	20
Others	0	11	5	0	5	0	0
Total	4	49	15	74	48	2	20
Otuogidi (T)	2	39	19	82	41	1	19
Others	0	6	2	0	4	0	0
Total	2	45	21	82	44	1	19

Source: Author

Table 7. 9 Minor livelihood sources in the Study Area

Livelihoods source	Category	Community
Snail trapping	Highly dependent on CPR	Elebele (4); Otuoke (5); Otakeme (8); Otuogidi (7)
Hunting	Highly dependent on CPR	Elebele (2); Otuoke (5); Otakeme (2); Otuogidi (2)
Sand mining	Highly dependent on CPR	Otakeme (4)
Lumbering	Moderately dependent on CPR	Elebele (3); Otuoke (10); Otakeme (5); Otuogidi (2)
Canoe carving	Moderately dependent on CPR	Otuoke (1); Otakeme (1)
Menial jobs	Neutrally dependent on CPR	Elebele (1); Otuoke (4); Otakeme (6); Otuogidi (4)
Unemployed		Elebele (1); Otuoke (2); Otakeme (5); Otuogidi (2)

Source: Author

There is communal ownership and management of surface water resource and forest and forest products in the Central Delta. However, the ownership of land is in the hands of family units or individuals. The dependence on surface water resources and forest and forest products has been categorised as highly dependent on CPR; in situation where forest products like palm fruits are exploited for livelihood purposes (such as palm cutting), these has been regarded as moderately dependent on CPR, because some of the palm trees are owned by family units or individuals. The use of land for livelihoods sustenance such as farming has been regarded less dependent of CPR. Neutral dependence on CPR implies situations in which there may not be a direct dependence on CPR, such as the involvement in trading and commerce, because the goods traded may be direct or indirect produce or products from CPR.

Non-dependence on CPR implies the earning of livelihoods from the formal economic sector. Payments of pensions have been irregular in Nigeria and in most cases pensions are rarely reviewed to reflect the current economic reality in Nigeria. Pensions and wages in the formal economic sector have been fixed in different groups based on the above premise. An average of: 43% of the respondents are highly dependent on CPR; 21% moderately dependent on CPR; 77% are dependent on CPR; 46% are neutrally dependent on CPR; 1.6% are non-dependent on CPR; and 26% are non-dependent on CPR and stable. 43% of the respondents from the sample community are highly dependent on CPRs, which implies that there is a significant dependence on CPR in the Study Area. Most inhabitants of rural communities in developing countries depend on local ecosystems for their livelihoods (Castillo, 2000; Sarch and Allison, 2002; Tamuno, *et al.* 2003a).

Generally about 50% of the inhabitants of the planet are people involved in agricultural practices that depend directly on a natural resource base for their livelihoods, and about 95% of these people are inhabitants of developing countries (Castillo, 2000). Africa's inland fisheries are important as a source of food, as well as providing livelihoods particularly in rural communities (Sarch and Allison, 2002). However, the population of fishers in Mali have significantly decreased since the early 1990s, due to lack of subsidies to fishers for the purchase of fishing tools, such as canoes, nets and outboard engines (Laë, *et al.* 2003). Therefore, as a livelihood coping strategy most unsuccessful fishers in Mali have become farmers in Mali (Laë, 1994). This may be one of the reasons why the present population of farmers in the Study Area is significantly greater than that of fishers.

A total of thirteen different livelihood sources have been identified in the Study Area (Table 7. 8 and Table 7. 9). The proportion of respondents involved in the thirteen identified livelihood sources as well as those unemployed have been used to describe the livelihood patterns in the Study Area. K-S Test for normality shows a deviation from normal distribution ($p < 0.05$). Hence, non-parametric tests have been performed on these variables.

The Kendall tau (τ) correlation coefficient on the percentage distribution on all livelihood sources and the non-earning variable (unemployed) shows a strong relationship ($p < 0.01$ 2-tailed) between all communities based on fourteen variables across all communities in the Study Area (see SPSS Output 7. 7), as well as based on the seven livelihoods category (SPSS Output 7. 8). Furthermore, the Kruskal-Wallis Test has been conducted to test for difference in livelihood categories between communities in the Study Area, which show that there is no significant difference between all seven categories in the Study Area (SPSS Output 7.9). This shows that there is no significant difference in the livelihoods pattern in the Study Area, and that farming, fishing and trading and commerce are the dominant livelihood sources in the Study Area. Moreover, there is a consistent livelihood pattern in the Study Area and there is a high dependence on CPR in the Study Area that has been represented by an average of about 44% of residents. Similarly farming and fishing have been reported as the main livelihood sources in the Central Niger Delta (World Bank, 1995b; Alagoa, 1999; Tamuno, *et al.* 2003b). An understanding of human dependence on ecosystems is required for the sustainable management of the environment (Turner, *et al.* 1998; Daily, *et al.* 2000)

SPSS Output 7. 7 Relationship between livelihood sources (Study Area)

Correlations

			Livelihoods Source (Elebele)	Livelihoods Source (Otuoke)	Livelihoods Source (Otakeme)	Livelihoods Source (Otuogidi)
Kendall's tau_b	Livelihoods Source (Elebele)	Correlation Coefficient	1.000	.612**	.802**	.893**
		Sig. (2-tailed)	.	.004	.000	.000
		N	14	14	14	14
	Livelihoods Source (Otuoke)	Correlation Coefficient	.612**	1.000	.608**	.605**
		Sig. (2-tailed)	.004	.	.004	.004
		N	14	14	14	14
	Livelihoods Source (Otakeme)	Correlation Coefficient	.802**	.608**	1.000	.817**
		Sig. (2-tailed)	.000	.004	.	.000
		N	14	14	14	14
	Livelihoods Source (Otuogidi)	Correlation Coefficient	.893**	.605**	.817**	1.000
		Sig. (2-tailed)	.000	.004	.000	.
		N	14	14	14	14

**. Correlation is significant at the .01 level (2-tailed).

SPSS Output 7. 8 Relationship between livelihood categories (Study Area)

Correlations

			Livelihoods Source - CPR (Elebele)	Livelihoods Source - CPR (Otuoke)	Livelihoods Source - CPR (Otakeme)	Livelihoods Source - CPR (Otuogidi)
Kendall's tau_b	Livelihoods Source - CPR (Elebele)	Correlation Coefficient	1.000	.800*	.781*	.700*
		Sig. (2-tailed)	.	.014	.015	.032
		N	7	7	7	7
	Livelihoods Source - CPR (Otuoke)	Correlation Coefficient	.800*	1.000	.976**	.900**
		Sig. (2-tailed)	.014	.	.002	.006
		N	7	7	7	7
	Livelihoods Source - CPR (Otakeme)	Correlation Coefficient	.781*	.976**	1.000	.878**
		Sig. (2-tailed)	.015	.002	.	.006
		N	7	7	7	7
	Livelihoods Source - CPR (Otuogidi)	Correlation Coefficient	.700*	.900**	.878**	1.000
		Sig. (2-tailed)	.032	.006	.006	.
		N	7	7	7	7

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

SPSS Output 7. 9 Kruskal Wallis Test on livelihood categories (Study Area)

Test Statistics [a,b]

	Unemployed	Highly dependent on CPR	Moderately dependent on CPR	Dependent on CPR	Neutrally Dependent on CPR	Non-depend ent on CPR	Non-depend ent on CPR and Stable
Chi-Square	3.000	3.000	3.000	3.000	3.000	3.000	3.000
df	3	3	3	3	3	3	3
Asymp. Sig.	.392	.392	.392	.392	.392	.392	.392
Exact Sig.	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Point Probability	1.000	1.000	1.000	1.000	1.000	1.000	1.000

a. Kruskal Wallis Test

b. Grouping Variable: Sample Communities

According to one of the respondents from Otakeme, "*hunting and fishing are no all-comers affairs*" (this means that skills and experience are necessary to successfully earn a livelihood from these sources). He further buttressed his argument that anybody can cultivate a piece of land or hire people to cultivate it and call themselves farmers, or be involved in trading, but hunting and fishing require exceptional skills and experience that have been developed over the years. Generally, some respondents view fishing as a cultural activity that is as old as the Ogbia ethnic group, for example children start fishing sometimes as young as five years and continue fishing until old age. Figure 7. 3 show young fishers fishing with hooks, and Figure 7. 4 show an elderly woman fishing (one of the respondents of this study).

Figure 7. 3 Young fishers in the Study Area

Figure 7. 4 An elderly woman fishing in the Study Area

7. 4 Baseline scenario of the Study Area

The state of baseline data (long-term scientific information) in most developing countries is inadequate and in most cases unavailable (Terano, *et al.* 1997; Tamuno, *et al.* 2003c). The dearth of scientific research may be responsible for the absence or inadequacy of baseline data in the developing world (Agarwal, 1997; Kwak, *et al.*2002), this lack of a theoretical body (baseline data) has limited the reliability of the prediction of ecological impacts (Bojórquez-Tapia *et at.*, 2002). This may have hampered policy and management plans for sustainable and equitable development.

Long term historic data are highly desirable, but are often lacking in developing counties (Coates, *et al.* 2003). Areas and situations where baseline data are unavailable or inadequate require environmental assessment tools that are flexible; transparent and integrate livelihoods values into the assessment process (Tamuno, *et al.* 2003a). Many societies have successfully used their indigenous knowledge for livelihood sustenance and sustainable management of their environment (Abakerli, 2001).

There is the need to develop and use appropriate methods for determining environmental baselines, as well as better approaches of sharing and disseminating research results. Therefore, carefully documented basic studies are needed for evaluating anthropogenic impacts on terrestrial and aquatic ecosystems (Landers, *et al.* 1995). In Indonesia, rapid rural appraisals have been used to gather information about local land and fire use over time, recent fire patterns and their underlying causes, major developments, ecological conditions, and livelihood sources. These information have been accessed from interviewees in all the villages that participated in the study (Chohhalingam, *et al.* 2005).

Statistical tests have been used in Mexico to analyze the responses from sample communities, in the study using ethno-botanical assessment of the effect of changes in mangrove forest in the Navachiste-San Ignacio-Macapule lagoon complex, Sinaloa. The result shows that 72% of interviewees have a very good knowledge of mangrove forest, which has been used as a basis for mangrove forest evaluation. In addition, the combination of age and knowledge using a G Test, showed no significant difference ($G = 29.6$, df. = 6; $p > 0.1$) between the age classes and knowledge of respondents ((Hernández-Cornejo, et al. 2005). Similarly, the people of the Bulamogi communities, Uganda, have good knowledge about cattle diseases and their treatment. 33 different cattle diseases have been identified by the Bulamogi people, of these they can locally treat 9 of these diseases as well as improve lactation in cattle by the use of herbal plants (Tabuti, *et al.* 2003). Local knowledge has been identified as a significant contribution to increased understanding of ecosystems (Coates, *et al.* 2003). This justifies the use of TELK of residents in the Kolo Creek to build a baseline scenario of the Study Area.

In addition to providing important information that have helped to increase the relevance of scientific research, the use of TEK has facilitated developing environmental policies in Canada that recognise and incorporate cultural values. Moreover, the use of TEK in scientific investigations gives local stakeholders an opportunity to be members of a team responsible for addressing shared conservation objectives. Such an approach is generally more productive than the sole use of scientific studies (Gilchrist, *et al.* 2005).

River use profile, environmental issues associated with the respective sample communities, as well as fishery resources have been used for the description of the eco-livelihoods baseline scenario of the Study Area.

7.4. 1 River use profile

Ecosystem services represent the benefits that people get from these systems (Daily, *et al.* 2000; Miller, 2002). The main feature of ecosystem services is that such an approach allows the integration of ecological and social aspects of ecosystem management into environmental policy and decision making systems. The first dominant appearance of the concepts of ecosystem services in scientific discuss was in the early 1970s, but its development has received remarkable attention in recent years (Bolund and Hunhammar, 1999; De Groot, *et al.* 2002; Maass, *et al.* 2005).

Generally, freshwater rivers constitute the basis for most productive activities, as service provider (Maass, *et al.* 2005). In addition, most tropical rivers play a major role in the livelihoods of rural dwellers along these rivers, but access to these resources depends on seasonal variation (Hartmann, 2003).

River use profile has been investigated and analysed based on seasonal variation in the Study Area. Table 7. 10 shows a summary of the river use profile of the Study Area based on the knowledge and experience (TK, TEK and TELK) of respondents (represented by percentage of respondents), and shows that there is seasonal variation in river usage. There is seasonal variation of river usage based on percentage of respondents. The colour codes represent percentage ranges: blank – 0%; yellow - 1 > 25% low; blue - 25 > 50% low to medium; green - 50 > 75% medium to high; and brown - > 75%.

The difference between communities on river usage for sewage and waste disposal may be as a result of the fact that most residents do not view disposal into the river as use. The use of the creeks for drinking and domestic use has been consistent irrespective of seasons; inland river fishing is most viable during the flood recession season; rainy and flood seasons have been the most favourable seasons for lumbering; palm cutting and processing and the use of the creeks for irrigation and recreation is highest during the dry season across the Kolo Creek. Both Elebele / Otuoke and Kolo creeks have been used for recreation purposes, but respondents from Elebele and Otuoke did not consider recreation as constituting usage. This does not however imply non-use of the river for recreation, but non-response. Figure 7. 5 shows over-hung toilets at Otuoke by the Elebele / Otuoke Creek that are used for excreta disposal.

Table 7. 10 The river use profile of the Study Area

		River Use profile									
Community	Season	FISHING	DOMESTIC	TRANS / CO.	SAND MINE	LUMBER	DISPOSAL	PALM PS.	RECREATE	FISH FEST.	IRRIGATE
Elebele (R)	Rainy	10	100	100	0	3	12	0	999	999	999
	Flood	6	100	100	0	3	12	0	999	999	999
	After Flood	83	100	100	0	0	12	7	999	999	999
	Dry	51	100	100	24	0	12	84	999	999	999
	Early Rains	3	100	100	5	0	12	84	999	999	999
Otuoke (T)	Rainy	21	100	100	0	18	7	1	999	999	0
	Flood	5	100	100	0	18	7	1	999	999	0
	After Flood	64	100	100	0	0	7	11	999	999	0
	Dry	38	100	100	4	0	7	91	999	999	1
	Early Rains	10	100	100	4	0	7	89	999	999	0
Otakeme (R)	Rainy	8	100	100	0	21	19	2	0	0	0
	Flood	3	100	100	0	21	19	2	0	0	0
	After Flood	64	100	100	2	2	19	9	0	0	0
	Dry	56	100	100	30	2	19	79	5	0	2
	Early Rains	36	99	100	21	2	19	83	1	1	1
Otuogidi (T)	Rainy	12	100	100	0	18	13	2	0	999	0
	Flood	2	100	100	0	17	13	2	0	999	0
	After Flood	74	100	100	1	0	13	13	0	999	0
	Dry	56	100	100	9	0	13	90	4	999	1
	Early Rains	18	100	100	9	0	13	91	2	999	0
Study Area	Rainy	13	100	100	0	16	13	0	0	0	0
	Flood	3	100	100	0	15	13	1	0	0	0
	After Flood	69	100	100	1	1	13	10	0	0	0
	Dry	51	100	100	17	1	13	86	2	0	1
	Early Rains	18	100	100	11	0	13	87	1	1	0

0% | 0 > 25 % | 25 > 50 % | 50 > 75 % | 75 > 100 %

FISHING – Inland river fishing; DOMESTIC – Domestic and Drinking; TRANS / CO. – Transportation and Commerce; SAND MINE – Sand mining; LUMBER – Lumbering; DISPOSAL – Sewage and waste disposal; PALM PS. – Palm processing; RECREATE – Recreation; FISH FEST. – Fishing festival; IRRIGATE – Irrigation; 999 – Non-use (code that is easy to isolate from other percentages)

Figure 7. 5 Over-hung toilets by the Elebele / Otuoke Creek

The K-S Test for normal distribution on the river use variables in Table 7. 10 shows a deviation from normality ($p < 0.05$) for river use categories in different seasons for each individual community. . Kendall's tau (τ) coefficient of correlation has been carried out on the river usage based on the summary in Table 7. 10. Kendall's tau (τ) is the most appropriate non-parametric correlation test for small data size (Field, 2005). SPSS Output 7. 10 show that there is a significant positive relationship in river usage in all communities in the Study Area. The Kruskal-Wallis Test (SPSS Output 7. 11) has also been carried out on each river use variable identified by respondents. The output shows that there is no significant difference ($p > 0.05$) in river usage on all except sewage and waste disposal and this may be due to the fact that most residents in the Study Area do not view sewage into rivers and waste disposal as river usage. Disposal of sewage is common practice in the Niger Delta (Egborge, 1980; Akinluyi and Odeyemi, 1984)

There is no significant difference on river usage for irrigation. All sample communities considered the use of surface water for irrigation to be of little significance, except Elebele. Elebele respondents did not consider irrigation as a use value, most likely because irrigation is a minor usage that is restricted to the short dry season in the Study Area. The dry season in the Niger Delta is comparatively short and lasts for about three months, during which period there are usually occasional rainy days (Abam and Okagbue, 1986; Okagbue, 1989; Gobo and Abam, 1991; HRW, 1999). Generally, there is no significant difference between all sample communities in their river use profile (SPSS Output 7. 12). Therefore the cultural and societal values of the creeks are not significantly different in the Study Area. In addition, the creeks have been used for recreation and general purposes (drinking and domestic use, recreation, fishing festival and sewage and waste disposal) and for livelihood sustenance (fishing, transportation and commerce, palm processing; irrigation; lumbering and sand mining). In addition, there is a general similarity in river usage in both creeks (see SPSS Output 8. 13 and SPSS Output 8. 14)

Furthermore, the environmental pressure on the creeks in the Study Area may not be significantly different as represented by the percentage of respondents that recognise the respective usage variable (see Table 7. 10). In the Study Area, inland river fishing constitutes one of the uses. Furthermore, fishing and fish diversity, abundance and the economic value of fish species have been used as additional variables for building the baseline scenario of the Study Area. In Togo-Benin, rivers have also been used for a variety of purposes, including domestic uses and navigation (Trebaol, 2003). This section (7.4.1) has shown that river use is similar in all four sample study communities based on the TK, TEK and TELK of respondents.

.

SPSS Output 7. 10 Relationship of river use profile (Study Area)

Correlations

			Elebele (River use)	Otuoke (River use)	Otakeme (River use)	Otuogidi (River use)
Kendall's tau_b	Elebele (River use)	Correlation Coefficient	1.000	.808**	.838**	.826**
		Sig. (2-tailed)	.	.000	.000	.000
		N	35	35	35	35
	Otuoke (River use)	Correlation Coefficient	.808**	1.000	.862**	.943**
		Sig. (2-tailed)	.000	.	.000	.000
		N	35	40	40	40
	Otakeme (River use)	Correlation Coefficient	.838**	.862**	1.000	.925**
		Sig. (2-tailed)	.000	.000	.	.000
		N	35	40	50	45
	Otuogidi (River use)	Correlation Coefficient	.826**	.943**	.925**	1.000
		Sig. (2-tailed)	.000	.000	.000	.
		N	35	40	45	45

**. Correlation is significant at the .01 level (2-tailed).

SPSS Output 7. 11 Kruskal Wallis Test of relationship of river use (Study Area)

Test Statistics [a,b]

	Fishing (Inland river)	Drinking and Domestic Use	Transportation and Commerce	Sand Minning	Lumbering	Sewage and Waste Disposal	Palm Processing	Recreation	Irrigation
Chi-Square	.100	3.000	.000	1.068	3.376	19.000	1.158	.000	.900
df	3	3	3	3	3	3	3	1	2
Asymp. Sig.	.992	.392	1.000	.785	.337	.000	.763	1.000	.638
Exact Sig.	.993	1.000	1.000	.802	.355	.000	.785	1.000	.725
Point Probability	.000	1.000	1.000	.001	.000	.000	.000	.159	.275

a. Kruskal Wallis Test

b. Grouping Variable: Sample Communities

SPSS Output 7. 12 Kruskal Wallis Test of river use profile (Study Area)

Test Statistics[a,b]

	River Use (Study Area)
Chi-Square	.849
df	3
Asymp. Sig.	.838

a. Kruskal Wallis Test

b. Grouping Variable: Sample Communities

SPSS Output 7. 13 K-S Z Test of river use profile (Elebele / Otuoke Creek)

Test Statistics [a]

		River Use (Elebele / Otuoke Creek)
Most Extreme Differences	Absolute	.146
	Positive	.146
	Negative	-.014
Kolmogorov-Smirnov Z		.633
Asymp. Sig. (2-tailed)		.818
Exact Sig. (2-tailed)		.621
Point Probability		.028

a. Grouping Variable: Sample Communities

SPSS Output 7. 14 K-S Z Test of river use profile (Kolo Creek)

Test Statistics [a]

		River Use (Kolo Creek)
Most Extreme Differences	Absolute	.169
	Positive	.078
	Negative	-.169
Kolmogorov-Smirnov Z		.822
Asymp. Sig. (2-tailed)		.509
Exact Sig. (2-tailed)		.355
Point Probability		.021

a. Grouping Variable: Sample Communities

7.4. 2 Fishing: fishing seasons and fisheries

Artisanal fisheries production (small scale local fishing) accounts for over 45% of the world fish catch and this constitutes over 40% of the total world food fish supply (Welcomme, 1983). Fishing in Nigeria is predominantly at the artisanal level, which contributes about 85% of the national total fish production from the inland surface water (Moses, *et al.* 2002).

Information on the actual population of fishers in the Niger Delta is inadequate (Laë, *et al.* 2003). In the context of this research, face-to-face administered questionnaires have been used with fishers and the responses have been used to build up a fisheries baseline scenario of the Study Area. Similarly, qualitative and semi-structured interviews used in Belize have provided detailed accounts of change in fishery, as well as used identifying key past events that may have affected fishery resources (Huitric, *et al.* 2005).

7.4.2. 1 Fishing seasons

Table 7. 11 show a summary of the favourable and non-favourable fishing seasons in the Study Area based on the TELK of local fishers that have been acquired over years of fishing (this has been represented by percentage of fishers). The flood recession and the dry seasons are generally the most favourable fishing seasons, while the rainy and flood seasons are the non-favourable fishing seasons. Similarly, inland river fishing in the Niger Delta has been reported to be characterised by seasonal variations associated with intensive exploitation during the dry and low water period (flood recession), with decreased exploitation during the flood and rainy season when fish are dispersed unto the floodplains (Sikoki and Otobotekere, 1999; Laë, *et al.* 2003). During the high water period, fishing is usually predominantly carried out in the floodplains (Sikoki and Otobotekere, 1999). In addition, traditionally, cast nets, drag/seine nets, gill nets of various mesh sizes, long lines and traps are commonly used in fishing in the Muni lagoon in Ghana, which shows that fish diversity varies from season to season (Koranteng, *et al.* 2000).

Except Otakeme, the early rainy seasons (April and May) have been identified as a non-favourable fishing seasons. The early rainy periods have been characterised by increased turbidity on the creeks as a result of run-off from the floodplains. It is a unanimous opinion of the fishers in the sample communities that increased turbidity may have resulted in migration of fish away from these creek sections. However, local fishers in Otakeme feel differently, which may be because the early rains fall within the fishing season (see Table 7. 10).

Based on the TELK of local fishers in the sample communities, annual variations of fish production in the Kolo Creek have been dependent on flood level. Increased flooding favours increased fish production. Water hyacinth, tree stumps and other tree parts in the creeks have also constrained fishing. See section 7.4.3 for a discussion on environmental issues in the Study Area. Figure 7. 6 show sections of creeks that are completely covered by water hyacinth in the Elebele / Otuoke Creek and Kolo Creek respectively. Tree stumps and logs from tree parts restrict access to fishing grounds. Figure 7. 7 and Figure 7. 8 illustrate constraints posed by tree stumps and other tree parts to fishing in the Study Area.

Fisheries of large river floodplains exhibit seasonal and inter-annual variations (Coates, *et al.* 2003; Laë, *et al.* 2003). In the River Niger, fish species have adapted to these variations that are dependent on successions of favourable and unfavourable environmental conditions that affect the migration and distribution of fish species (Laë, *et al.* 2003).

Table 7. 11 Inland river freshwater fishing seasons (Study Area)

		Inland freshwater river fishing seasons (Percentage)	
Community	**Perception**	**Favourable / "fishing"**	**Non-favourable / "non-fishing"**
Elebele (R)	Rainy season	17	67
	Flood season	6	33
	Flood recession	89	6
	Dry Season	39	28
	Early rains	11	33
Otuoke (T)	Rainy season	13	53
	Flood season	9	56
	Flood recession	75	3
	Dry Season	63	13
	Early rains	9	41
Otakeme (R)	Rainy season	6	81
	Flood season	3	50
	Flood recession	69	3
	Dry Season	64	19
	Early rains	31	11
Otuogidi (T)	Rainy season	13	63
	Flood season	0	60
	Flood recession	67	0
	Dry Season	63	10
	Early rains	20	13
Study Area	Rainy season	12	66
	Flood season	4	50
	Flood recession	75	3
	Dry Season	57	17
	Early rains	18	25

Key

None	0%
Very low to low	0 > 25 %
Low to medium	25 > 50 %
Medium to high	50 > 75 %
High to very high	75 > 100 %

Source: Author

Figure 7. 6 Water hyacinth a constraint to fishing (Study Area)

Figure 7. 7 Sorry Fisher: a log of wood not a fish (Elebele / Otuoke Creek)

Figure 7. 8 A tree stump across Elebele / Otuoke Creek

The K-S Test for normality on the data in Table 7. 11 show a deviation from normal distribution ($p < 0.05$) by season. Kendall's tau correlation coefficient shows a significant relationship of the TELK of fishers in the sample communities in the Study Area as regard fishing seasons (see SPSS Output 7. 15. Fishing seasons has been used to represent favourable / "fishing" and unfavourable / "non-fishing" seasons).

SPSS Output 7. 15 Relationship between fishing seasons (Study Area)

Correlations

			Elebele - Fishing	Otuoke - Fishing	Otakeme - Fishing	Otuogidi - Fishing
Kendall's tau_b	Elebele - Fishing	Correlation Coefficient	1.000	.860**	.759**	.777**
		Sig. (2-tailed)	.	.001	.003	.003
		N	10	10	10	10
	Otuoke - Fishing	Correlation Coefficient	.860**	1.000	.644*	.753**
		Sig. (2-tailed)	.001	.	.011	.004
		N	10	10	10	10
	Otakeme - Fishing	Correlation Coefficient	.759**	.644*	1.000	.837**
		Sig. (2-tailed)	.003	.011	.	.001
		N	10	10	10	10
	Otuogidi - Fishing	Correlation Coefficient	.777**	.753**	.837**	1.000
		Sig. (2-tailed)	.003	.004	.001	.
		N	10	10	10	10

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Using the Kruskal Wallis Test on the fishing and non-fishing seasons shows that there is no significant difference between all communities in the Study Area ($p > 0.05$) (SPSS Output 7.16). In addition Two-Sample Kolmogorov-Smirnov Tests on communities along Elebele / Otuoke Creek and Kolo Creek show that there is no significant difference in the perception of which are suitable fishing and non-fishing seasons (SPSS Output 7. 17 and SPSS Output 7. 18 respectively). Generally, there is no significant difference based on the experience and knowledge of local fishers on the suitability of fishing seasons in the Kolo Creek. Furthermore, the TELK of fishers in the sample communities have been accessed via the face-to-face questionnaires to understand the factors that have been affecting fishing in the Study Area.

SPSS Output 7. 16 Kruskal Wallis Test of fishing seasons (Study Area)

Test Statistics[a,b]

	Fishing Seasons (Study Area)	Non-fishing Seasons (Study Area)
Chi-Square	.014	.180
df	3	3
Asymp. Sig.	1.000	.981
Exact Sig.	1.000	.984
Point Probability	.000	.001

a. Kruskal Wallis Test

b. Grouping Variable: Sample Communities

SPSS Output 7. 17 Fishing seasons (Elebele / Otuoke Creek)

Test Statistics[a]

		Fishing Seasons (Elebele / Otuoke Creek)	Non-fishing Seasons (Elebele / Otuoke Creek)
Most Extreme Differences	Absolute	.200	.400
	Positive	.200	.400
	Negative	-.200	-.200
Kolmogorov-Smirnov Z		.316	.632
Asymp. Sig. (2-tailed)		1.000	.819
Exact Sig. (2-tailed)		1.000	.873
Point Probability		.190	.587

a. Grouping Variable: Sample Communities

SPSS Output 7. 18 Fishing seasons (Kolo Creek)

Test Statistics [a]

		Fishing Seasons (Kolo Creek)	Non-fishing Seasons (Kolo Creek)
Most Extreme Differences	Absolute	.200	.200
	Positive	.200	.200
	Negative	-.200	-.200
Kolmogorov-Smirnov Z		.316	.316
Asymp. Sig. (2-tailed)		1.000	1.000
Exact Sig. (2-tailed)		1.000	1.000
Point Probability		.127	.127

a. Grouping Variable: Sample Communities

7.4.2. 2 Factors affecting fishing

Table 7. 12 contain a summary of the eco-livelihood issues (represented by percentage of respondents) that may have affected fish diversity across seasons in the Study Area. This summary is based on the TEK and TELK of respondents in the four sample communities. Flooding, tidal actions and fish migration and spawning tend to have a positive effect on fish abundance across seasons. Similarly, in Cambodia, the magnitude of flooding is positively related to fish productivity (Van Zalinge, *et al.* 1998). However, seasonal changes (associated with early rains), water hyacinth, tree stumps, upstream dams, dredging, shallow depth of the rivers, lunar actions (full moon have a negative impact on fish abundance), and fishing festivals have been perceived by respondents to have negative impact on fishing. Sikoki and Otobotekere (1999), have reported that “good” fish catches have generally been recorded about 4 days before the new moon and that the periods between July and October (rainy and early flood seasons) usually experiences low fishing activities in the Central Niger Delta.

Specifically, water hyacinth and trees stump and other tree parts constitute the major limiting factors to fishing. In addition, inland river dredging have been identified as an environmental issue that have negatively affected the creek sections along Otuoke (T) and Otuogidi (T)

The K-S Test of normality on the variables in Table 7. 12 show a deviation from normality ($p < 0.05$). The Kruskal Wallis Test on these variables shows that there is no significant difference ($p > 0.05$) based on the TELK of the fishers in the Study Area (SPSS Output 7.19). This may be because four of the identified eleven environmental issues are common to all sample communities (Table 7. 12). The above results shows that except inland river dredging that have affected inland river fishing in the Test communities, the constraints on fishing are not significantly different across the sample communities. A more detailed discussion of these eco-livelihood issues and other issues is presented in section 7.4.3. As part of the baseline scenario of the Study Area, the TELK of fishers have been accessed to understand fisheries using: fish species diversity and abundance; commercial value of fish species; and trend in the abundance, diversity and economic relevance of fishing.

Table 7. 12 Environmental issues that affect fishing (Study Area)

Issues	Elebele (R) (%)	Otuoke (T) (%)	Otakeme (R) (%)	Otuogidi (T) (%)
Flooding	22	44	47	53
Migration / Spawning	46	33	51	60
Tidal actions	0	0	3	7
Fishing Festival	0	0	11	7
Seasonal changes	22	41	33	17
Water hyacinth	72	63	42	30
Tree stump and others	44	25	6	0
Up stream dams	0	6	3	3
Lunar actions	0	0	0	3
Low river depth	11	0	14	3
Dredging	0	41	0	57

SPSS Output 7. 19 Kruskal Wallis Test of factors affecting fishing (Study Area)

Test Statistics[a,b]

	Factors affecting fishing (Study Area)
Chi-Square	.478
df	3
Asymp. Sig.	.924

a. Kruskal Wallis Test

b. Grouping Variable: Sample Communities

7.4.2. 3 Fish species abundance and diversity

Much of what is known about the fish migrations in the Mekong River basin, Cambodia has been gained by tapping the local knowledge of fishers that have resided along the rivers and through ecological monitoring of selected landing sites (Van Zalinge, *et al.* 2003). Specifically, the knowledge and experience of fishers has been used in understanding the relative composition of fish species in Cambodia (Diep and Zalinge, 1998).

The Upper Niger and Central Delta is home to between 130 and 140 fish species, which belong to 62 genera and 26 families. Along the Niger River, 98 species belonging to 22 families have been recorded. Among these species, 83 are regularly fished while 15 are very rare (Laë, *et al.* 2003). In the context of this research, the perception of fishers on fish diversity and abundance in the Study Area has been accessed via the TELK of local fishers. Table 7. 13 show a summary of the major fished species in the Study Area. A 3% (based on fishers' knowledge and experience) cut-off mark has been used to separate major and minor fish species in the Study Area. A total of 16 fish species fall into major fish category. Of these, 9 and 10 fish species have been reported as species caught by fishers in the Central Niger Delta and among the major species caught by fishers in the years 1991 and 1992 respectively (see Table 6.6 and Table 6.7 respectively). Table 7. 14 contains a summary of the less regularly fished fish species in the Study Area. The scientific names of some of the minor fish species have not been identified. Similarly, 1 fish species from Table 7.14 has been reported as common in inland freshwater rivers in Bayelsa State (see Table 6.6); and 2 fish species from Table 7.14 have been recorded in the fish catch of fishers in 1991 and 1992 respectively (Table 6.7). In summary, 71% and 86% of the species recorded in Table 6.6 and Table 6.7 have been identified by fishers in the Study Area based on their TELK. This shows that the TELK of fishers in the Study Area is valid and a reliable source of knowledge.

Table 7. 13 Major fish species (Study Area)

Local name	Scientific name	Community
Epete / Aporu	*Citharinus spp*	Elebele, Otuoke, Otakeme, Otuogidi
Okolokolo	*Alestes spp*	Elebele, Otuoke, Otakeme, Otuogidi
Ewela	*Tilapia spp*	Elebele, Otuoke, Otakeme, Otuogidi
Esa	*Gymnarchus niloticus*	Elebele, Otuoke, Otakeme, Otuogidi
Eferere	*Distichodus spp*	Elebele, Otuoke, Otakeme, Otuogidi
Orobhobhi	*Clarias spp*	Elebele, Otuoke, Otakeme, Otuogidi
Obulo	*Ophiocephalus obscurus*	Elebele, Otuoke, Otakeme, Otuogidi
Ogbolokaka	*Heterotis niloticus*	Elebele, Otuoke, Otakeme, Otuogidi
Obhari	*Papyrocranus afer*	Elebele, Otuoke, Otakeme, Otuogidi
Olari	*Pareutropius sp*	Elebele, Otuoke, Otakeme, Otuogidi
Ogulo / Egbo	*Chrysichthys nigrodigitatus*	Elebele, Otuoke, Otakeme, Otuogidi
Okpoki / Opogoin	*Synodontis spp*	Elebele, Otuoke, Otakeme, Otuogidi
Ebhe	*Marcusenius spp*	Elebele, Otuoke, Otakeme, Otuogidi
Ibutu	*Labeo sp*	Elebele, Otuoke, Otakeme, Otuogidi
Ebede	*Petrocephalus spp*	Elebele, Otuoke, Otakeme, Otuogidi
Ogbuda	*Schilbe mystus*	Otakeme, Otuogidi

Source: Author

The local names of these fish species have been given by the local fishers (18 from Elebele, 32 from Otuoke, 36 from Otakeme and 30 from Otuogidi) and fish species identified during the ecological survey have been presented to other local fishers in the Study Area for the purpose of triangulation and confirmation of the names given by the fishers involved in the ecological survey. In addition the book by Reed, *et al.* (1967) containing photographs of Northern Nigerian fish have been used for triangulation of the names of the fish species. The ecological surveys have been used for further triangulation and confirmation of the fish names. Similarly, in Mexico local taxonomy with the help of key informants assisted in sampling and identification of plant species (Potvin, *et al.* 2005).

Fish species have been based on rankings fishers assign to the respective species (rankings from 1 to 5). This ranking has been based on fishers ranking the 5 most abundant fish species based on their respective catches. 5 representing the most abundant and 1 representing the fifth most abundant species. Fishers were further asked to list any other five species they consider to constitute a considerable proportion of their catches (these have been assigned a rank of 0.5). A rank of 0.5 indicates species that are of lesser abundance in the catch of fishers that participated in the social survey. Specifically, the relative rank (total fish species rank divided by total rank of all fish species multiplied by 100) of each species represents the abundance of the respective species. In addition, the percentage of fishers that identified individual fish species has also been used to represent species abundance.

Table 7. 14 Other fish species (Study Area)

Local name	Scientific name	Community
Orim	*Hepsetus odoe*	Elebele, Otuoke, Otakeme, Otuogidi,
Otikiri / Omose	*Malapterurus electricus*	Elebele, Otuoke, Otakeme, Otuogidi
Agbara	*Lates niloticus*	Elebele, Otuoke, Otuogidi,
Ofio / Oduro	*Bagrus spp*	Otuoke, Otakeme, Otuogidi
Edegere	*Micralestes spp*	Elebele, Otakeme
Obuyan	*Mormyrus spp*	Elebele, Otuogidi
Ekudo	*Unidentified*	Otuoke, Otuogidi
Ebelem / Azoru	*Xenomystus nigri (Pez cuchillo Africano)*	Otakeme, Otuogidi
Ebiesene	*Protopterus annectens*	Otakeme, Otuogidi
Apamu / Isongo	*Pantodon bucholzi*	Otakeme, Otuogidi
Ofuroma	*Mugil cephalus*	Otakeme, Otuogidi
Ohabh	*Hydrocynus linaetus*	Otakeme, Otuogidi
Egbetuki	*Unidentified*	Elebele
Epelepele	*Unidentified*	Elebele
Okpokpozi	*Notopterus chitala*	Elebele
Esasam	*Ctenopoma kingsleyae*	Otuoke
Epelia	*Trachinotus goreensis*	Otuoke
Omiozogboro	*Unidentified*	Otuoke
Gbagbakurukuru	*Unidentified*	Otakeme
Oduro / Ofio	*Bagrus spp*	Otakeme
Okolobosigoin	*Ichthyborus monody*	Otakeme

Source: Author

Table 7. 15 contains a summary of the fish diversity and abundance in the Study Area based on TELK. The five most abundance fish species in the Study Area are: *Alestes spp*; *Citharinus spp*; *Tilapia spp*; *Distichodus spp*; and *Gymnarchus niloticus*. See Appendix 34 to Appendix 37 for details of all the sample communities. The ranks and proportion of Fishers that have listed the respective fish species have been used as indicators for fish abundance and diversity in the Study Area

Table 7. 15 Fish species abundance and diversity based on TELK (Study Area)

	Fish species name																		
	Scientific name	*Citharinus spp*	*Alestes spp*	*Tilapia spp*	*Gymnarchus niloticus*	*Distichodus spp*	*Clarias spp*	*Chrysichthys nigrodigitatus*	*Ophiocephalus obscurus*	*Heterotis niloticus*	*Synodontis spp*	*Marcusenius spp*	*Papyrocranus afer*	*Pareutropius sp*	*Labeo sp*	*Schilbe mystus*	*Petrocephalus spp.*	*Other species*
Sample	Local name	Epete	Okolokolo	Ewela	Esa	Eferere	Orobhobhi	Ogulo/Egbo	Obulo	Ogbolokaka	Okpoki / Opogoin	Ebhe	Obhari	Olari	Ibutu	Ogboda	Ebede	Others
Elebele (R)	Ranking	7.0	14.8	13.9	6.2	4.1	8.8	2.8	3.9	4.6	6.3	6.8	3.6	6.5	0.3	0.0	4.4	5.8
Elebele (R)	Perception	50.0	72.2	77.8	66.7	50.0	83.3	44.4	55.6	66.7	55.6	72.2	44.4	61.1	11.1	0.0	27.8	77.8
Otuoke (T)	Ranking	11.4	14.7	9.6	11.6	10.5	6.8	6.1	5.8	9.4	1.5	1.3	2.9	4.1	0.8	0.0	0.6	3.0
Otuoke (T)	Perception	65.6	90.6	68.8	93.8	81.3	78.1	65.6	56.3	84.4	28.1	28.1	37.5	37.5	18.8	0.1	9.4	93.8
Otakeme (R)	Ranking	19.4	16.3	15.8	4.5	10.4	3.4	3.5	6.3	4.0	1.9	3.1	0.8	3.2	0.6	0.0	3.7	3.3
Otakeme (R)	Perception	88.9	86.1	86.1	80.6	63.9	47.2	52.8	66.7	63.9	36.1	36.1	19.4	50.0	16.7	0.0	41.7	81.7
Otuogidi (T)	Ranking	17.2	23.3	9.6	3.7	15.3	1.7	8.6	0.9	2.7	3.2	0.2	0.9	2.0	2.8	1.3	2.0	4.5
Otuogidi (T)	Perception	83.3	100.0	76.7	83.3	90.0	36.7	80.0	16.7	50.0	43.3	3.3	26.7	16.7	26.7	26.7	23.3	96.7
Elebele/Otuoke Creek	Ranking	9.2	14.8	11.8	8.9	7.3	7.8	4.5	4.9	7.0	3.9	4.1	3.3	5.3	0.6	0.0	2.5	4.4
Elebele/Otuoke Creek	Perception	57.8	81.4	73.3	80.2	65.7	80.7	55.0	55.9	75.5	41.8	50.2	41.0	49.3	14.9	0.1	18.6	85.8
Kolo Creek	Ranking	18.3	19.8	12.7	4.1	12.9	2.6	6.1	3.6	3.4	2.6	1.7	0.9	2.6	1.7	0.7	2.9	3.9
Kolo Creek	Perception	86.1	93.1	81.4	81.9	76.9	41.9	66.4	41.7	56.9	39.7	19.7	23.1	33.3	21.7	13.3	32.5	89.2
Study Area	Ranking	13.8	17.3	12.2	6.5	10.1	5.2	5.3	4.2	5.2	3.2	2.9	2.1	4.0	1.1	0.3	2.7	4.2
Study Area	Perception	72.0	87.2	77.3	81.1	71.3	61.3	60.7	48.8	66.2	40.8	34.9	32.0	41.3	18.3	6.7	25.5	87.5

Source: Author

See previous page for explanation of how these values were obtained

The K-S Test for normality on fish diversity and abundance in the Study Area based on the perception of fishers (percentage of fishers) shows a normal distribution ($p > 0.05$) for Otuoke, and Otakeme, as well as relative ranking (Otuoke). However, there is deviation in perception of fishers for: Elebele, and Otuogidi, and in relative ranking (Elebele, Otakeme and Otuogidi). Based on the above results, Pearson (r) correlation coefficient has been carried out to test for relationship between the variables in Table 7. 15, which are normally distributed, while Kendall tau (τ) coefficient of correlation has been carried out on variables that show deviation from normality.

The coefficients of correlation show there are significant relationships in fish abundance and diversity between all sample communities, as well as in the Study Area: Elebele t = 0.617, p (two tailed) < 0.01 (Appendix 38); Otuoke (T) r = 0.817, p (two-tailed) < 0.01 (Appendix 39); Otakeme (R) t = 0.7851, p (two-tailed) < 0.01 (Appendix 40); Otuogidi (T) t = 0.717 p (two-tailed) < 0.01 (Appendix 41); and in all sample communities (Kolo Creek) t = 0.706 p (2-tailed) < 0.01 (Appendix 42). In addition, the Kruskal Wallis Test (all sample communities), and Kolmogorov-Smirnov Z Tests on relative ranking and perception of fish diversity and abundance shows that there is no significant difference in these variable across all the sample communities. SPSS Output 7. 20, SPSS Output 7. 21 and SPSS Output 7. 22 show the above results (DV / AB represents fish diversity and abundance).

These results show that generally, fish species abundance and diversity is consistent across all communities in the Study Area, and that TELK could be used to represent the assessment baseline scenario of fish abundance and diversity in the Study Area and in areas or scenarios where fishing is a major livelihood source. Furthermore, relative ranking and fishers' perceptions are consistent and reliable indicators of fish species abundance and diversity in the Study Area and have application in similar areas. Similarly, the comparison of biodiversity levels from whole river systems to river segments within a floodplain are reliable and valid (Ward, *et al.* 1999).

SPSS Output 7. 20 Kruskal Wallis on species diversity and abundance (Study Area)

Test Statistics [a,b]

	Fish species DV-AB - Perception (Study Area)	Fish species DV-AB - Ranking (Study Area)
Chi-Square	.255	1.318
df	3	3
Asymp. Sig.	.968	.725

a. Kruskal Wallis Test

b. Grouping Variable: Sample Community

SPSS Output 7. 21 K-S Z Test on species diversity and abundance (Elebele / Otuoke Creek)

Test Statistics[a]

		Fish species DV-AB - Perception (Elebele / Otuoke Creek)	Fish species DV-AB - Ranking (Elebele / Otuoke Creek)
Most Extreme Differences	Absolute	.294	.235
	Positive	.294	.235
	Negative	-.235	-.235
Kolmogorov-Smirnov Z		.857	.686
Asymp. Sig. (2-tailed)		.454	.734
Exact Sig. (2-tailed)		.361	.751
Point Probability		.131	.320

a. Grouping Variable: Sample Community

SPSS Output 7. 22 K-S Z Test on species diversity and abundance (Kolo Creek)

Test Statistics[a]

		Fish species DV-AB - Perception (Kolo Creek)	Fish species DV-AB - Ranking (Kolo Creek)
Most Extreme Differences	Absolute	.235	.294
	Positive	.176	.118
	Negative	-.235	-.294
Kolmogorov-Smirnov Z		.686	.857
Asymp. Sig. (2-tailed)		.734	.454
Exact Sig. (2-tailed)		.719	.435
Point Probability		.310	.207

a. Grouping Variable: Sample Community

7.4.2. 4 Commercial value of fish species

The knowledge and experience of fishers in the sample communities have been explored to identify fish species of commercial value in the Study Area. Fishers have been requested to rank fish species between 5 and 1, in order of increasing order of commercial values. Table 7. 16 and Table 7. 17 show a summary of fish species of commercial value and other species of commercial value respectively. Nine of the thirteen species of high commercial value are common to all sample communities, except one species that is exclusive to Elebele.

Table 7. 18 show a summary of the relative ranking and perception of fish species of commercial value in the Study Area based on the TELK of local fishers. See Appendix 43 to Appendix 46 for details of all the commercial value of fish species in the sample communities. The relative ranking and perceptions have been computed as in Table 7. 15. *Gymnarchus niloticus*, *Clarias spp*, *Heterotis niloticus*, *Distichodus spp*, and *Chrysichthys nigrodigitatus* are the five species of highest commercial value, and all of these have been identified as species of high abundance in

the Study Area (see Table 7. 13). 6 and 10 of the species of commercial values (Table 7.16) have been reported as major species in the catch of inland freshwater fishers and reported in the catch of fishers in 1991 and 1992 respectively. Similarly, 3 and 2 of the other fish species of commercial value (Table 7.17) have been reported as species of high abundance in the catch of inland river fishers and in the catch of fishers in 1991 and 1992 respectively (refer to Table 6.6 and Table 6.7). Generally the fish species identified as species of commercial value represents 71% and 86% of the fish species reported to be among the major fish catch of inland river fishers in the Central Niger Delta and those caught by fishers in 1991 and 1992 in the Central Niger Delta respectively. These results demonstrate the reliability and validity of TELK of fishers in the Study Area.

Table 7. 16 Fish species of commercial value (Study Area)

Local name	Scientific name	Community
Epete / Aporu	*Citharinus spp*	Elebele, Otuoke, Otakeme, Otuogidi
Okolokolo	*Alestes spp*	Elebele, Otuoke, Otakeme, Otuogidi
Ewela	*Tilapia spp*	Elebele, Otuoke, Otakeme, Otuogidi
Esa	*Gymnarchus niloticus*	Elebele, Otuoke, Otakeme, Otuogidi
Eferere	*Distichodus spp*	Elebele, Otuoke, Otakeme, Otuogidi
Orobhobhi	*Clarias spp*	Elebele, Otuoke, Otakeme, Otuogidi
Obulo	*Ophiocephalus obscurus*	Elebele, Otuoke, Otakeme, Otuogidi
Ogbolokaka	*Heterotis niloticus*	Elebele, Otuoke, Otakeme, Otuogidi
Ogulo / Egbo	*Chrysichthys nigrodigitatus*	Elebele, Otuoke, Otakeme, Otuogidi
Obhari	*Papyrocranus afer*	Elebele, Otuoke, Otakeme
Olari	*Pareutropius sp*	Elebele, Otuoke, Otuogidi
Agbara	*Lates niloticus*	Elebele, Otuoke, Otuogidi
Emunu	*Unidentified*	Elebele

Source: Author

Table 7. 17 Other fish species of commercial value (Study Area)

Local name	Scientific name	Community
Ofio / Oduro	*Bagrus spp*	Elebele, Otuoke, Otakeme
Okpoki / Opogoin	*Synodontis spp*	Elebele, Otakeme, Otuogidi
Ebhe	*Marcusenius spp*	Elebele, Otuoke
Orim	*Hepsetus odoe*	Otuoke, Otuogidi
Obuyan	*Mormyrus spp*	Otuoke, Otuogidi
Okpokpozi	*Notopterus chitala*	Elebele
Ebiesene	*Protopterus annectens*	Otakeme
Ogbuda	*Schilbe mystus*	Otuogidi
Ibutu	*Labeo sp*	Otuogidi
Ofuroma	*Mugil cephalus*	Otuogidi

Source: Author

Table 7. 18 Commercial values of fish species based on TELK (Study Area)

	Fish species name														
	Scientific name	*Citharinus spp*	*Alestes spp*	*Tilapia spp*	*Gymnarchus niloticus*	*Distichodus spp*	*Clarias spp*	*Ophiocephalus obscurus*	*Heterotis niloticus*	*Papyrocranus afer*	*Pareutropius sp*	*Lates spp*	*Chrysichthys nigrodigitatus*	*Unidentified*	*Other fish species*
Sample	Local name	Epete	Okolokolo	Ewela	Esa	Eferere	Orobhobhi	Obulo	Ogbolokaka	Obhari	Olari	Agbara	Ogulo/Egbo	Emonu	Others
Elebele (R)	Ranking	1.1	0.4	0.7	26.2	6.4	21.7	6.4	15.4	10.9	1.9	0.4	2.2	2.2	4.1
Elebele (R)	Perception	16.7	5.6	5.6	83.3	44.4	88.9	33.3	66.7	61.1	1.1	5.6	11.1	16.7	38.9
Otuoke (T)	Ranking	1.3	1.5	1.7	30.9	6.7	20.6	4.8	15.1	0.8	0.4	5.7	8.0	0.0	2.5
Otuoke (T)	Perception	9.4	12.5	9.4	96.9	40.6	87.5	31.3	81.3	9.4	3.1	31.3	43.8	0.0	31.3
Otakeme (R)	Ranking	3.8	3.0	3.8	30.1	10.5	12.2	4.9	22.6	2.4	0.0	0.0	4.3	0.0	2.4
Otakeme (R)	Perception	25.0	25.0	25.0	91.7	61.1	58.3	44.4	86.1	22.2	0.0	0.0	27.8	0.0	13.9
Otuogidi (T)	Ranking	2.3	2.1	5.0	29.3	9.2	12.6	0.2	11.9	0.0	0.0	10.5	14.0	0.0	3.0
Otuogidi (T)	Perception	23.3	13.3	36.7	90.0	50.0	60.0	3.3	60.0	0.0	0.0	43.3	73.3	0.0	13.3
Elebele/Otuoke Creek	Ranking	1.2	1.0	1.2	28.6	6.6	21.2	5.6	15.3	5.9	1.2	3.1	5.1	1.1	3.3
Elebele/Otuoke Creek	Perception	13.1	9.1	7.5	90.1	42.5	88.2	32.3	74.0	35.3	2.1	18.5	27.5	8.4	35.1
Kolo Creek	Ranking	3.1	2.6	4.4	29.7	9.9	12.4	2.6	17.3	1.2	0.0	5.3	9.2	0.0	2.7
Kolo Creek	Perception	24.2	19.2	30.9	90.9	55.6	59.2	23.9	73.1	11.1	0.0	21.7	50.6	0.0	13.6
Study Area	Ranking	2.1	1.8	2.8	29.1	8.2	16.8	4.1	16.3	3.5	0.6	4.2	7.1	0.6	3.0
Study Area	Perception	18.6	14.1	19.2	90.5	49.0	73.7	28.1	73.5	23.2	1.1	20.1	39.0	4.2	24.4

Source: Author

** Compare with Table 7.15, which shows Ranking and Perceptions for fish abundance and diversity*

Figure 7. 9 shows *Heterotis niloticus* (one of the fish species of commercial importance in the Study Area) caught by Complete Odoko, one of the Fishers involved in the ecological survey (This fish is very strong and has been reported to break fishing nets, hence this fisher had to dive into the river to avoid net breakage and escape of the fish).

The K-S Test for normality has been carried out on the relative rankings and perceptions (variables) across all the sample communities (see Table 7. 18). The variables show a deviation from normality ($p < 0.05$), except the variables of Otuogidi (T).

Figure 7. 9 *Heterotis niloticus* caught by one of the fishers involved in the survey

The correlation coefficients of relative ranking and perceptions shows that there is a significant relationship between these variables (perception of fishers and relative ranking) as measure of the commercial value of fisheries in the Study Area: Elebele $\tau = 0.874$ p (2-tailed) < 0.01 (Appendix 47); Otuoke $\tau = 0.904$ p (2-tailed) < 0.01 (Appendix 48); Otakeme $\tau = 0.906$ p (2-tailed) < 0.01 (Appendix 49); Otuogidi $r = 0.937$ p (2-tailed) < 0.01 (Appendix 50); and the Study Area $\tau = 0.915$ p (2-tailed) < 0.01 (Appendix 51). In addition, there is a significant relationship between these variables across Creeks (Kolo Creek and Elebele / Otuoke Creek): Elebele / Otuoke Creek τ = 0.895 p (2-tailed) < 0.01 (Appendix 52); τ = 0.936 (Appendix 53).

Furthermore, the Kruskal Wallis Test (all sample communities), and the Kolmogorov-Smirnov Z Test on ranking and perception of commercial value of fish species in all sample communities shows that there is no significant difference in these two variables (relative ranking and perception) across all the sample communities (SPSS Output 7. 23, SPSS Output 7. 24 and SPSS Output 7. 25. ECONS represent commercial values). Therefore, the TELK of Fishers about the commercial value of fish species is consistent across the sample communities in the Study Area. Moreover the ranking and perception (as represented by percentage of Fishers that identified the respective species) of Fishers are reliable indicators of the commercial value of fish species in the Study Area.

SPSS Output 7. 23 Kruskal Wallis Test of commercial value of species (Study Area)

Test Statistics[a,b]

	Species ECONS - Ranking (Study Area)	Species ECONS - Percentage (Study Area)
Chi-Square	.014	.066
df	3	3
Asymp. Sig.	1.000	.996

a. Kruskal Wallis Test

b. Grouping Variable: Sample Community

SPSS Output 7. 24 K-S Z Test on commercial value of species (Elebele / Otuoke Creek)

Test Statistics[a]

		Species ECONS - Ranking (Elebele / Otuoke Creek)	Species ECONS - Percentage (Elebele / Otuoke Creek)
Most Extreme Differences	Absolute	.143	.143
	Positive	.071	.143
	Negative	-.143	-.143
Kolmogorov-Smirnov Z		.378	.378
Asymp. Sig. (2-tailed)		.999	.999
Exact Sig. (2-tailed)		.999	.998
Point Probability		.087	.109

a. Grouping Variable: Sample Communities

SPSS Output 7. 25 K-S Z of commercial value of species (Kolo Creek)

Test Statistics[a]

		Species ECONS - Ranking (Kolo Creek)	Species ECONS - Percentage (Kolo Creek)
Most Extreme Differences	Absolute	.214	.214
	Positive	.214	.143
	Negative	-.214	-.214
Kolmogorov-Smirnov Z		.567	.567
Asymp. Sig. (2-tailed)		.905	.905
Exact Sig. (2-tailed)		.897	.886
Point Probability		.354	.314

a. Grouping Variable: Sample Communities

7.4.2. 5 Current fishery trends

Historical data of fisheries in the Niger Delta are rare (Sikoki and Otobotekere, 1999; Laë, *et al.* 2003). However, it has been possible to qualitatively trace major changes in fish diversity and abundance over a period of about fifty years. Pre-1970s, fishing was profitable and fish abundance was relatively high in the Niger River, with a high proportion of *Synodontis spp, Polypterus senegalus* and *Gymnarchus niloticus*. Specifically, between 1973 and 1979 most of the abundant fish species became infrequent and most probably disappeared (Laë, *et al.* 2003).

In the context of this research, the experience and knowledge (TELK) of fishers in the sample communities have been explored (and represented by percentage of fishers) to gain an understanding of the current trend in fishing and fishery in the Study Area. There has been a decline in fish abundance and diversity, which may have affected the economic relevance of fishing as a livelihood source (see Table 7. 19). A ranking of -2 to +2 has been used to represent the current trends in fishery in the Study Area. Negative signs imply reduction while positive signs represent increase. The summation of the product of the ranking and the percentage of respondents gives a summary of the trends in fishery in the Study Area on each parameter. Fish species diversity, fish species abundance and economic importance of fishing as livelihood source). The perceptions are based on the TELK of fishers and have been represented by percentage of this specialised respondent. Despite the decline in fishery resources, fishing remains a major livelihood source in the Study Area (see section 7.3.2); the reason for this is that despite this high reduction in fish abundance, the reduction in the economic importance of fishery is relatively lower. Therefore, generally fishing continues to be an economically viable livelihood option in the Study Area.

Table 7. 19 Trends in fishery (Study Area)

Community	Ranking	Current trends of fishery (Percentage)		
		Fish species diversity	Fish species abundance	Economic importance of fishing
Elebele (R)	Reduced significantly (-2)	0	78	72
	Reduced (-1)	6	22	22
	No change (0)	95	0	0
	Increased (+1)	0	0	6
	Increased Significantly (+2)	0	0	0
	Summary – Elebele (R)	-6	-178	-160
Otuoke (T)	Reduced significantly (-2)	0	81	75
	Reduced (-1)	3	19	16
	No change (0)	97	0	3
	Increased (+1)	0	0	6
	Increased Significantly (+2)	0	0	0
	Summary – Otuoke (T)	-3	-181	-160
Otakeme (R)	Reduced significantly (-2)	0	67	44
	Reduced (-1)	6	25	31
	No change (0)	94	6	0
	Increased (+1)	0	3	11
	Increased Significantly (+2)	0	0	14
	Summary – Otakeme (R)	-6	-156	-80
Otuogidi (T)	Reduced significantly (-2)	0	73	57
	Reduced (-1)	10	17	23
	No change (0)	90	7	7
	Increased (+1)	0	3	10
	Increased Significantly (+2)	0	0	3
	Summary – Otuogidi (T)	-10	-160	-121
Study Area	Reduced significantly (-2)	0	75	62
	Reduced (-1)	6	20	23
	No change (0)	94	3	2
	Increased (+1)	0	1	9
	Increased Significantly (+2)	0	0	4
	Summary – Study Area	-6	-169	-130

Key

0%
0 > 25 %
25 > 50 %
50 > 75 %
75 > 100 %

Source: Author

The K-S Test for normality on the variables on Table 7. 19 show a deviation from normality ($p < 0.05$) on all variables. Kendall tau's (τ) coefficient of correlation between all variables that measures fishing trends show a strong relationship across all sample communities p (2-tailed) < 0.01 and 0.05 respectively (See SPSS Output 7. 26). In addition the Kruskal Wallis Test on trends in fishing across all sample communities show that there is no significant difference ($p > 0.05$) in fishing trend in the Study Area (SPSS Output 7.27) as well as across the Elebele / Otuoke Creek and Kolo Creek Kolmogorov-Smirnov Z Test ($p > 0.05$). SPSS Output 7. 28 and SPSS Output 7. 29 contain the results respectively. This implies that in the Study Area, fish species abundance and economic importance of fishing is significantly declining, while there has been no significant reduction in fish diversity.

SPSS Output 7. 26 Relationship between trends in fishing (Study Area)

Correlations

			Trend in fishery (Elebele)	Trend in fishery (Otuoke)	Trend in fishery (Otakeme)	Trend in fishery (Otuogidi)
Kendall's tau_b	Trend in fishery (Elebele)	Correlation Coefficient	1.000	.938**	.834**	.483*
		Sig. (2-tailed)	.	.000	.000	.024
		N	15	15	15	15
	Trend in fishery (Otuoke)	Correlation Coefficient	.938**	1.000	.747**	.471*
		Sig. (2-tailed)	.000	.	.000	.025
		N	15	15	15	15
	Trend in fishery (Otakeme)	Correlation Coefficient	.834**	.747**	1.000	.421*
		Sig. (2-tailed)	.000	.000	.	.040
		N	15	15	15	15
	Trend in fishery (Otuogidi)	Correlation Coefficient	.483*	.471*	.421*	1.000
		Sig. (2-tailed)	.024	.025	.040	.
		N	15	15	15	15

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

SPSS Output 7. 27 Kruskal Wallis Test of trends in fishing (Study Area)

Test Statistics [a,b]

	Fish species diversity (Study Area)	Fish species abundance (Study Area)	Economic importance of fishery (Study Area)
Chi-Square	.004	.613	.727
df	3	3	3
Asymp. Sig.	1.000	.893	.867
Exact Sig.	1.000	.905	.881
Point Probability	.002	.001	.000

a. Kruskal Wallis Test

b. Grouping Variable: Sample Communities

SPSS Output 7. 28 K-S Z Test on fishing trend (Elebele / Otuoke Creek)

Test Statistics [a]

		Fish species diversity (Elebele / Otuoke Creek)	Fish species abundance (Elebele / Otuoke Creek)	Economic importance of fishery (Elebele / Otuoke Creek)
Most Extreme Differences	Absolute	.200	.200	.200
	Positive	.200	.200	.200
	Negative	-.200	-.200	-.200
Kolmogorov-Smirnov Z		.316	.316	.316
Asymp. Sig. (2-tailed)		1.000	1.000	1.000
Exact Sig. (2-tailed)		1.000	1.000	1.000
Point Probability		.317	.317	.190

a. Grouping Variable: Sample Communities

SPSS Output 7. 29 K-S Z Test on fishing trends (Kolo Creek)

Test Statistics [a]

		Fish species diversity (Kolo Creek)	Fish species abundance (Kolo Creek)	Economic importance of fishery (Kolo Creek)
Most Extreme Differences	Absolute	.200	.200	.400
	Positive	.200	.200	.200
	Negative	-.200	-.200	-.400
Kolmogorov-Smirnov Z		.316	.316	.632
Asymp. Sig. (2-tailed)		1.000	1.000	.819
Exact Sig. (2-tailed)		1.000	1.000	.873
Point Probability		.317	.127	.516

a. Grouping Variable: Sample Communities

Generally, the perceived reduction in fish diversity in the Study Area by a section of the fishers may imply significant reduction in general diversity of fish catch (rare fish species), because no specific species have been reported to be completely extinct. Furthermore, fishing is becoming less economically profitable compared to the recent past (over 20 years). It is a general consensus in the sample communities that there have been general declines in fish abundance since the construction of Dams upstream (particularly the Kainji Dam). Other factors that have affected fishing and fishery resources in the Study Area are discussed in section 7.4.3.

7.4. 3 Eco-livelihoods issues

So far this chapter has considered the sample communities livelihood patterns, and distribution, relation of the livelihoods of respondents and common pool resources (CPRs), river usage, fishing; fish diversity and abundance, and commercial value of fish species in the Study Area. This section considers how environmental changes affect the ecological systems that maybe of livelihoods consequences (eco-livelihood impacts).

Fish diversity, abundance, the economic relevance of fishing as livelihood option, fishing seasons and river use profile of the Study Area are dependent on the eco-livelihood issues that have occurred in the respective rivers. Some of these environmental issues are: seasonal (flooding; seasonal changes associated with early rains; fishing festival; pollution from oil palm processing; and lumbering); one-off event(s) / occurrence(s) (oil pollution and inland river dredging); and all-year-round (water hyacinth *Eichhornia crassipes,* sewage and waste disposal; shallow depth; tree stumps and other tree parts in river; and upstream dams). The environmental problems in the Niger Delta are caused by many factors that are complex and interconnected (Laë, *et al.* 2003)

The respondents of the social survey from the sample communities have identified and ranked eco-livelihood issues that have occurred or which are prevalent in their respective communities. A range of -2 to +2 has been used, -2 represent very significant negative impacts and +2 very significant beneficial impacts. A summary of these rankings has been presented based on percentage of respondents in Table 7. 20.

The K-S Test for normality on the eco-livelihood variables (represented by percentage respondents) from all the sample communities shows deviation from normality ($p < 0.05$). The eco-livelihood issues identified by respondents in the sample communities are: Water hyacinth; Tree stump and other tree parts in the creeks; sewage and waste disposal; oil pollution; flooding; shallow river depth; seasonal changes associated with early rains; pollution from palm processing; lumbering; upstream dams; upstream fishing festival; and inland river dredging. Kendall's tau correlation coefficient has been carried out on these eco-livelihoods variable and show that there is generally a significant positive linear relationships p (2-tailed) < 0.01 in these eco-livelihood issues between all sample communities in the Study Area (See SPSS Output 7. 30). However, as shown in Table 7.20, there are differences between the Sample communities in the eco-livelihoods issues. These differences have appropriately been discussed.

Table 7. 20 Eco-livelihoods issues (Study Area)

		Eco-livelihood issues (percentage)											
Community	**Perception**	**HYACINTH**	**T.STUMP**	**WASTE**	**OIL.POL**	**FLOOD**	**DEPTH**	**CHANGES**	**PS.POL**	**LUMBER**	**UP.DAM**	**F.FESTIVAL**	**DREDGE**
Elebele (R)	Very bad	91	43	19	10	0	1	16	1	999	999	999	999
	Bad	5	49	0	0	12	10	6	0	999	999	999	999
	Neutral	0	0	0	0	1	0	0	0	999	999	999	999
	Good	1	0	0	0	1	0	0	0	999	999	999	999
	Very good	0	0	0	0	3	0	0	0	999	999	999	999
Otuoke (T)	Very bad	91	11	3	8	2	1	37	999	999	1	999	44
	Bad	2	23	0	0	15	2	6	999	999	0	999	9
	Neutral	0	0	0	0	5	0	0	999	999	0	999	1
	Good	0	0	0	0	2	0	0	999	999	0	999	2
	Very good	0	0	0	0	0	0	0	999	999	0	999	999
Otakeme (R)	Very bad	87	16	13	4	2	1	36	999	6	2	3	999
	Bad	7	3	0	1	6	6	3	999	6	0	1	999
	Neutral	2	0	0	0	2	0	2	999	1	0	0	999
	Good	0	0	0	0	7	0	0	999	0	0	0	999
	Very good	0	0	0	0	0	0	1	999	0	0	0	999
Otuogidi (T)	Very bad	74	3	6	21	0	999	9	999	2	2	2	69
	Bad	4	4	0	1	5	999	7	999	4	0	0	3
	Neutral	0	0	0	0	6	999	0	999	0	0	0	3
	Good	0	0	0	0	3	999	0	999	0	0	0	1
	Very good	0	0	0	0	0	999	0	999	0	0	0	0
0%		0 > 25 %		25 > 50				50 > 75			75 > 100		

HYACINTH – Water hyacinth; T.STUMP – Tree stump and other tree parts; WASTE – Sewage and waste disposal; OIL.POL – Oil pollution; FLOOD – flooding; DEPTH – River depth (Shallow); CHANGES – Seasonal changes (early rains); PS.POL – Pollution from palm processing; LUMBER – Lumbering; UP.DAM – Upstream dams; F.FESTIVAL – Fishing festival; DREDGE – Dredging issues; 999 – Not referred (the code used to imply that these eco-livelihood issues have not been identified by respondents)

Fishers in the Study Area regard water hyacinth as a significant constraint to fishing and navigation, as well as constituting nuisance value to the use of the rivers for domestic uses. Only 1% of the respondents have a contrary opinion that these weeds serve both as habitat for fish species and food for herbivorous fish. Water hyacinth is commonly called "Abiola" because these weeds were first seen in the Study Area in 1993 (the year Chief M. K. O. Abiola was the leading candidate in the annulled presidential election). The impact of water hyacinth does not show any significant difference across the sample communities based on respondents' TELK $p > 0.05$ (SPSS Output 7. 31).

Elsewhere, the invasion of non-indigenous water hyacinth (water hyacinth is native to South Africa), have been reported in Lake Kyoga, Uganda, in 1988 and in Lake Victoria in 1989. In addition, water hyacinth have become established along the Nile, and Lake Victoria, and as at 1995, these weeds covered about 80% of the shoreline of Lake Victoria (Twong, *et al.* 1995), and invaded the Ouémé River (Togo-Benin) since the early 1980s (Trebaol, 2003). Water hyacinth have been reported to have significant socioeconomic and environmental impacts, such as: disruption of recreational business; riverine transportation, fishing, and fish marketing activities; negative impacts on water quality for humans and livestock; depletion of available oxygen; and spread of waterborne diseases (Twong, *et al.* 1995; Njiru, *et al.* 2002; Balirwa, *et al.* 2003). Moreover, Fishers of Lake Victoria regard water hyacinth as a nuisance, because valuable fish species such as *C. gariepinus* and *P. aethiopicus,* hide under these weeds (Njiru, *et al.* 2002).

The impact of flooding in the Study Area ranges from those that consider it a blessing for fishing and those that regard flooding as a significant hazard to farming. A proportion of respondents consider flooding as an environmental issue of neutral impact based on the premise that the negative impact (on farming and other landed assets) and benefits (on fish abundance) cancel out.

Generally, flooding is good for the fishing business (Table 7. 12) in the Study Area. Similarly, flood disturbance processes play a key role in the functioning of riparian ecosystems and in the maintenance of biodiversity along river corridors (Hughes, *et al.* 2005). In addition, fish abundance and diversity are dependent on flood cycles and degree of inundation of the floodplains, as reported in the Lower Mekong Basin (Cambodia) (Van Zalinge, *et al.* 2003); Yangtze River floodplains (Chen, *et al.* 2003); and the Central Niger Delta (World Bank, 1995a; NDES, 1997; Sikoki and Otobotekere, 1999; Abam, 2001; Tamuno, 2001). SPSS Output 7. 31 show that there is no significant difference on the perception of the impacts of flooding between all the sample communities in the Study Area.

The construction of upstream dams (particularly the Kainji dam) has adversely affected fish abundance and the economic importance of fishing as a livelihood source. There is no significant difference on the perception of the impact of upstream dam on the Study Area, although Elebele respondents did not consider upstream dams as an eco-livelihood issue (See SPSS Output 7. 31 and Table 7. 20).

The Kainji dam is the major impoundment across the Niger River, which has significant environmental consequences, such as: the loss of biodiversity of the river-floodplain system as well as the destruction of the natural habitats of indigenous fish species. Fish abundance has been reported to decline from 90 000 metric tonnes to 45 000 metric tonnes (50% decline) in the Central Delta between 1968 (when the dam was built) and 1989, but species richness has remained unchanged (Laë, *et al.* 2003). In addition, the construction of Kainji Dam has been responsible for a 50% reduction in fish catches between Jebba and Lokoja between 1967 and 1969, as well as a 60% decline of fish catches in the Anambra basin (Otobo, 1977). Elsewhere, dam construction caused a decline in the ecological integrity of riparian system in the Upper Danube (Karr, 1991; Schiemer, *et al.* 2003), as well as adversely affecting the migratory and spawning grounds with associated negative effects on fisheries, recreational, domestic usage and the self-purification potential of the floodplain system (Schiemer, *et al.* 2003).

One of the major eco-livelihood issues that have constrained fishing and navigation are tree stumps and other tree parts that have fallen into the river. As well as being constraint to fishing in the rivers, boats have been reported to capsize over these obstructions with associated economic costs, (Figure 7. 1 show a tree stump across the Elebele / Otuoke Creek). There is no significant difference in the perception of the impact of tree stumps and tree parts in the Study Area (See SPSS Output 7. 31)

Waste and sewage disposal into the surface water is common practice in the Study Area, and has been identified by respondents of this survey as constituting a nuisance value. Residents are of the opinion that because the rivers flows and takes wastes away there is no significant health consequences of the disposal of sewage and waste into the rivers. There is no significant difference between communities in the perceptions of the eco-livelihood consequences of sewage and waste disposal in the Study Area (SPSS Output 7. 31). Similarly, sewage and solid waste disposal have been reported to constitute an environmental and health risk in communities in the Niger Delta (Akinluyi and Odeyemi, 1984; World Bank, 1995a). Therefore, if the present volume of solid waste and sewage increases as human population increases in the Kolo Creek, this may eventually constitute a health risk. Consequently, alternative safe options for solid waste and sewage management are an urgent necessity in the Study Area.

Furthermore, the Study Area has experienced: pollution from crude oil; seasonal changes associated with surface run-off during the early rainy season; and effluent from palm processing (Table 7. 20). There is no significant difference between communities in the perception of the impact of these eco-livelihood issues in the Study Area based on TELK of respondents (see SPSS Output 7. 31). However, pollution from palm processing has been acknowledged as an eco-livelihood issue only in Elebele. This does not imply that pollution from palm processing does not occur in the other three sample communities; it may be because palm processing is a seasonal livelihood source in the Study Area (see Table 7. 10). Hence, may have been ignored as an eco-livelihood issue in the other three sample communities. Pollution from crude oil has been associated with the Study Area since 1968 when crude oil was first discovered. However, surface water pollution from crude oil has not occurred in the Study Area in recent times (the last pollution was recorded based on TELK was mid 1980s).

Lumbering is one of the means of livelihood in the Study Area (See Table 7. 9). Lumbering has been considered an eco-livelihood issue of concern in the Study Area, and there is no significant difference between communities on the TELK of residents on this issue (see SPSS Output 7. 31). On the contrary, respondents in communities along the Elebele / Otuoke Creek do not consider lumbering an eco-livelihood issue of any concern. Nevertheless, Floating logs have a negative impact on fishing and compound the effect of water hyacinth by obstructing river flow, thereby restricting fishing grounds.

Fishing and navigation have severely been affected by shallow depth of the rivers in the Study Area. Shallow depth has not being considered an eco-livelihood issue of significance in Otuogidi, this may be as a result that a considerable section of the Kolo Creek within Otuogidi community has been dredged; hence the river depth has been increased in comparison to other sample communities. Generally, there is no significant difference between the consequences of shallow creeks among respondents from Elebele, Otuoke and Otakeme based on TELK (See SPSS Output 7. 31).

SPSS Output 7. 30 Relationship between the eco-livelihoods issues (Study Area)

Correlations

			Eco-livelihood issues (Elebele)	Eco-livelihood issues (Otuoke)	Eco-livelihood issues (Otakeme)	Eco-livelihood issues (Otuogidi)
Kendall's tau_b	Eco-livelihood issues (Elebele)	Correlation Coefficient	1.000	.821**	.690**	.633**
		Sig. (2-tailed)	.	.000	.000	.000
		N	40	35	35	30
	Eco-livelihood issues (Otuoke)	Correlation Coefficient	.821**	1.000	.801**	.692**
		Sig. (2-tailed)	.000	.	.000	.000
		N	35	45	40	40
	Eco-livelihood issues (Otakeme)	Correlation Coefficient	.690**	.801**	1.000	.614**
		Sig. (2-tailed)	.000	.000	.	.000
		N	35	40	50	45
	Eco-livelihood issues (Otuogidi)	Correlation Coefficient	.633**	.692**	.614**	1.000
		Sig. (2-tailed)	.000	.000	.000	.
		N	30	40	45	50

**. Correlation is significant at the .01 level (2-tailed).

SPSS Output 7. 31 Kruskal Wallis Test on eco-livelihoods issues (Study Area)

Test Statistics [a,b]

	Water hyacinth and other water weeds	Tree stump and other tree parts	Sewage and waste disposal	Oil Pollution	Flooding	River depth (Shallow)	Seasonal changes and early rains	Lumbering	Upstream Dam	Fishing festival	Dredging
Chi-Square	.536	1.361	.058	.600	1.839	.026	.571	.613	.031	.413	.011
df	3	3	3	3	3	2	3	1	2	1	1
Asymp. Sig.	.911	.715	.996	.896	.606	.987	.903	.434	.985	.521	.916
Exact Sig.	.918	.701	1.000	.948	.632	1.000	.914	.444	1.000	.722	.968
Point Probability	.001	.017	.129	.034	.000	.080	.002	.079	.275	.278	.071

a. Kruskal Wallis Test

b. Grouping Variable: Sample Communities

Communities upstream of Otakeme (See Figure 6.4) organise an annual fishing festival in May; these festivals have been considered to significantly affect fish abundance and diversity as well as increasing turbidity that affects the usability of the Kolo Creek, particularly during the festival and for about three months afterwards. Temporal migration of fish species from Otakeme fishing grounds due to the fishing festival has been considered an eco-livelihoods issue of concern. There is no significant difference between communities in the environmental consequences of the impact of fishing festival in the Kolo Creek based on TELK (SPSS Output 7. 31). However, the fishing festival has been considered responsible for temporary increases in fish catch in Otakeme during the early rainy seasons which is a deviation from the pattern in other communities (see Table 7. 11).

Inland river dredging has been carried out in Otuoke (T) and Otuogidi (T) and has been considered to have a wide range of eco-livelihood consequences. A majority of the respondents consider dredging an issue of significant hazard (Table 7. 20). There is no significant difference in the eco-livelihoods consequence of inland river dredging based on the TELK of respondents in the Test communities (SPSS Output 7. 31).

Dredging made the source of drinking water non-potable and non-usable for domestic purposes (see Table 7. 10) in Otuoke (T) and Otuogidi (T) during the dredging projects. The increased turbidity resulted in massive fish death and presently water snails have been reported to be extinct along the Otuogidi section of the Kolo Creek after the dredging projects (water snails serve as a protein source and income earner in the Study Area). In addition, the usage of the river for navigational and commercial purposes was adversely affected during the dredging project phase. Similarly, about 200 communities in the Niger Delta opposed the dredging of the lower Niger River based on fears of associated environmental and livelihoods consequences of inland river dredging (Olaniyi, 2003). However, the benefits of dredging have been experienced due to the economic “boom” during the dredging project as well as direct financial benefits to those that were employed by the dredging companies. Furthermore landlords (landowners whose land has been affected by the dredging projects) were financially compensated by the companies. Despite the benefits from inland river dredging, dredging is generally perceived to be of significant eco-livelihood consequence in the Study Area. Chapter 8 contains a detailed discussion of inland river dredging as an eco-livelihood issue in the Study Area.

7. 5 Chapter summary

The sampling criteria of respondents and the baseline scenario of the Study Area have been analysed. The analyses of the baseline scenario in the sample communities were based on the

TK of respondents and the TELK of fishers. The parameters used in understanding the baseline scenario of the Study Area are: livelihood options of respondents; level of dependence of residents of sample communities on CPRs; river usage; fishing as livelihood source; fishery as a resource base (using fish diversity, abundance and commercial value of fish species); trends in fishery and fishing; and eco-livelihood issues that have occurred in the Study Area.

The Gender and age range of respondents has been shown to be statistically similar to the Nigeria 1991 census results, and about 35% of the respondents have been resident in the Study Area for a minimum of 35 years. There is a low educational level (93% of the respondent have a maximum of secondary school certificate). In addition the livelihood profile of the Study Area show a strong dependence on CPR (47% of the respondents are strongly dependent on surface water resource for their livelihoods). Generally, fishing is a major livelihoods source in the Study Area.

Surface water is used for a variety of purposes such as: fishing; drinking and domestic use; transportation and commerce; sand mining; lumbering; sewage and waste disposal; discharge of palm processing effluent; recreational purposes; fishing festival and irrigational purposes. There is no significant difference in river usage between communities in the Study Area except with respect to sewage and waste disposal, and irrigational purposes. Despite these differences, there is specifically no significant difference in the pressures humans (represented by river usage) may have impacted on the surface waters in the Study Area.

In addition, TELK has been used to identify favourable and non-favourable fishing seasons. The flood recession and early rainy seasons are the most favourable fishing seasons, while the rainy and flood seasons are the most unfavourable fishing seasons in the Study Area. The TELK of fishers shows that fishery is under threat from human induced factors, which may have affected the economic importance of fishing. Presently, *Alestes spp*, *Chitarinus spp*, *Tilapia spp*, and *Distichodus spp* are the most abundant fish species in the Study Area, while *Gymnarchus niloticus, Clarias spp,* and *Heterotis niloticus* are the species of the highest commercial importance in the Study Area.

Eco-livelihood issues of concern that have been identified to be associated with the Kolo Creek are: invasion of water hyacinth; tree stumps and other tree parts; sewage and waste disposal; crude oil pollution; flooding; shallow depth of the creeks; seasonal changes (early rains); pollution from palm processing; construction of upstream dams; upstream fishing festival (Kolo Creek) and dredging (only in Otuoke (T) and Otuogidi (T) communities). There is no significant difference based on the TELK of respondents from different communities in terms of the eco-livelihood issues in the Study Area except the impacts of inland river dredging and the upstream fishing festivals. The assessment of the eco-livelihoods impacts of inland river dredging have been presented and discussed in the light of the baseline scenario.

Chapter 8 Eco-livelihood assessment of dredging

8. 1 Background

TELK and expertise of local fishers have been explored in the ecological sampling in the Study Area. The ecological sampling, carried out in 2004, represents three of the five fishing seasons: dry season (February), early rains (April) and rainy season (June and July), such as to represent seasonal fish variation in the Study Area. Fish productivity and yield of floodplains are dependent on seasonal flood cycles that are highly variable between localities. Large floods provides extensive opportunities for fish feeding and growth (Hoggarth, 1999). Flooding has been reported as one of the natural hazards associated with the Central Niger Delta (World Bank, 1995a; Abam, 2001; Tamuno, 2001), and the magnitude and duration of flooding in the Central Delta is quite variable but usually about three months in duration (Tamuno, *et al.* 2003b). Therefore, the seasonal variation of fish catch, fish abundance, and diversity in the Central Delta may be dependent on the magnitude of annual flooding.

The social survey has been used to also explore the TK and TELK of respondents to understand the eco-livelihood (using fish as indicator) consequences of inland river dredging in Otuoke (T) and Otuogidi (T) communities. In addition, the social survey has been used to understand the mitigation preferences of respondents and to test the reliability of the TK of respondents based on information from the dredging companies.

Statistical analyses of the results from the ecological survey have been used to compare: Test (Otuoke and Otuogidi), and Reference (Elebele and Otakeme) communities; between Reference communities; and between Test communities. The comparison between Test and Reference communities is for the purpose of establishing the eco-livelihoods consequences of inland river dredging in the Study Area and to demonstrate the reliability of the assessment indicators. The comparison between Test communities and between Reference communities has been used to demonstrate the reliability of the assessment indicator. Furthermore, the ecological survey results have been presented in the light of the baseline scenario. Box 7. 1 contains a summary of the statistical analyses that has been used in the assessment of the eco-livelihood impacts of dredging in the Study Area.

Fish species have been used as an indicator of the ecological impact of inland dredging that may impact livelihoods in the Study Area. The parameters used in the context of this research are fish abundance, diversity and trophic structure. The metrics used are: fish catch per unit effort (CPUE) and fish catch per unit hour (CPUH) for fish abundance; fish species diversity per sampling day for species diversity; and percentage – omnivores, carnivores; herbivores, invertivores and detritivores per sampling day for trophic structure. The trophic characteristics have been analysed based on percentage of: omnivores, herbivores; carnivores; Invertivores and detritivores per sampling day from all sampling communities.

8. 2 The dredging projects

Global Seaways (a dredging contracting company) was responsible for the dredging project that was carried out in the Otuoke section of the Elebele / Otuoke Creek, while the Ballast Ham dredging company was responsible for the dredging of the Otuogidi section of the Kolo Creek. It was difficult obtaining specific information from the dredging companies about the respective projects. The information about the projects has been given by the Operations Managers of both companies: Global Seaways via face-to-face discussion; and Ballast Ham dredging via email correspondence.

About 10, 000 m3 of sand has been dredged along the Otuoke section of the Elebele / Otuoke Creek and has been stock-piled (dump-site opposite the Otuoke community) for the purpose of land reclamation for road construction. Figure 8.1 shows the author's Interpreter at Otuoke in front of the stock-pile of dredged sand at Otuoke). The sand is gradually used for road construction as planned. The duration of the dredging project was about six months (between June and December 2002), which was longer than anticipated. One of the reasons for the delay in the project was the disruption of the project by residents of the host community. This disruption of the project was due to the un-resolution of their demands (these demands are reflected in the mitigation preferences of respondents of Otuoke in Table 8. 2) of the host community on the dredging company. As a compromise, Global Seaways gave temporary employment to 12 unskilled residents (all males who worked only during the project phase) from the host community, that were paid between ₦10, 000 and ₦15, 000 ($76.63 and $114.94) per month, this wage range has been considered barely palliative to the host community (as at 2002, the Nigerian national minimum wage was ₦7, 500 - $57.47),

In addition, compensation was paid to the landlords whose land was affected by the project. Some dredged sand was also allocated for the host community's use as a community relations gesture. Despite the company's concessions to the community, the Operations Manager (Global Seaways) is of the opinion that it would have been preferable for the dredging project to have been executed in areas of little, or if possible no, community influence.

There is technically no best dredging season in the Niger Delta, because the dredging impacts are equal across all seasons. However, the Operations Manager (Global Seaways) was of the opinion that the obvious impacts of the dredging projects on the Otuoke community are:

- Increased turbidity during the project execution that resulted in the reduction of available dissolved oxygen;
- The resultant increased turbidity reduced the usage value of the surface water for domestic use during the projects;
- The dump-site became non-available for agricultural purpose, hence there was a reduction of available farmland;
- Loss of land due to erosion of the river bank and impact from the dredging project;
- Navigational constraints as a result of the buried dredging pipes; and
- Negative impact on fishery and other aquatic biota (though qualitative).

Very limited information has been given about the dredging operations on the Otuogidi sections of the Kolo Creek. An estimated 1.2 cubic million metre of sand were dredged from Otuogidi section of the Kolo Creek and stock-piled on farmland (Figure 8.2 shows a section of the stock-pile of dredged sand behind one of the fishers involved in the ecological survey). The duration of the project was about 18 months between 1999 and 2000; the purpose of the dredging was for road construction, and the sand is continually used for the project purpose. The relationship between the community and community has been described by the Operations Manager of Ballast Ham dredging as “generally fair”.

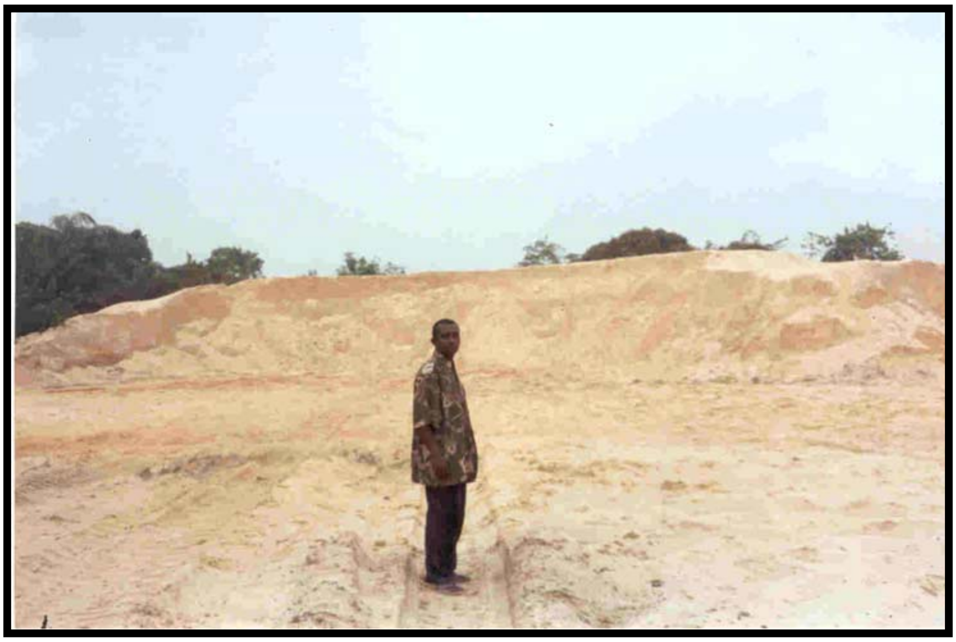


Figure 8. 1 Stock-pile of dredged sand at Otuoke

Figure 8. 2 Stock-pile of dredged sand at Otuogidi

The dredging of both creeks was carried out at the convenience (technical and economic efficiency) of the dredging companies rather than consideration for environmental or livelihoods issues. The dredging approach adopted for these projects were not obtained from the respective dredging companies. However, based on descriptions from residents of the Test communities the dredger used is most likely hydraulic pipeline dredgers (suction dredger). Similarly, Ohimain (2004), reported that the hydraulic pipeline dredgers are commonly used for land reclamation in the Central Niger.

8.2. 1 The dredging projects based on TK

The knowledge and experience TK of respondents has been accessed via the questionnaire survey in Otuoke (T) and Otuogidi (T) to understand the eco-livelihoods consequences of inland river dredging (using fish as indicators). This has been used to test whether TK and TELK are valid and reliable tools for building environmental baseline data.

The Operations Manager of Ham Dredging stated that the dredging project was carried out between 1999 and 2000. Figure 8. 3 shows that: 44.4% of the respondents of Otuogidi have a very good knowledge (very precise) of the year the dredging project was carried out (1999-2000); 35.2% have good knowledge (precise, but not exact) of the year of dredging (between 1999 and 2000); 10.2% of the respondent have a fair knowledge of the year of dredging (1998, between 2000 to 2001 and 2001); and 10.2% of the respondents do not have any idea or have forgotten when the project was carried out.

Figure 8. 3 Year of dredging based on knowledge of Otuogidi respondents

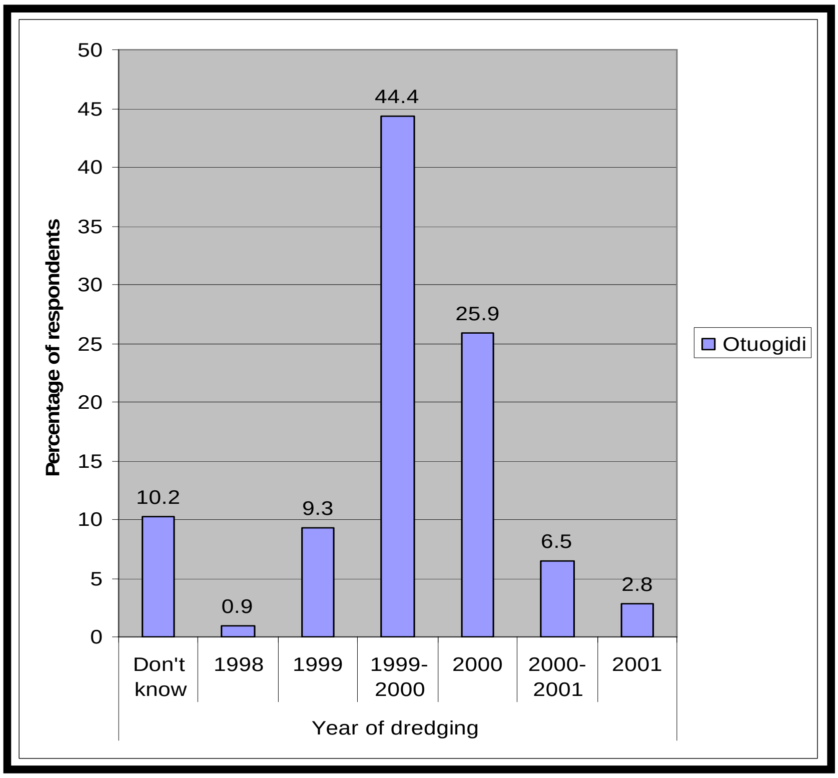
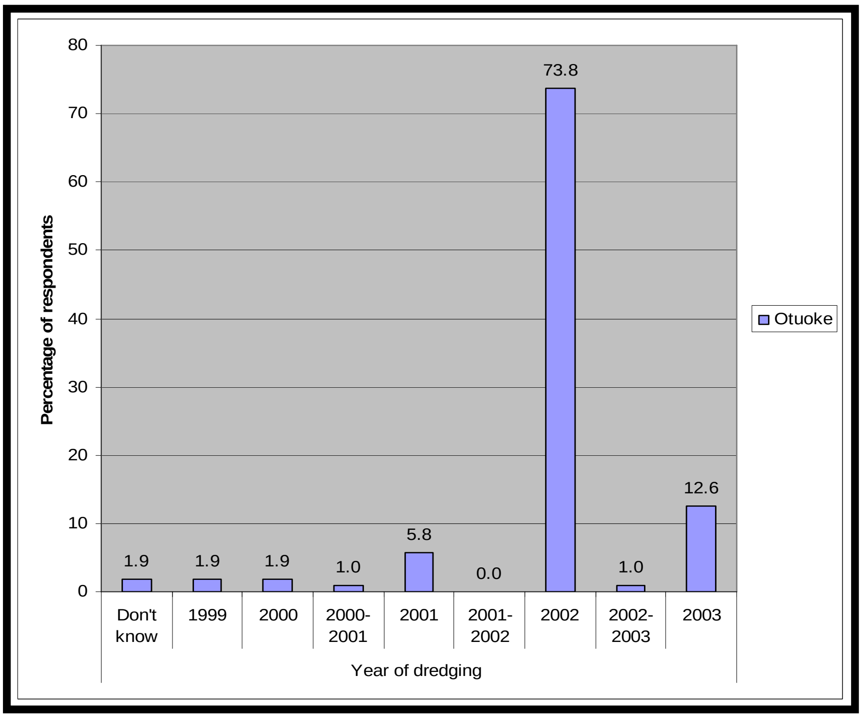


Figure 8. 4 Year of dredging based on knowledge of Otuoke respondents



Similar comparison has been made between the year stated by the Operations Manager of Global Seaways that the project was executed and the knowledge of respondents in Otuoke. Figure 8. 4 shows that 73.8% have a very good knowledge of the year of dredging (2002); 6.8% have a good knowledge of the year of dredging (2001; and between 2002 and 2003); 14.5% have a fair knowledge of the year of dredging (2000 and 2003); 1.9% have a poor knowledge of the year of dredging (1999); and 1.9% cannot remember or are not aware of the year of dredging.

The duration of the dredging projects as stated by the respective Operations Managers have been compared to the knowledge of residents. Figure 8. 5 shows that in Otuogidi: 12.1% of the respondents have a very good knowledge of the duration of dredging (those that of the opinion that the dredging project was executed between 17 and 20 months); 17.9% of the respondents have good knowledge of the duration of the project (13 to 16 months and 21 to 24 months); 41.7% of the residents have a fair knowledge about the duration of the dredging project (9 to 12 months); 18.5% have poor knowledge of the duration of the dredging (5 to 8 months); and 0.9% of the residents have very poor knowledge about the duration of the dredging (1 to 4 months); 9.3% do not know or cannot remember the duration of the dredging project (similarly 2.8% of the resident have been resident in Otuogidi for less than 5 years).

Figure 8. 6 shows that: 27.2% of Otuoke respondents have a very good knowledge about the duration of the dredging project (between 5 and 6 months); 53.5% have good knowledge of the duration of the dredging project (between 3 and 4 and 7 and 8 months); 7.7% of the respondents have a fair knowledge of the duration of the dredging; 2.9% have poor knowledge of the dredging duration; and 8.7% of the residents do not have an idea of the duration of dredging or cannot remember the duration. Conversely, all respondents from Otuoke and Otuogidi know the location of the dredged sand stock-pile, which was at the time of the field work a landmark in both Test communities (see Figure 8.1 and Figure 8.2 respectively for the stock-pile of dredged sand). Events and issues that have been part of communal life are clearly recognised by residents.

The trend in the validity of the knowledge of residents of the Study Area on the time and duration of the respective dredging projects are dependent on the time between dredging and time of the survey. In both communities the dredging projects were recent, although one of the projects was carried out between 1999 and 2000, and the other in 2002. There was about two years difference between the projects, which could explain why 73.8% of Otuoke residents had a very good knowledge about the time of the dredging project compared a significantly fewer residents of Otuogidi (44.4%). It is likely that detailed information about the timing and duration may deteriorate over a longer period of time. In addition, TELK is a factor that is dependent on the duration of residency of informants in the Study Area.

Figure 8. 5 Duration of dredging based on knowledge of Otuogidi respondents

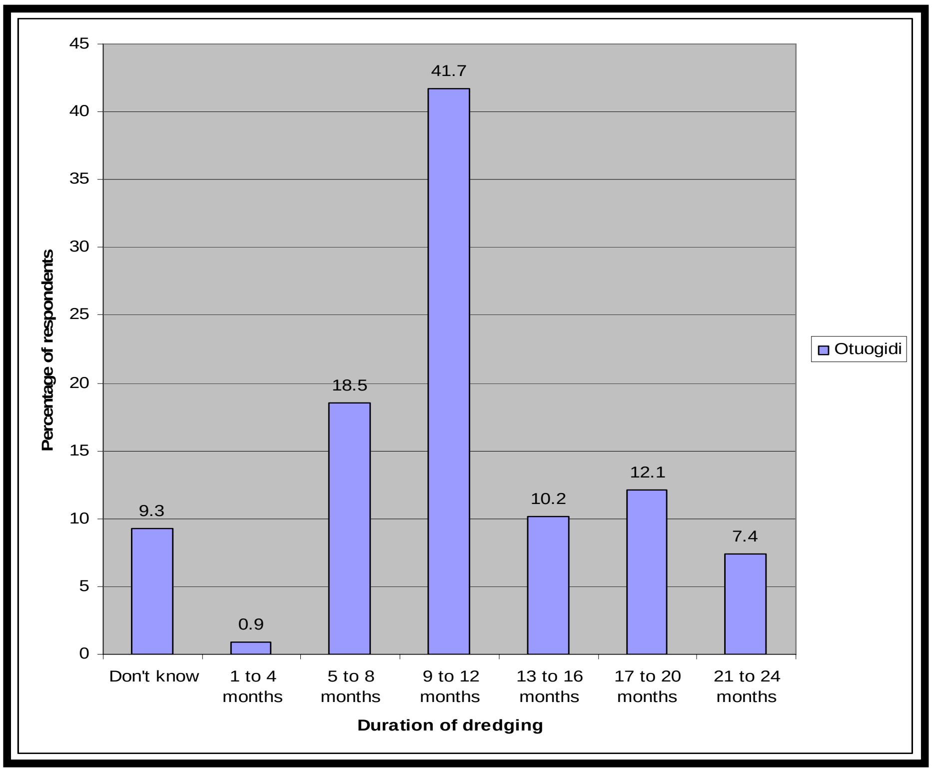
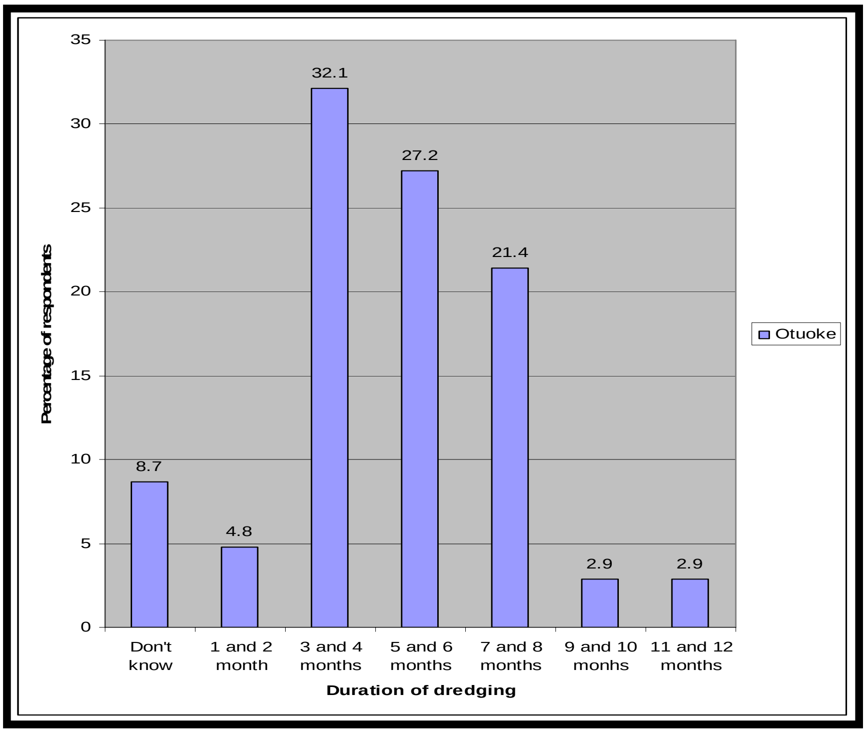


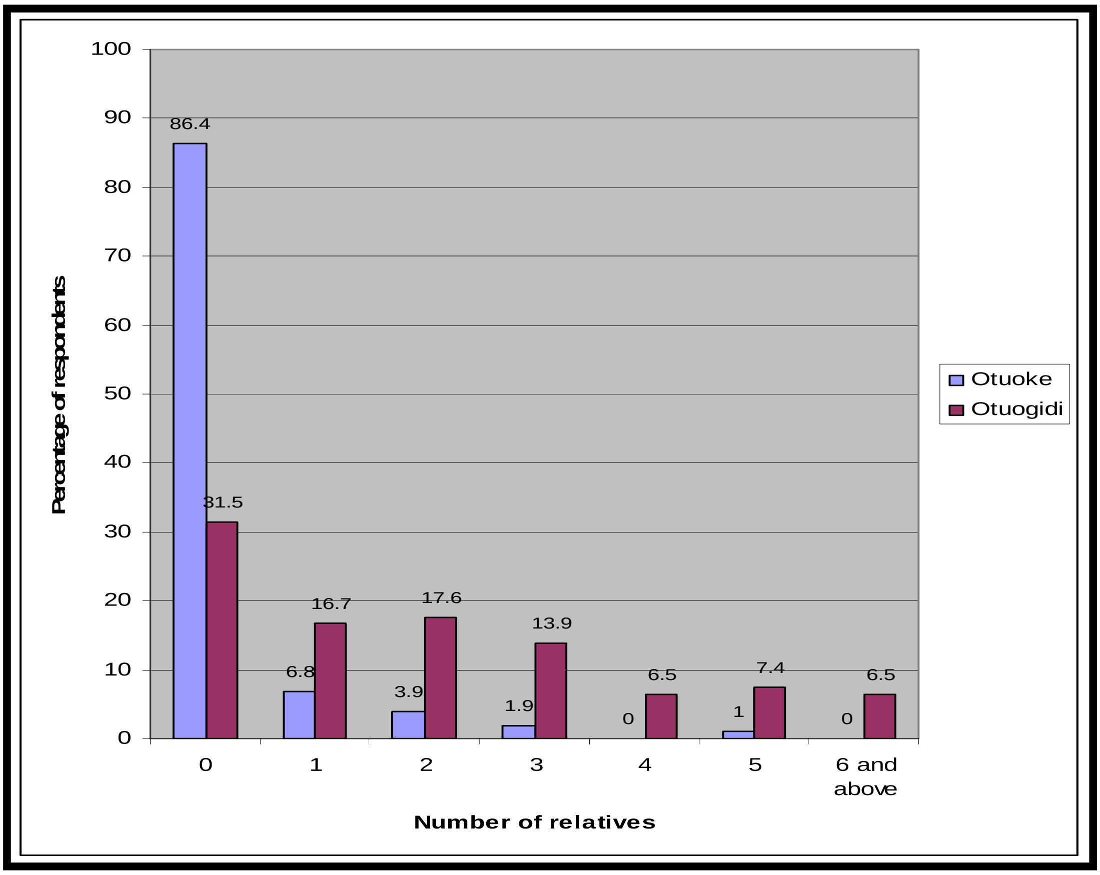
Figure 8. 6 Duration of dredging based on the knowledge of Otuoke respondents



The knowledge of respondents about the respective dredging projects have been analysed in the light of community involvement. 83.5% of Otuoke (T) residents compared to 19.4% of Otuogidi residents do not know the name of the companies that carried out the dredging project in the Otuoke Section of the Elebele / Otuoke Creek and Otuogidi (T) section of the Kolo Creek. While 16.5% compared to 80.6% of residents of the Otuoke and Otuogidi communities know the names of the respective dredging companies. Furthermore, 70.4% (Otuogidi) and 2.7% (Otuoke) of the respondents were employed by the dredging companies during the respective project phase. In addition, 68.5% (Otuogidi) and 13.6% (Otuoke) of the respondents have relatives that had worked with the respective dredging companies.

There is a higher involvement of residents from Otuogidi in the dredging project than Otuoke. In addition, there are more relatives of Otuogidi respondents that have been employed by the dredging company than Otuoke. The implication of these results is that community involvement in the dredging projects has a positive relationship with community knowledge about the project as well as improving community relations. The Ballast Ham Dredging Operation Manager categorised community relations as fair compared to the hostile host community by his Global Seaways counterpart. Similarly, there is strong positive linear relationship between the educational qualification of respondents in Otuoke (T) and Otuogidi (T) ($\tau = 1.0$ p 2-tailed < 0.01), this implies that the TELK is independent of educational qualification (see Appendix 54). No woman has been employed by either dredging company, and one respondent argues that "*dredging is a man's business*", however the impact of dredging is "*everybody's business*" (it affects everybody irrespective of gender). The knowledge and experience of respondents from Otuoke (T) and Otuogidi (T) has been used to understand the livelihood (focused on fishing as livelihood source and fishery as a resource) consequences in the Study Area.

Figure 8. 7 Employment of respondents' relative by dredging company



8. 3 Livelihood assessment of dredging

The TK and TELK of respondents have been explored via the questionnaire survey to understand the livelihood consequences of the respective dredging projects in the Test communities. In addition the TK of respondents has been accessed to understand issues surrounding the dredging projects in the Test communities.

8.3. 1 Livelihood consequences of dredging

The impacts of inland river dredging on fishing and fisheries based on TELK of respondents from Otuogidi (T) and Otuoke (T) have been summarised in Table 8. 1. 88% and 92.2% of Otuogidi and Otuoke respondents respectively consider inland river dredging as very detrimental to fishing and fishery. Only, 7.4% and 3.9% of Otuogidi and Otuoke respondents are of the opinion that inland river dredging is of benefit to local fishing and fishery. A minority (4.6% and 3.9% of

Otuogidi and Otuoke respondent) consider inland river dredging as having no net impact on fishing and fishery.

Detrimental consequences of dredging on fishing have been associated with increased turbidity which may have resulted in migration of fish species away from traditional fishing grounds as well as destroying fish spawning and breeding grounds. In addition, the depth of the dredged sections poses an additional risk to fishers and other river users. As mentioned earlier (in section 6.3.3.1), a fisher drowned in the dredged section in January 2004. Furthermore, there is yet to be recovery from the physical destruction of the spawning grounds as well as species that have been pumped out of the dredged sections onto land. Similarly, in the USA, Brookes (1988), reported even after about 80 years after river channelisation, there has not been complete recovery in rivers.

Table 8. 1 Perceived impact of inland river dredging on fishery based on TELK

	Percentage respondents				
	Very good	**Good**	**Neutral**	**Bad**	**Very bad**
Otuoke	0.0	3.9	3.9	27.2	65.0
Otuogidi	0.9	6.5	4.6	6.5	81.5
Average	0.5	5.2	4.3	16.9	73.3

Key
0%
0 > 25%
25 > 50%
50 > 75%
> 75%

Benefits of dredging on fishing have been attributed to fact that the dredged sections are serving as appropriate breeding grounds for fish species and that the increased commercial activities during the dredging project have had a positive effect on fishing. In addition, compensation paid by the dredging companies has served as a source of investment for fishing and other livelihood sustaining ventures.

The proportion of the respondents that are of the opinion that there is no net gain or loss from dredging because the benefits highlighted above have been able to cancel the negative consequences. However, the predominant perception in the Test communities is that dredging has had and still has negatively affected fishing and fisheries. Therefore, a section of the fishers in Otuoke (T) and Otuogidi (T) are canvassing for compensation for loss of livelihood (fishing) as a result of dredging. Such a demand is not new, because Bray (1998), had advocated for monetary compensation for fishermen who earn their livelihoods from areas that have been affected by dredging. Section 8.4 contains the result of the ecological survey, which shows the eco-livelihood consequences of inland river dredging in the Test communities (using fish as indicators).

The K-S Test for normality of the perception of the impacts of inland river dredging using percentage of respondents from the respective Test communities show that there is a deviation from normality ($p < 0.05$). Appendix 55 contains the result of the Kendall tau correlation coefficient on the relationship between the TELK on impact of dredging on fishing, which shows a significant relationship between Otuoke (T) and Otuogidi (T) ($\tau = 0.889$, p < 2-tailed 0.05). In addition, the Kolmogorov-Smirnov Z Test shows that there is no significant difference in the perception on the impact of dredging on fishing and fisheries between the Test communities (SPSS Output 8. 1). These results imply that dredging is perceived to have a significant detrimental impact on fishing and fishery in the Kolo. Despite these impacts respondents of the Test communities have suggested options / measures that may reduce the localised impacts (mitigation preference) of inland river dredging. In addition, the season that the respective respondents have considered to be the best dredging seasons (season in which the localised impact of dredging will be minimal), have been accessed via the social survey.

SPSS Output 8. 1 K-S Z Test on impact of dredging on fishing (Study Area)

Test Statistics[a]

		Impact of dredging on fishery
Most Extreme Differences	Absolute	.400
	Positive	.400
	Negative	-.200
Kolmogorov-Smirnov Z		.632
Asymp. Sig. (2-tailed)		.819
Exact Sig. (2-tailed)		.810
Point Probability		.524

a. Grouping Variable: Test Communities

8.3. 2 Mitigation preferences based on TK

The mitigation preferences of residents of the Test communities to offset the negative impacts of dredging have been summarised in Table 8. 2. Provision of alternative water source, employment of residents of host communities (at least temporary, but preferably permanent employment positions); financial compensation for the detrimental consequences of dredging; provision of health facilities, and educational support (such as scholarship, provision of educational material, and construction of classroom blocks) constitute the major mitigation options advocated by the residents.

Table 8. 2 Mitigation preferences of respondents

	Percentage of respondent	
Mitigation option	**Otuoke**	**Otuogidi**
Water supply	97	98
Financial compensation	41	38
Employment	50	43
Educational support	8	16
Health services and electricity	35	51
Water hyacinth	4	1
Dredge to remove obstructions	1	0
Alternative source of sand	1	1
Duration	8	0
Location of dredging	1	0
Dredge along (rather than across) river	0	1
Participation	0	1
Road construction	0	11

Other mitigation options advocated by respondents of the Test communities are: removal of water hyacinth and obstructions in the rivers (such as tree stumps and other tree parts); dredging along river sections rather than at one single location; and road construction. 1% of respondents are of the opinion that an alternative source of sand would be the best option instead of inland river dredging for land reclamation. K-S Test for normality on these parameters shows a deviation from normality. The Kendall tau correlation coefficient shows (Appendix 56) a strong relationship on the mitigation options advocated by residents of both Test communities (τ = 0.486 p < 2-tailed 0.05). In addition Kolmogorov-Smirnov Test shows that statistically there is no significant difference on mitigation preference (SPSS Output 8. 2). This implies that there is a consensus of mitigation preferences between Otuoke (T) and Otuogidi (T) as shown in Table 8. 2. However, there are differences in preference of respondents. For example, the preference of Otuogidi respondents for road construction was because the sand dredged from the Otuogidi section of Kolo creek was used for construction of roads that did not pass through this community.

Seasons in which the impact of dredging on the Test communities would be less detrimental have been termed good dredging seasons and the rainy seasons are considered most favourable by respondents (See Figure 8.8**Error! Reference source not found.**). Rainy seasons have been preferred because an alternative source of water (rain water) is available during the project phase. Nevertheless, 46% and 40% of Otuoke and Otuogidi respondents are of the opinion that there is no period of the year when dredging would be suitable.

SPSS Output 8. 2 K-S Test of mitigation options (Study Area)

Test Statistics [a]

		Mitigation option(s)
Most Extreme Differences	Absolute	.154
	Positive	.154
	Negative	-.077
Kolmogorov-Smirnov Z		.392
Asymp. Sig. (2-tailed)		.998
Exact Sig. (2-tailed)		.991
Point Probability		.231

a. Grouping Variable: Test Communities

SPSS Output 8. 3 K-S Z Test on good dredging season (Study Area)

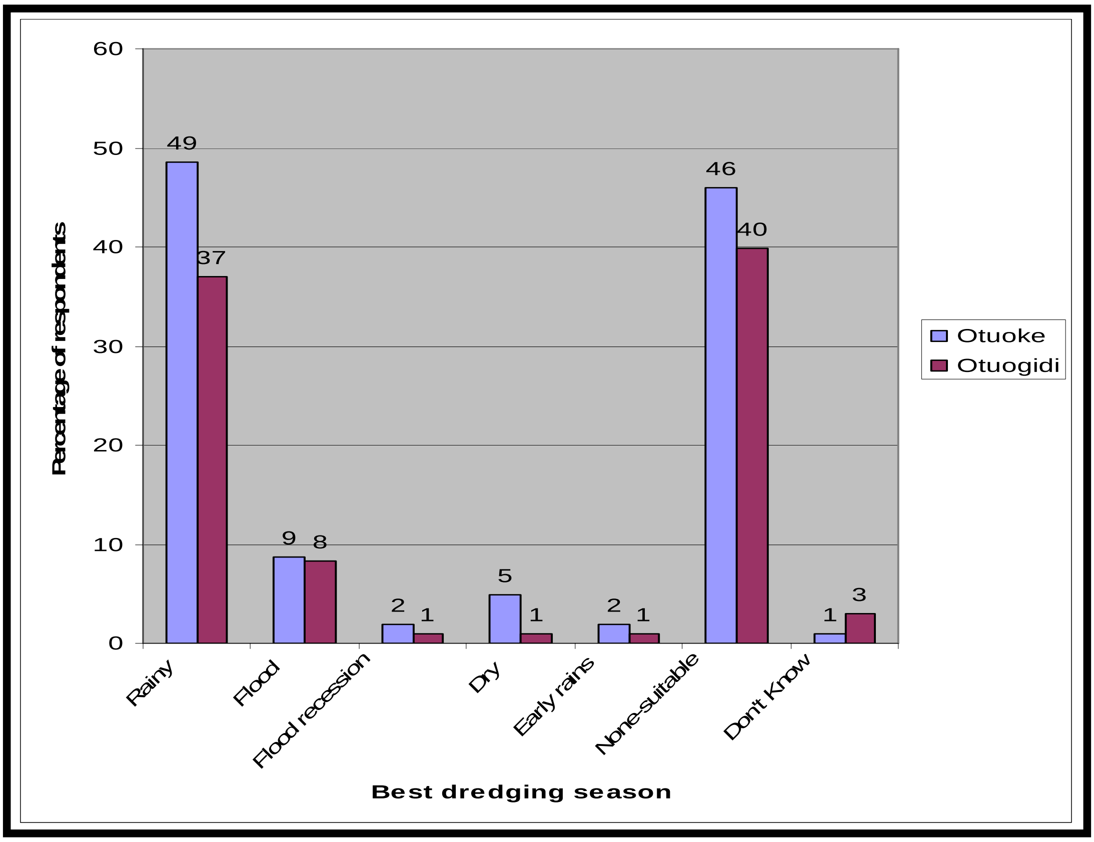
Test Statistics [a]

		Best dredging season
Most Extreme Differences	Absolute	.286
	Positive	.000
	Negative	-.286
Kolmogorov-Smirnov Z		.535
Asymp. Sig. (2-tailed)		.938
Exact Sig. (2-tailed)		.944
Point Probability		.479

a. Grouping Variable: Test Communities

The K-S Test for normality on percentage of respondents in the two Test communities on good dredging seasons show a deviation from normality. In addition, the Kolmogorov-Smirnov Test shows that there is no significant difference ($p > 0.05$) in good dredging season among Test communities. Generally, respondents in the Test communities are of the opinion that there is no suitable season for dredging, but for compromise, the rainy season has been recognised as the best dredging season in the Study Area, because the rains serve as alternative source of water for drinking and domestic use. In addition, the analyses of the results of the ecological survey have been used to further understand the eco-livelihood impacts of inland river dredging. These statistical analyses have been presented in section 8.4.

Figure 8. 8 Good dredging seasons based on TELK



8. 4 Ecological impacts of dredging

Approaches focused on people and their livelihoods provide a basis for proposing development projects that are equitable to all (particularly to those most at risk from the project impacts) (Coates, *et al.* 2003). Fishing has been a major livelihood component among the dominant ethnic groups that live in the Kutai and the Banjar swamps, East Kalimatan (Chokkalingam, 2005). Fish are also important livelihood sources in most rural communities in West Africa (Baran, 2000), and major sources of food and income for residents of the Amazon floodplains (Almeida, *et al.* 2002).

In addition, fish have been recognised as the single most important indicator for assessing the status of aquatic habitats (Schiemer, *et al.* 2003), and abundance and diversity of fish species have been successfully used in the evaluation of anthropogenic impact on the environment (Whitfield and Elliot, 2002). For example, a decline in fish catch between 1961 to 1972 in the Danube delta has been used as an indicator of the impact of dam construction (Balon and Holcík,1999).

8.4. 1 Fish community as an eco-livelihood indicator

The advantages of using fish as eco-indicators notwithstanding, the use of fish is presently less widely applied than physico-chemical indicators (Coates, *et al.* 2003). This research has explored an adaptive assessment approach, and fish have been used as eco-livelihood indicators. The choice of fish species has been based on the premise that fishing is one of the major livelihoods in the Study Area; hence any significant impacts on fishery resources (represented by impact on fish species) may result in livelihood consequences.

Table 8. 3 contain a summary of all fish species that have been caught and identified during the ecological survey. This shows that the Elebele / Otuoke Creek and the Kolo Creek contain a wide range of species (25 species in all), and that the species caught could be compared to the species identified by respondents from the Study Area (See Table 7. 13 and Table 7. 14) as the most abundant species in the Study Area. Appendix 57 contains a catalogue of all fish species that have been identified in the study. 51% of the fish species from the ecological survey have been identified by fishers in the Study Area as species of high abundance (see Table 7.13 and Table 7.14). Similarly, 54% and 57% or 7 and 8 species that have been recorded from the ecological survey have been recorded as species commonly caught by Central Niger Delta fishers from inland freshwater rivers, and caught by fishers from inland freshwater rivers in 1991 and 1992 respectively (see Table 6.6 and Table 6.7).

In the context of this research, fish species abundance (Catch per unit effort – CPUE and catch per unit hour – CPUH) and species diversity (number of different species per sampling day), as well as trophic characteristics (percentage of different trophic category: Omnivores, herbivores, carnivores; detritivores and invertivores) have been used to assess the eco-livelihood impacts of inland river dredging in the Study Area. Similarly, species richness, species diversity and trophic structure are among the ecological metrics that have successfully been used in defining the status of ecological systems (Karr and Chu, 1999; Dale and Beyeler, 2001; Welcomme, 2001).

Table 8. 3 Summary of species caught during the ecological survey

Local name	Scientific name	Community
Okolokolo	*Alestes spp*	Elebele, Otuoke, Otakeme, Otuogidi
Eferere	*Distichodus spp*	Elebele, Otuoke, Otakeme, Otuogidi
Ogbolokaka	*Heterotis niloticus*	Elebele, Otuoke, Otakeme, Otuogidi
Epete / Aporu	*Citharinus spp*	Elebele, Otuoke, Otakeme, Otuogidi
Ewela	*Tilapia spp*	Elebele, Otuoke, Otakeme, Otuogidi
Okpoki / Opogoin	*Synodontis spp*	Elebele, Otuoke, Otakeme, Otuogidi
Ogulo / Egbo	*Chrysichthys nigrodigitatus*	Elebele, Otuoke, Otakeme, Otuogidi
Ebede	*Petrocephalus spp*	Elebele, Otakeme, Otuogidi
Ebhe	*Marcusenius spp*	Elebele, Otuoke, Otakeme
Olari	*Pareutropius sp*	Elebele, Otuoke, Otakeme
Ohabh	*Hydrocynus linaetus*	Elebele, Otuogidi
Ogbuda	*Bagrus spp*	Otakeme, Otuogidi
Apamu / Isongo	*Pantodon bucholzi*	Elebele
Okpokpozi	*Notopterus chitala*	Elebele
Edegere	*Micralestes spp*	Elebele
Ibutu	*Labeo sp*	Otuoke
Ebelem	*Xenomystus nigri*	Otakeme
Ogbolomo-obele	*Polycentropsis abbreviate*	Otakeme
Ofuroma	*Mugil cephalus*	Otuogidi
Ekwei	*Phago loricatus*	Otuogidi
Oduro / Ofio	*Bagrus spp*	Otuogidi
Baracuda	*Acestrorhynchus sp*	Otuogidi
Okolobosogoin	*Ichthyborus monody*	Otuogidi
Oza	*Raiamas senegalensis*	Otuogidi
Orim	*Hepsetus odoe*	Otuogidi

8.4.1. 1 Fish species diversity and abundance

A summary (average of each species and variable) of the ecological survey has been presented in Table 8. 4 (Appendix 58 to Appendix 61 shows individual summaries for the six sampling days for each community). The survey result from Otakeme have been divided into three: a general average (represented by all scenarios); rainy season that have been affected by the fishing festival; and non-impacted – dry and early rainy season). The values in Table 8. 4 specifically represent average fish species and metrics of the six sampling days for each sample community (see Table 6. 9 for a summary of the ecological survey). The result in Table 8.4 has been used specifically to test the ecological impact of inland river dredging that may be of livelihoods significance in the Study Area. This has been done by statistical comparison of fish abundance and diversity per sampling day in the Test and Reference communities. Note that there some differences between the lists of fish species shown in Tables 7.15 and 8.4. A significant reason for this is that fishers in the Study Area use a variety of fishing techniques, but the ecological survey only used one method. This limited the range of fish species caught during the survey.

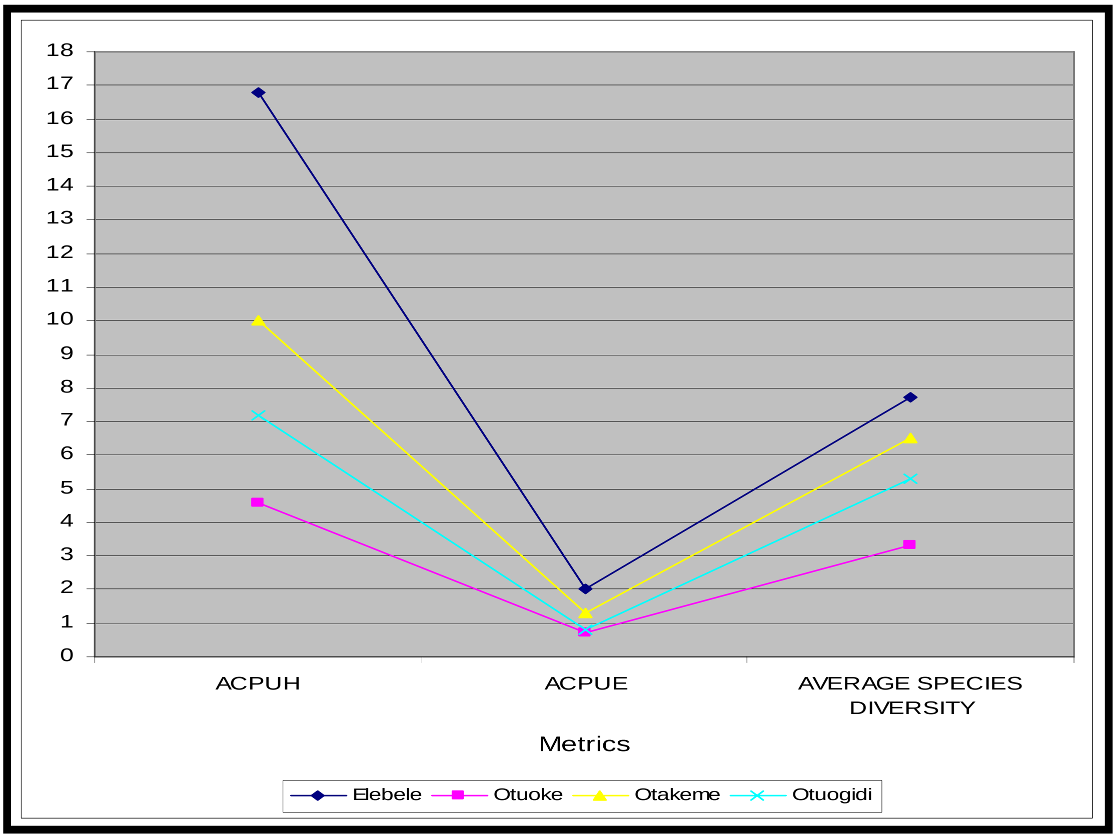
Table 8. 4 Summary of ecological survey (Fish abundance and diversity)

	FISH SPECIES (Scientific and Native names)																													
	Aletes spp	*Distichodus spp*	*Heterotis niloticus*	*Citharinus spp*	*Tilapia spp*	*Bagrus spp*	*Mugil cephalus*	*Micralestes spp*	*Petrocephalus spp.*	*Marcusenius spp*	*Pareutropius sp*	*Phago loricatus*	*Synodontis spp*	*Chrysichthys nigrodigitatus*	*Hydrocynus linaetus*	*Pantodon bucholzi*	*Notopterus chitala*	*Bagrus spp*	*Acestrorhynchus sp.*	*Labeo sp*	*Ichthyborus monodi.*	*Xenomystus nigri (Pez cuchillo Africano)*	*Raiamas senegalensis*	*Hepsetus odoe*	*Polycentropsis abbreviata*						
Community	OKOLOKOLO	EFERERE	OGBOLOKA	EPETE / APORU	EWELA	OGBUDA	OFUROMA	EDEGERE	EBEDE	EBHE	OLARI	EKWEI	OKPOKI / OPOGOIN	OGULO / EGBO	OHABH	APAMU / ISONGO	OKPOKOZI	ODURO / OFIO	BARACUDA	IGBUTU	OKOLOBOSIGOIN	EBELEM	OZA	ORIM	OGBOLOMO-OBELE	AVERAGE FISH CATCH	AVERAGE ATTEMPT	AVERAGE FISHING DURATION (MIN.)	AVERAGE CATCH PER UNIT HOUR	AVERAGE CATCH PER UNIT EFFORT	AVERAGE SPECIES DIVERSITY
A	23.0	0.5	0.3	8.3	0.5	0.0	0.0	14.2	18.5	8.7	6.0	0.0	0.5	2.5	0.0	0.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.3	36.2	294.5	16.8	2.0	7.7
B	6.7	0.5	0.0	17.2	0.3	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	26.5	35.8	338.0	4.6	0.7	3.3
C	7.9	1.4	0.0	26.6	3.4	0.4	0.0	0.0	3.4	4.3	2.5	0.0	1.6	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.1	54.9	42.5	372.5	10.5	1.4	6.5
C-X	9.3	1.8	0.0	34.5	4.8	0.5	0.0	0.0	2.0	5.0	3.5	0.0	2.3	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.5	39.8	298.5	13.6	1.7	6.8
C-Y	4.5	0.5	0.0	7.0	0.0	0.0	0.0	0.0	7.0	2.5	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.5	26.0	49.5	557.5	2.7	0.5	6.0
D	10.3	0.5	0.0	14.0	0.2	0.7	0.5	0.0	0.3	0.0	0.0	0.2	0.3	2.7	0.3	0.0	0.0	0.5	0.2	0.0	0.2	0.0	0.2	0.2	0.0	31.2	44.5	325.0	7.2	0.8	5.3

Key: A – Elebele (R); B – Otuoke (T); C – Otakeme (R); C-X – Otakeme (Less fishing festival effects); C-Y – Otakeme (Affected by fishing festival); D – Otuogidi (T)

Average catch per unit effort (ACPUE); average catch per unit hour (ACPUH) and average species diversity (average fish species / type in the fish catch) per sampling day have been compared between the Test communities (Otuoke and Otuogidi) and reference communities (Elebele and Otakeme). The qualitative comparison of fish abundance and diversity shows that the reference communities show more species abundance and diversity than the Test communities (see Figure 8. 9). The differences in fish species abundance and diversity have been attributed to the impact of inland river dredging in the Study Area. Graphical presentations of human induced impacts on ecological systems provide a better representation of impact than purely statistical tools, based on the premise that graphs are clear and easily comprehensible by all environmental stakeholders (Augspurger, 1996; Karr and Chu, 1999). However, statistical tools can show the significance of impacts which is required in the environmental impact decision making process.

Figure 8. 9 Qualitative comparisons of Test and Reference communities



Furthermore, the average of the indices shows that there are differences between the Test and Reference communities: there is a difference of 73% and 28% in ACPUH in the Elebele / Otuoke Creek and the Kolo Creek respectively; a difference of 65% and 38% in ACPUE in the Elebele / Otuoke Creek and Kolo Creek respectively; and 57% and 18% in average species diversity in the

Elebele / Otuoke Creek and Kolo Creek respectively. In addition, the differences between the Test and Reference communities across Elebele / Otuoke Creek and Kolo Creek are: 57%, 60% and 31% in ACPUH, ACPUE, and species diversity respective (Elebele to Otuogidi); 54%, 46% and 49% in ACPUH, ACPUE and species diversity respectively (Otakeme to Otuoke).

Similarly, land reclamation resulted in a decline in fish catches and affected the fish recruitment rate (rate of fish production), as well as destroyed the spawning grounds of some resident fish species. For example, in China, reclamation of 80,000 hectares and 160,000 of land from Lake Poyang, and Lake Dongting, resulted in 50% of fish spawning grounds and 36% of resident fish specifies respectively (Chen, *et al.* 2003). In addition, lower fish diversity is a good indicator of a stressed ecosystem and the higher the fish diversity the more stable the fish community (Lévêque, 1995; Albert and Laë, 2003).

Moreover, qualitative comparison (non-directional) of fish species abundance and diversity across Test and Reference communities show: 36%, 13% and 38% in ACPUH, ACPUE and species diversity between Otuoke and Otuogidi (Test communities) respectively; 40%, 35%, 16% (all seasons) in ACPUH, ACPUE and species diversity between Elebele and Otakeme (Reference communities); and 19%, 15% and 12% (exclusion of the fishing festival - impacted season in Otakeme) in ACPUH, ACPUE and species diversity between Elebele and Otakeme communities.

Figure 8. 10 shows that there are qualitative differences in metrics between the sampling season that have been affected by increased turbidity by the fishing festival upstream (the sampling was carried out about one month after the end of the fishing festival) on ACPUH, ACPUE, and average species diversities the Otakeme fishing grounds. The difference in metrics between the non-affected and affected are: 80% difference in ACPUH; 71% in ACPUE and 13% in species diversity. Moreover, the differences between Test and Reference communities across Creeks (Elebele / Otuoke Creek and Kolo Creek) in the light of the exclusion of impacts from upstream fishing festival are: 66%; 59% and 51% on ACPUH, ACPUE and species diversity respectively. This implies that the fishing festival does not have much impact on species diversity compared to fish abundance immediately after the fishing festival. However, a decreased fish catch is not unusual even in “non-overfished” rivers (Albert and Laë, 2003). On the contrary, increased turbidity from the fishing festival may have resulted to increased migration away from the Otakeme fishing grounds.

Figure 8. 11 show that all affected areas or seasons have an ACPUE that is less than 1: Test communities (Otuogidi 0.8; and Otuoke 0.7) and 0.5 for the effects of upstream fishing festival on Otakeme fishing grounds. In addition, the difference in metrics between Otakeme and Otuogidi is

higher when the un-affected sampling season has been used. Using these results show a difference of 47% in ACPUH; 53% in ACPUE; and 22% in average species diversity between the Test and Reference communities across the Kolo Creek. Specifically, environmental degradation and habitat loss, not overfishing, is reported as the major cause of declining fisheries in most rivers under stress (Coates, *et al.* 2003). Therefore, fishing festival constitutes environmental noise in the case of this study.

In other studies, CPUE, species composition of catch and size of distribution have been used as the main components of the decision support system in the subsistence fisheries by the Cree people of James Bay in northern Canada (Moller, *et al.* 2004). In addition, CPUE have been used in understanding local fishery resources and as a fish biomass index in Ebrie lagoon, Ivory Coast (Albert and Laë, 2003). Specifically, a higher CPUE show that an area contain more fish species or less impaired than an area with lower CPUE or more adversely impaired (Brightbill and Bilger, 1999).

Figure 8. 10 Qualitative Comparison of effect of fishing festival on assessment

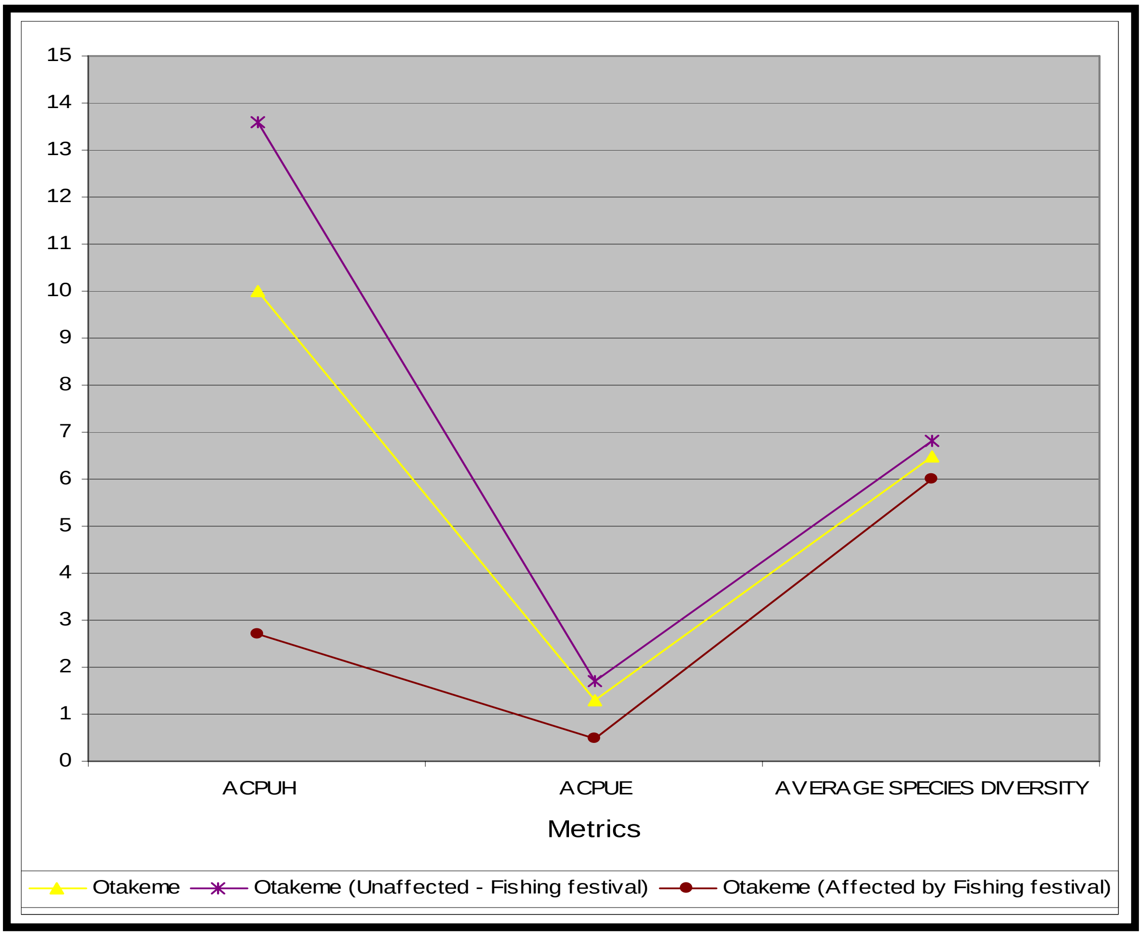
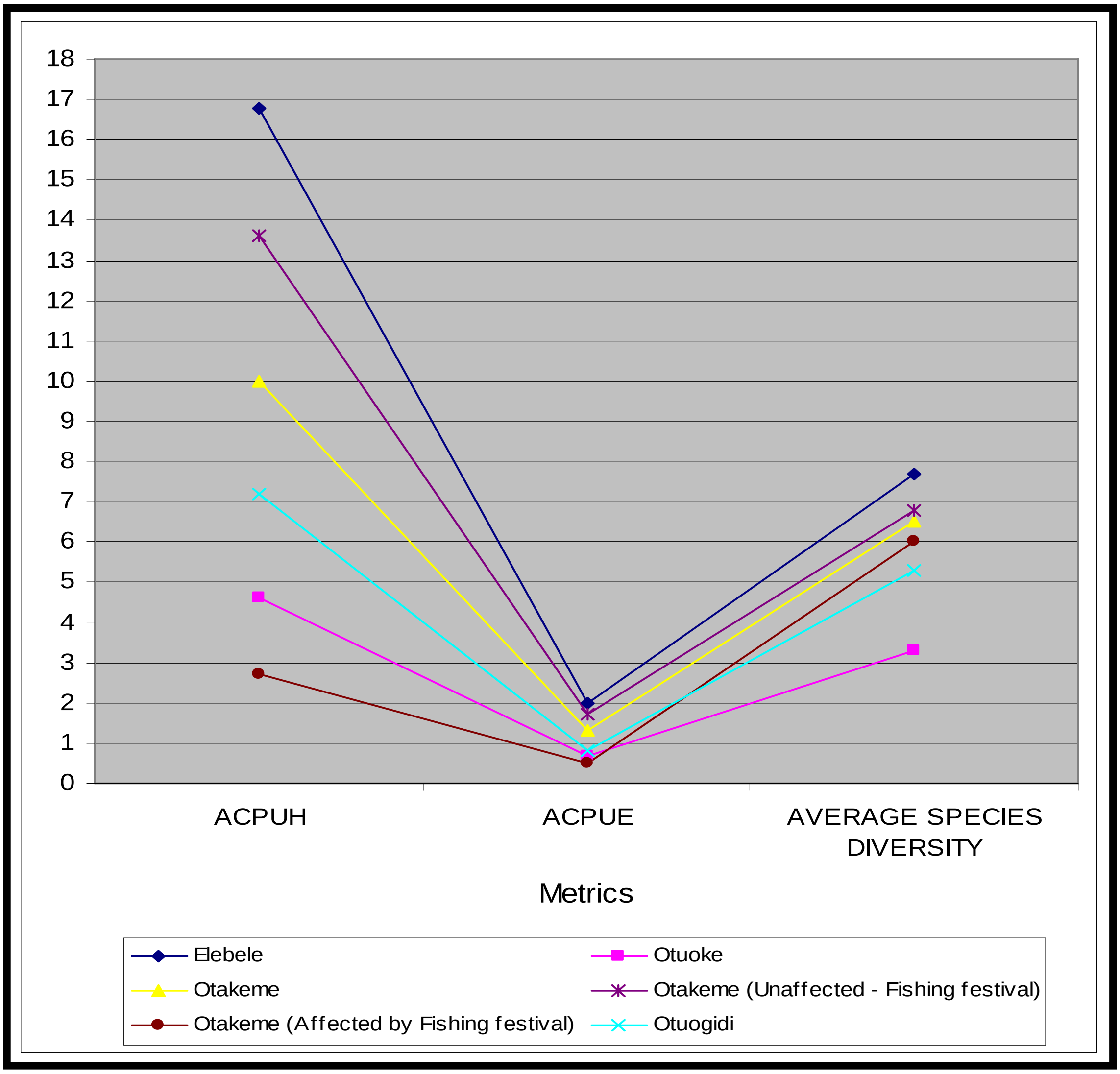


Figure 8. 11 Qualitative comparisons of all assessment scenarios



Environmental professionals and managers that are responsible for decision-making about complex systems (such as ecological systems) require multiple levels of information. In addition, in some regulatory situations, statistical evidences are required to show that the changes that had occurred in the ecological system are significant (Karr and Chu, 1999). Therefore, in furtherance of the comparison between the Test and Reference communities, statistical tests have been carried out to test for relationships between metrics in sample communities, as well as to check if the difference between the Test and Reference communities are significantly different. The K-S Test for normality shows that: there is no deviation in abundance metrics (CPUE and CPUH), but a deviation in species diversity (Elebele); no deviation from normality on abundance and diversity metrics (Otuoke); no deviation in abundance metrics, except on species diversity (Otakeme); and no deviation from normality on species abundance metrics and species diversity (Otuogidi).

Correlation analysis on fish abundance and species diversity show there are significant relationships between: all metrics in Elebele (R) (SPSS Output 8. 4); between CPUH and CPUE in Otuoke (T) (SPSS Output 8. 5); between CPUH and CPUE in Otakeme (R) (SPSS Output 8.6); and no significant relationship in abundance metrics and species diversity in Otuogidi (T) (SPSS Output 8. 7). This implies that generally there is a significant relationship between CPUE and CPUH as metrics that evaluate the status of ecological systems. Similarly, correlation analysis has been used as a measure to assess the magnitude of the fishing effort in South-Eastern Nigeria, which show that monthly catch and effort have a highly significant correlation coefficient (r = 0:8305, P < 0:01 and d:f: = 10) (Moses, *et al.* 2002).

SPSS Output 8. 4 Relationship between abundance and diversity metrics (Elebele)

Correlations

			Catch per unit hour - Elebele (CPUH)	Catch per unit effort - Elebele (CPUE)	Species diversity - Elebele
Kendall's tau_b	Catch per unit hour - Elebele (CPUH)	Correlation Coefficient	1.000	.966**	.931*
		Sig. (2-tailed)	.	.007	.011
		N	6	6	6
	Catch per unit effort - Elebele (CPUE)	Correlation Coefficient	.966**	1.000	.889*
		Sig. (2-tailed)	.007	.	.017
		N	6	6	6
	Species diversity - Elebele	Correlation Coefficient	.931*	.889*	1.000
		Sig. (2-tailed)	.011	.017	.
		N	6	6	6

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

SPSS Output 8. 5 Relationship between abundance and diversity metrics (Otuoke)

Correlations

			Catch per unit hour - Otuoke (CPUH)	Catch per unit effort - Otuoke (CPUE)	Species diversity - Otuoke
Kendall's tau_b	Catch per unit hour - Otuoke (CPUH)	Correlation Coefficient	1.000	.828*	.276
		Sig. (2-tailed)	.	.022	.444
		N	6	6	6
	Catch per unit effort - Otuoke (CPUE)	Correlation Coefficient	.828*	1.000	.357
		Sig. (2-tailed)	.022	.	.330
		N	6	6	6
	Species diversity - Otuoke	Correlation Coefficient	.276	.357	1.000
		Sig. (2-tailed)	.444	.330	.
		N	6	6	6

*. Correlation is significant at the .05 level (2-tailed).

SPSS Output 8. 6 Relationship between abundance and diversity metrics (Otakeme)

Correlations

			Catch per unit hour - Otakeme (CPUH)	Catch per unit effort - Otakeme (CPUE)	Species diversity - Otakeme
Kendall's tau_b	Catch per unit hour - Otakeme (CPUH)	Correlation Coefficient	1.000	1.000**	.645
		Sig. (2-tailed)	.	.005	.079
		N	6	6	6
	Catch per unit effort - Otakeme (CPUE)	Correlation Coefficient	1.000**	1.000	.645
		Sig. (2-tailed)	.005	.	.079
		N	6	6	6
	Species diversity - Otakeme	Correlation Coefficient	.645	.645	1.000
		Sig. (2-tailed)	.079	.079	.
		N	6	6	6

**. Correlation is significant at the .01 level (2-tailed).

SPSS Output 8. 7 Relationship between abundance and diversity metrics (Otuogidi)

Correlations

			Catch per unit hour - Otuogidi (CPUH)	Catch per unit effort - Otuogidi (CPUE)	Species diversity - Otuogidi
Kendall's tau_b	Catch per unit hour - Otuogidi (CPUH)	Correlation Coefficient	1.000	.467	.234
		Sig. (2-tailed)	.	.188	.537
		N	6	6	6
	Catch per unit effort - Otuogidi (CPUE)	Correlation Coefficient	.467	1.000	.234
		Sig. (2-tailed)	.188	.	.537
		N	6	6	6
	Species diversity - Otuogidi	Correlation Coefficient	.234	.234	1.000
		Sig. (2-tailed)	.537	.537	.
		N	6	6	6

One-way analysis of variance (ANOVA) on CPUH and CPUE between the Elebele (R) and Otuoke (T) (Communities along Elebele / Otuoke Creek) shows that there is a significant ($p < 0.05$) difference in fish abundance based on these metrics (see SPSS Output 8. 8). Furthermore, Kolmogorov-Smirnov Test shows that there is a significant difference ($p < 0.05$) in fish species diversity between Elebele and Otuoke (see SPSS Output 8. 9). These results imply that the difference in CPUH, CPUE and species diversity between Otuoke (T) and Elebele (R) has been attributed to the dredging of the Otuoke section of the Elebele / Otuoke Creek.

SPSS Output 8. 8 ANOVA on fish abundance (Elebele / Otuoke Creek)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Catch per Unit Hour - Elebele / Otuoke Creek (CPUH)	Between Groups	439.952	1	439.952	5.452	.042
	Within Groups	806.963	10	80.696		
	Total	1246.915	11			
Catch per Unit Effort - Elebele / Otuoke Creek (CPUE)	Between Groups	4.813	1	4.813	6.528	.029
	Within Groups	7.373	10	.737		
	Total	12.187	11			

SPSS Output 8. 9 K-S Z Test on species diversity (Elebele / Otuoke Creek)

Test Statistics [a]

		Species Diversity - Elebele / Otuoke Creek
Most Extreme Differences	Absolute	.833
	Positive	.000
	Negative	-.833
Kolmogorov-Smirnov Z		1.443
Asymp. Sig. (2-tailed)		.031
Exact Sig. (2-tailed)		.026
Point Probability		.026

a. Grouping Variable: Sample Communities

Furthermore, One-way ANOVA on CPUH and CPUE between the Otakeme (R) and Otuogidi (T) (Communities along Kolo Creek) shows that there is no significant difference ($p > 0.05$) on these metrics (including the season affected by fishing festival) (see SPSS Output 8. 10). In addition, the Kolmogorov-Smirnov Test shows that the difference in fish species diversity between Otakeme (R) and Otuogidi (T) is not significantly different ($p > 0.05$) (see SPSS Output 8.11). However, a one-way ANOVA of species abundance (isolating the sampling season that had been impacted by the fishing festival), shows that the difference between Otakeme (R) and Otuogidi (T) in species abundance is significant ($p < 0.05$) (see SPSS Output 8. 12), but the difference in species diversity is not significantly different ($p > 0.05$) between Otakeme and Otuogidi (see SPSS Output 8. 13).

ANOVA have been carried out to assess the impact of the environmental noise (the upstream fishing festival) that had affected the ecological survey (Otakeme). SPSS Output 8. 14 shows that there is a significant difference between non-affected and affected seasons in terms of fish species abundance $p < 0.05$, but there is no significant difference ($p > 0.05$) in species diversity between affected and non-affected seasons (SPSS Output 8.15).

SPSS Output 8. 10 ANOVA of fish abundance – impacted (Kolo Creek)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Catch per Unit Hour - Kolo Creek (CPUH)	Between Groups	22.662	1	22.662	.827	.385
	Within Groups	274.081	10	27.408		
	Total	296.743	11			
Catch per Unit Effort - Kolo Creek (CPUE)	Between Groups	.801	1	.801	2.300	.160
	Within Groups	3.482	10	.348		
	Total	4.282	11			

SPSS Output 8. 11 K-S Test of species diversity – impacted (Kolo Creek)

Test Statistics[a]

		Species Diversity - Kolo Creek
Most Extreme Differences	Absolute	.333
	Positive	.000
	Negative	-.333
Kolmogorov-Smirnov Z		.577
Asymp. Sig. (2-tailed)		.893
Exact Sig. (2-tailed)		.844
Point Probability		.764

a. Grouping Variable: Sample Communities

SPSS Output 8. 12 ANOVA of species abundance – non-impacted (Kolo Creek)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Catch per Unit Hour - Kolo Creek (CPUH)	Between Groups	98.396	1	98.396	7.118	.028
	Within Groups	110.594	8	13.824		
	Total	208.991	9			
Catch per Unit Effort - Kolo Creek (CPUE)	Between Groups	2.091	1	2.091	13.728	.006
	Within Groups	1.218	8	.152		
	Total	3.309	9			

SPSS Output 8. 13 K-S Z Test on species diversity – non-impacted (Kolo Creek)

Test Statistics[a]

		Species Diversity - Kolo Creek
Most Extreme Differences	Absolute	.500
	Positive	.500
	Negative	-.083
Kolmogorov-Smirnov Z		.775
Asymp. Sig. (2-tailed)		.586

a. Grouping Variable: Sample Communities

SPSS Output 8. 14 Species abundance of impacted and non-impacted seasons (Otakeme)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Catch per Unit Hour - Otakeme (CPUH)	Between Groups	160.270	1	160.270	44.103	.003
	Within Groups	14.536	4	3.634		
	Total	174.806	5			
Catch per Unit Effort - Otakeme (CPUE)	Between Groups	2.083	1	2.083	15.723	.017
	Within Groups	.530	4	.133		
	Total	2.613	5			

SPSS Output 8. 15 Species diversity of impacted and non-impacted seasons (Otakeme)

Test Statistics[a]

		Species Diversity - Otakeme
Most Extreme Differences	Absolute	.500
	Positive	.250
	Negative	-.500
Kolmogorov-Smirnov Z		.577
Asymp. Sig. (2-tailed)		.893
Exact Sig. (2-tailed)		.867
Point Probability		.733

a. Grouping Variable: Otakeme

In addition, statistical comparisons have been carried out on Test and Reference communities across Creeks (Elebele / Otuoke Creek to Kolo Creek). One-way ANOVA on CPUH and CPUE, and a non-parametric t-Test on species diversity on sampling results from Elebele (Elebele / Otuoke Creek – Reference community) and Otuogidi (Kolo Creek – Test community) show that there are significant differences ($p < 0.05$) in CPUE and species diversity and no significant difference ($p > 0.05$) on CPUH (see SPSS Output 8. 16 and SPSS Output 8. 17 respectively).

SPSS Output 8. 16 ANOVA of species abundance (Elebele to Otuogidi)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Catch per Unit Hour - Elebele / Otuogidi (CPUH)	Between Groups	271.890	1	271.890	3.106	.108
	Within Groups	875.378	10	87.538		
	Total	1147.269	11			
Catch per Unit Effort - Elebele / Otuogidi (CPUE)	Between Groups	4.083	1	4.083	5.435	.042
	Within Groups	7.513	10	.751		
	Total	11.597	11			

SPSS Output 8. 17 K-S Z Test of species diversity (Elebele to Otuogidi)

Test Statistics[a]

		Species Diversity - Elebele / Otuogidi
Most Extreme Differences	Absolute	.833
	Positive	.167
	Negative	-.833
Kolmogorov-Smirnov Z		1.443
Asymp. Sig. (2-tailed)		.031
Exact Sig. (2-tailed)		.026
Point Probability		.026

a. Grouping Variable: Sample Communities

Similarly; one-way ANOVA of CPUH and CPUE, and the Kolmogorov-Smirnov Test on species diversity across creeks (Otakeme – Reference community Kolo Creek; and Otuoke – Test community Elebele / Otuoke Creek) show that there are no significant differences ($p > 0.05$) in CPUH and CPUE, as well as in species diversity (when all seasons are compared – including the season affected by the upstream fishing festival) (see SPSS Output 8. 18 and SPSS Output 8. 19 respectively). However, the exclusion of the season that has been affected by the upstream fishing festival show that there are significant differences ($p < 0.05$) between Otakeme (R) and Otuoke (T) in CPUH and CPUE (see SPSS Output 8. 20), and significant similarity ($p > 0.05$) in species diversity (see SPSS Output 8. 21). These results show that irrespective of the creek in which Reference and Test communities are selected, eco-livelihood assessment has been sensitive to identify the impacts of inland rive dredging across communities in the same eco-livelihood zone.

SPSS Output 8. 18 ANOVA of species abundance – all season (Otakeme to Otuoke)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Catch per Unit Hour - Otakeme / Otuoke (CPUH)	Between Groups	86.080	1	86.080	4.177	.068
	Within Groups	206.078	10	20.608		
	Total	292.158	11			
Catch per Unit Effort - Otakeme / Otuoke (CPUE)	Between Groups	1.080	1	1.080	3.208	.104
	Within Groups	3.367	10	.337		
	Total	4.447	11			

SPSS Output 8. 19 K-S Z Test of species diversity – all season (Otakeme to Otuoke)

Test Statistics[a]

		Species Diversity - Otakeme / Otuoke
Most Extreme Differences	Absolute	.667
	Positive	.667
	Negative	.000
Kolmogorov-Smirnov Z		1.155
Asymp. Sig. (2-tailed)		.139
Exact Sig. (2-tailed)		.069
Point Probability		.054

a. Grouping Variable: Sample Communities

SPSS Output 8. 20 ANOVA on species abundance – non-impacted (Otakeme to Otuoke)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Catch per Unit Hour - Otakeme / Otuoke (CPUH)	Between Groups	194.686	1	194.686	36.366	.000
	Within Groups	42.828	8	5.354		
	Total	237.514	9			
Catch per Unit Effort - Otakeme / Otuoke (CPUE)	Between Groups	2.481	1	2.481	17.987	.003
	Within Groups	1.103	8	.138		
	Total	3.584	9			

SPSS Output 8. 21 K-S Z Test on species diversity – non-impacted (Otakeme to Otuoke)

Test Statistics[a]

		Species Diversity - Otakeme / Otuoke
Most Extreme Differences	Absolute	.750
	Positive	.750
	Negative	.000
Kolmogorov-Smirnov Z		1.162
Asymp. Sig. (2-tailed)		.134
Exact Sig. (2-tailed)		.095
Point Probability		.048

a. Grouping Variable: Sample Communities

Table 8. 5 have been used to present a summary to show the degree of sensitivity of the metrics used to measure species abundance (CPUE and CPUH) and species diversity. The expected scenario has been derived based on literature, while the actual scenario has been from the analyses of the ecological survey results. Based on the expected criteria, the metrics have been arranged in order of decreasing sensitivity: CPUE has been identified as the most sensitive metric (correct for seven of seven expected and precise scenarios); followed by CPUH (correct for six of seven expected and precise scenarios) and species diversity (correct for five of seven expected and precise scenarios). Therefore CPUE is the most sensitive metric for the retrospective assessment of the ecological impact of inland river dredging that is of livelihood significance.

Table 8. 5 Comparison of reliability of species abundance and diversity metrics

	Eco-livelihood metrics					
	CPUH		**CPUE**		**Species diversity**	
Scenario	Expected	Actual	Expected	Actual	Expected	Actual
Elebele (R) – Otuoke (T)	D	D	D	D	D	D
Otakeme[1] (R) – Otuogidi (T)	d	S	d	S	d	S
Otakeme[2] (R) – Otuogidi (T)	D	D	D	D	D	S
Otakeme[2] (R) – Otakeme[3]	D	D	D	D	D	D
Elebele (R) – Otuogidi (T)	D	S	D	D	D	D
Otakeme[1] (R) – Otuoke (T)	d	S	d	S	d	S
Otakeme[2] (R) – Otuoke (T)	D	D	D	D	D	S
Elebele (R) – Otakeme[1] (R)	d	S	s	S	s	S
Elebele (R) – Otakeme[2] (R)	S	S	S	S	S	S
Otuoke (T) – Otuogidi (T)	S	S	S	S	S	S

Key

Otakeme1 = all sampling season; Otakeme2 = Less impacted season (non-impacted); Otakeme3 = impacted season; D = Expected (precise) significant difference; d = Expected (not precise) significant difference; S = Expected (precise) no significant difference; s = Expected (not precise) no significant difference

For the purpose of triangulation and to check for the validity of the selection criteria (Test and Reference communities) and the validity and reliability of the assessment metrics, statistical comparisons have been carried out on the relationship between the Test communities and Reference communities irrespective of location (Creek) in the Study Area. The Independent Sample t-test on CPUH and CPUE, and non-parametric t-Test show that there are no significant differences ($p > 0.05$) between Test communities (Otuoke (T) {Elebele / Otuoke Creek} and Otuogidi (T) {Kolo Creek}); as well as between Reference communities (Elebele (R) {Elebele / Otuoke Creek} and Otakeme (R) {Kolo Creek}) in all situations on CPUH, CPUE and species diversity (see SPSS Output 8. 22 and SPSS Output 8. 23– Test communities; to SPSS Output 8. 24, SPSS Output 8. 25, SPSS Output 8. 26, and SPSS Output 8. 27– Reference communities respectively). Values of "Sig. (2-tailed)" in SPSS Outputs 8.22, 8.24, and 8.26; and values of "Exact Sig. (2-tailed)" in SPSS Outputs 8.23, 8.25, and 8.27 are all greater than 0.05. This implies that the selection criteria and the assessment metrics (CPUH, CPUE and species diversity) used in this study are valid and reliable.

SPSS Output 8. 22 Student t-test on species abundance (Test communities)

Independent Samples Test

		Independent Sample t-test	
		df	Sig. (2-tailed)
Catch per Unit Hour - Test community (CPUH)	Equal variances assumed	10	.245
	Equal variances not assumed	7.874	.252
Catch per Unit Effort - Test community (CPUE)	Equal variances assumed	10	.679
	Equal variances not assumed	9.928	.679

SPSS Output 8. 23 K-S Z Test on species abundance (Test communities)

Test Statistics[a]

		Species Diversity - Test community
Most Extreme Differences	Absolute	.500
	Positive	.500
	Negative	.000
Kolmogorov-Smirnov Z		.866
Asymp. Sig. (2-tailed)		.441
Exact Sig. (2-tailed)		.242
Point Probability		.182

a. Grouping Variable: Test Communities

SPSS Output 8. 24 Student t-test on species abundance – all season (Reference communities)

Independent Samples Test

		Independent Sample t-test	
		df	Sig. (2-tailed)
Catch per Unit Hour - Reference communities (CPUH)	Equal variances assumed	10	.258
	Equal variances not assumed	7.142	.268
Catch per Unit Effort - Reference communities (CPUE)	Equal variances assumed	10	.257
	Equal variances not assumed	8.415	.262

SPSS Output 8. 25 K-S Z Test on species diversity – all season (Reference communities)

Test Statistics[a]

		Species Diversity - Reference communities
Most Extreme Differences	Absolute	.500
	Positive	.167
	Negative	-.500
Kolmogorov-Smirnov Z		.866
Asymp. Sig. (2-tailed)		.441
Exact Sig. (2-tailed)		.416
Point Probability		.400

a. Grouping Variable: Reference Communities

SPSS Output 8. 26 Student t-test on species abundance – non-impacted (Reference communities)

Independent Samples Test

		Independent Sample t-test	
		df	Sig. (2-tailed)
Catch per Unit Hour - Reference communities (CPUH)	Equal variances assumed	8	.641
	Equal variances not assumed	5.356	.573
Catch per Unit Effort - Reference communities (CPUE)	Equal variances assumed	8	.689
	Equal variances not assumed	6.228	.634

SPSS Output 8. 27 K-S Z on species diversity – non-impacted (Reference communities)

Test Statistics [a]

		Species Diversity - Reference communities
Most Extreme Differences	Absolute	.500
	Positive	.167
	Negative	-.500
Kolmogorov-Smirnov Z		.775
Asymp. Sig. (2-tailed)		.586
Exact Sig. (2-tailed)		.429
Point Probability		.362

a. Grouping Variable: Reference Communities

Specifically, inland river dredging has a significant ecological impact in the Study Area, which implies livelihood impacts. Similarly, Ohiamain, *et al.* (2005), have demonstrated that the impact of dredging in the Warri River, Niger Delta , Nigeria, is significant (93% reduction in the population of macro-benthic invertebrate; a reduction in the Margalef's diversity index from 3.8 to 1.4; and species reduction from 15 species identified during the pre-dredging studies, to only *Nereis operta* and *Baetis sp*. post dredging). A severe reduction in invertebrates could eventually result in both short and long-term reductions in numbers of invertivorous fish species (fish that feed on invertebrates). The succeeding section (8.4.2) contains the analysis of the impact of inland river dredging in the Study Area using fish trophic structure as assessment indicator.

8.4. 2 Trophic structure of fish species

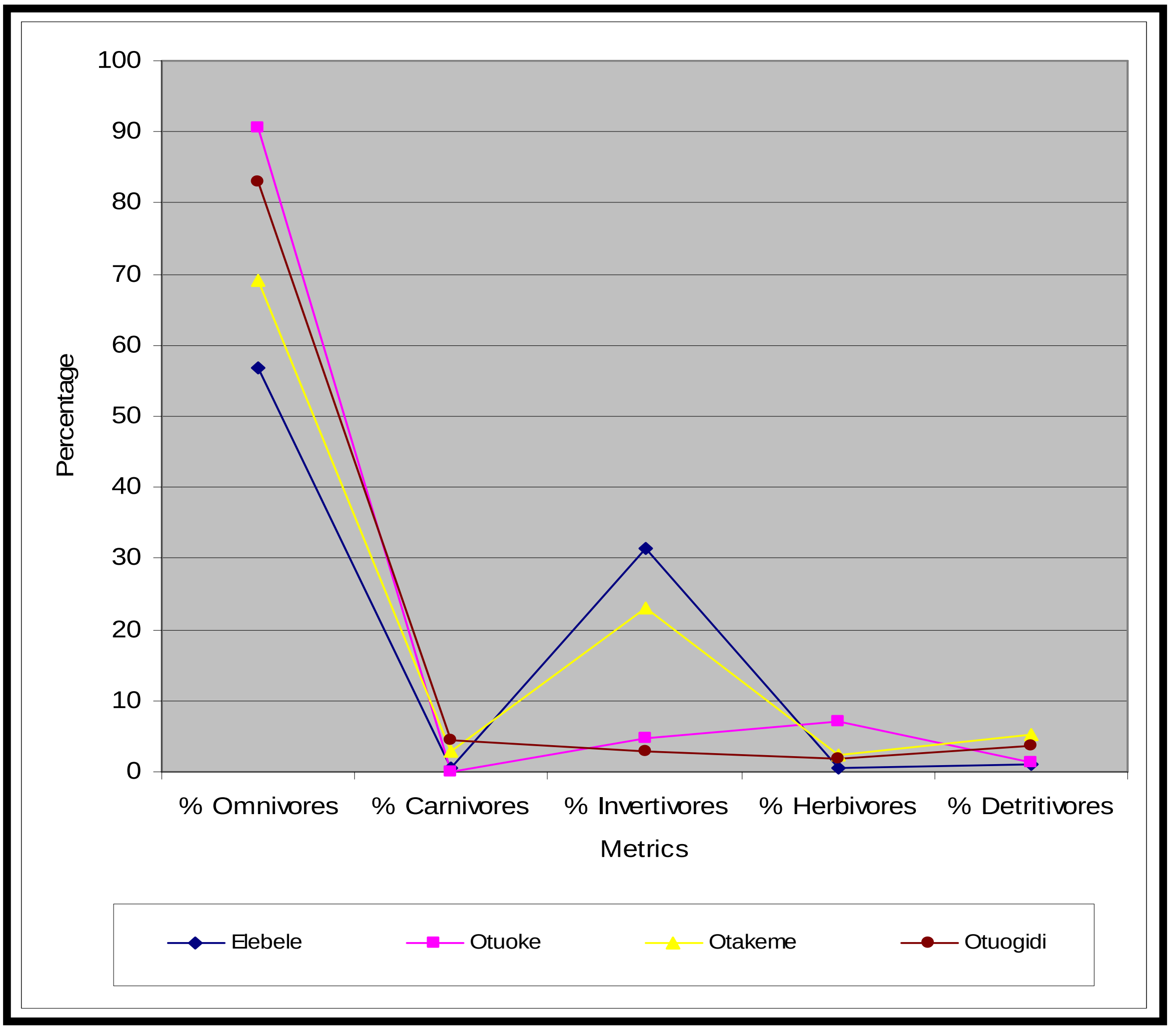
Sustainable management of surface waters and fisheries depends upon understanding the basis of fish productivity, linked to the trophic characteristics and to food web structure (Arthington, *et al.* 2003). In the context of this thesis the average number of species per sampling day as represented by the trophic structure has been used to describe trophic characteristics as shown in Table 8. 6. The average of species in each trophic category (omnivores, carnivores, invertivores, herbivores and detritivores) has been used to show the qualitative relationship in trophic characteristics between the respective Test and Reference communities (along creeks and between creeks), as well as between Test and Reference communities (Figure 8. 12). There are deviations in trends in trophic structure in: percentage of omnivores species, invertivores species and herbivores species between Elebele and Otuoke (Test and Reference communities of Elebele / Otuoke Creek); differences in: percentage of omnivores species and invertivores species between Otakeme and Otuogidi (Test and Reference communities of Kolo Creek); percentage of Invertivores and detritivores between Elebele and Otuogidi (Test and Reference communities across Creeks); and in percentage of invertivores, herbivores and detritivores species between Otakeme and Otuoke (Test and Reference communities across creeks).

Table 8. 6 Summary of ecological survey (Trophic structure)

	FISH SPECIES (Native and Scientific and Diet)																																
	Diet	Omnivores	Herbivores	Detritivores	Omnivores	Detritivores	Carnivores	Detritivores	Omnivores	Invertivores	Invertivores	Invertivores	Detritivores	Invertivores	Omnivores	Carnivores	Invertivores	Carnivores	Omnivores	Carnivores	Herbivores	Carnivores	Carnivores	Invertivores	Carnivores						
	Aletes spp	*Distichodus spp*	*Heterotis niloticus*	*Citharinus spp*	*Tilapia spp*	*Bagrus spp*	*Mugil cephalus*	*Micralestes spp*	*Petrocephalus spp.*	*Marcusenius spp*	*Pareutropius sp*	*Phago loricatus*	*Synodontis spp*	*Chrysichthys nigrodigitatus*	*Hydrocynus linaetus*	*Pantodon bucholzi*	*Notopterus chitala*	*Bagrus spp*	*Acestrorhynchus sp.*	*Labeo sp*	*Ichthyborus monodi.*	*Xenomystus nigri (Pez cuchillo Africano)*	*Raiamas senegalensis*	*Hepsetus odoe*	*Polycentropsis abbreviata*						
Community	OKOLOKOLO	EFERERE	OGBOLOKA	EPETE / APORU	EWELA	OGBUDA	OFUROMA	EDEGERE	EBEDE	EBHE	OLARI	EKWEI	OKPOKI / OPOGOIN	OGULO / EGBO	OHABH	APAMU / ISONGO	OKPOKOZI	ODURO / OFIO	BARACUDA	IGBUTU	OKOLOBOSIGOIN	EBELEM	OZA	ORIM	OGBOLOMO-OBELE	AVERAGE FISH CATCH	% OMNIVORES	% CARNIVORES	% INVERTIVORES	% HERBIVORES	% DETRITIVORES
A	23.0	0.5	0.3	8.3	0.5	0.0	0.0	14.2	18.5	8.7	6.0	0.0	0.5	2.5	0.0	0.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.3	56.9	0.6	31.5	0.6	1.0
B	6.7	0.5	0.0	17.2	0.3	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	26.5	90.6	0.0	4.8	6.9	1.3
C	7.9	1.4	0.0	26.6	3.4	0.4	0.0	0.0	3.4	4.3	2.5	0.0	1.6	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.1	54.9	69.0	2.9	23.0	2.3	5.4
C-X	9.3	1.8	0.0	34.5	4.8	0.5	0.0	0.0	2.0	5.0	3.5	0.0	2.3	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.5	70.8	0.9	18.1	2.7	7.5
C-Y	4.5	0.5	0.0	7.0	0.0	0.0	0.0	0.0	7.0	2.5	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.5	26.0	64.6	7.9	35.4	1.3	0.0
D	10.3	0.5	0.0	14.0	0.2	0.7	0.5	0.0	0.3	0.0	0.0	0.2	0.3	2.7	0.3	0.0	0.0	0.5	0.2	0.0	0.2	0.0	0.2	0.2	0.0	31.2	82.9	4.5	2.9	1.8	3.7

Key: A – Elebele (R); B – Otuoke (T); C – Otakeme (R); C-X – Otakeme (Less fishing festival effects); C-Y – Otakeme (Affected by fishing festival); D – Otuogidi (T).

Figure 8. 12 Qualitative comparison of trophic structure (Study Area)

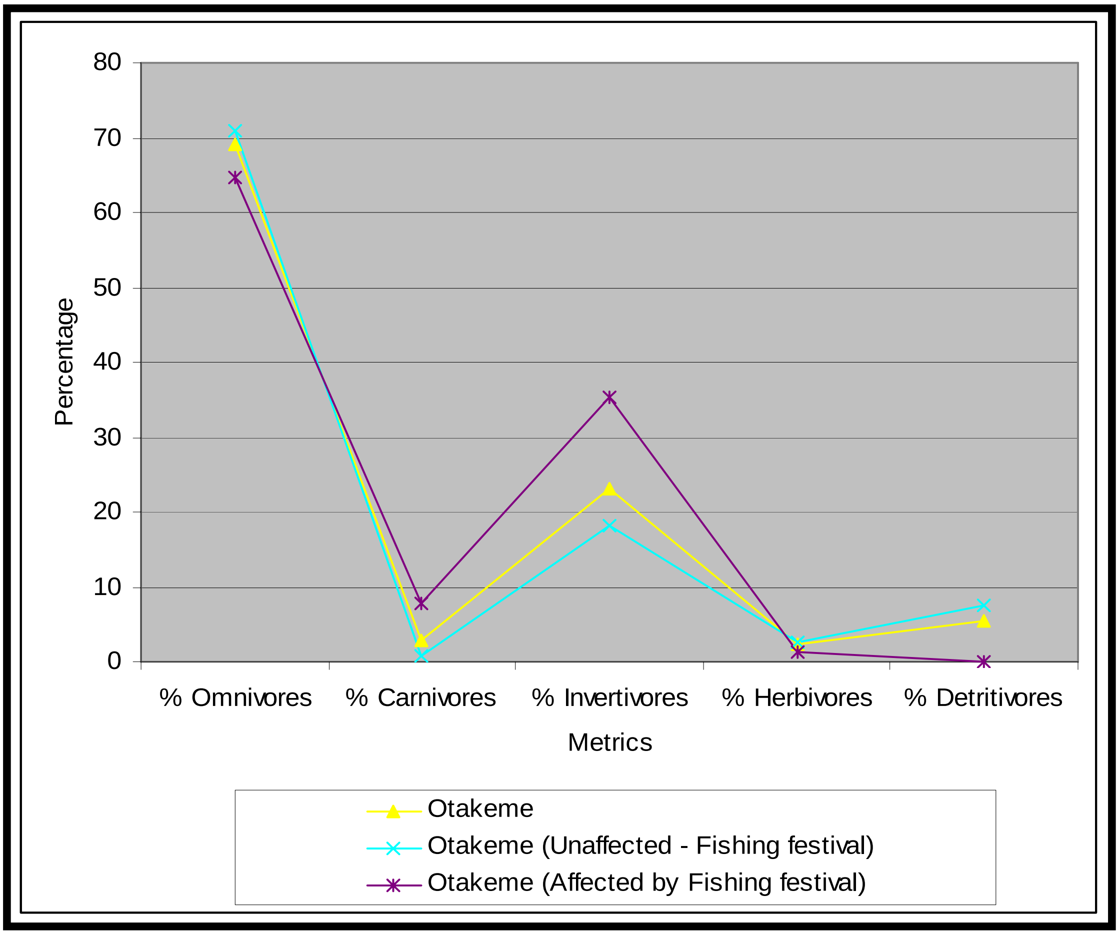


However, despite these differences, the established ecological criteria for distinguishing highly degraded and minimally degraded habitats show that all sample communities used in this research have been adversely impacted by human or natural induced factors (See Table 7. 20). Rivers with 20% or more piscivorous (carnivores) species imply minimally disturbed rivers, while rivers with 40% or more omnivore species are indication of highly degraded rivers (Karr and Chu, 1999).

The increased percentage of omnivores in the Test communities compared to the Reference communities implies that the level of degradation of the Test communities is higher than that of the Reference communities. In addition, the reduced proportion of Invertivores in the Test communities could be as a result of depletion of the proportion of Invertivores due to inland river dredging. Ohimain, *et al.* (2005) reported that dredging in the Warri River, Nigeria had resulted in significant reduction in macro-invertebrates.

The annual fishing festival upstream of Otakeme represents an environmental noise. Figure 8. 13 show that there are differences between the non-affected and the affected sampling seasons on the percentage of invertivorous and detritivorous fish species.

Figure 8. 13 Qualitative comparison of trophic structure (Otakeme)



In addition, statistical analyses have been carried out for further comparison on the trophic characteristics (represented by percentage of the respective trophic groups) of the Test and Reference communities. The K-S Test for normality on all trophic structure metrics shows deviation from normality ($p < 0.05$) except: Omnivores and Invertivores (Elebele R); Omnivores, Invertivores and Herbivores (Otakeme R); and Carnivores and Invertivores (Otuogidi T).

There is no significant relationship between the trophic structure metrics across all sample communities, except a significant negative relationship between percentage omnivores and invertivores at Otakeme (R) (τ = 0.87 df = 6 $p < 0.015$). Furthermore, non-parametric t-Tests show that the difference in percentage of omnivores and invertivores are significantly different (Elebele / Otuoke Creek $p < 0.05$) (Table 8.7), but there are no significant differences between all trophic structure metrics of both the season affected by upstream fishing festival and non-affected seasons (Kolo Creek) (Table 8.8 and Table 8.9).

In addition, comparison of Test and Reference communities across creeks shows that: there are significant differences ($p < 0.05$) in percentage of omnivores and invertivores between Elebele (R) and Otuogidi (T) (Table 8.10); but no significant difference in any trophic metrics in all scenarios between Otakeme and Otuoke (Table 8.11 and Table 8.12). The impact of the annual upstream fishing festival may have affected the trophic structure in Otakeme, hence the lack of any significant difference in all trophic structures in all situations in which Otakeme has been used as a Reference community.

Table 8. 7 Trophic structure comparisons (Elebele / Otuoke Creek)

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.260	0.130
Percentage Carnivores	1.000	0.500
Percentage Invertivores	0.260	0.130
Percentage Herbivores	0.697	0.348
Percentage Detritivores	0.318	0.159

Table 8. 8 Trophic structure comparison – impacted (Kolo Creek)

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.474	0.237
Percentage Carnivores	0.896	0.448
Percentage Invertivores	0.143	0.076
Percentage Herbivores	1.000	0.500
Percentage Detritivores	1.000	0.500

Table 8. 9 Trophic structure comparisons – non-impacted (Kolo Creek)

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.295	0.148
Percentage Carnivores	0.295	0.148
Percentage Invertivores	0.295	0.148
Percentage Herbivores	0.971	0.486
Percentage Detritivores	0.619	0.309

Table 8. 10 Trophic structure comparisons across Creeks (Elebele to Otuogidi)

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.026	0.013
Percentage Carnivores	0.113	0.056
Percentage Invertivores	0.026	0.13
Percentage Herbivores	0.827	0.414
Percentage Detritivores	0.827	0.414

Table 8. 11 Trophic structure comparison across Creeks – impacted (Otakeme to Otuoke)

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.474	0.237
Percentage Carnivores	0.182	0.091
Percentage Invertivores	0.143	0.072
Percentage Herbivores	0.827	0.414
Percentage Detritivores	0.182	0.091

Table 8. 12 Trophic structure comparisons across Creeks – non-impacted (Otakeme to Otuoke)

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.295	0.148
Percentage Carnivores	0.400	0.200
Percentage Invertivores	0.438	0.219
Percentage Herbivores	0.619	0.309
Percentage Detritivores	0.330	0.165

Non-parametric t-Tests have been carried out on the trophic structure metrics between Test and Reference to check for the validity of the selection criteria of the sample communities. Table 8.13, Tables 8.14, 8.15 and 8.16 shows that there are no statistically significant differences in trophic structure between the Test and Reference communities in all metrics except in the percentage of carnivores between Otuoke and Otuogidi (Test communities). The implication of these results is that the Test and Reference communities have been appropriately selected in the investigation of the eco-livelihood impacts of dredging in the Study Area. However, the trophic structure of fish species is a less sensitive eco-livelihoods metrics in highly degraded catchments.

Table 8. 13 Trophic structure comparison between Reference communities - impacted

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.295	0.148
Percentage Carnivores	0.182	0.091
Percentage Invertivores	0.931	0.466
Percentage Herbivores	0.416	0.208
Percentage Detritivores	0.827	0.414

Table 8. 14 Trophic structure comparisons between Reference communities –non-impacted

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.295	0.148
Percentage Carnivores	0.733	0.366
Percentage Invertivores	0.695	0.348
Percentage Herbivores	0.295	0.148
Percentage Detritivores	0.295	0.148

Table 8. 15 Trophic structure comparisons between Test communities

Trophic structure (Metrics)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Percentage Omnivores	0.931	0.466
Percentage Carnivores	0.015	0.008
Percentage Invertivores	0.827	0.414
Percentage Herbivores	0.697	0.348
Percentage Detritivores	0.697	0.348

8. 5 Chapter summary

The exclusive use of conventional scientific methods in the management of water resources is quite appropriate in most developed countries, because a large proportion of the population of these countries is unlikely to have direct interest in or knowledge of river ecology (Lorenzen and Arthington, 2003). However, in most developing countries local knowledge of river ecology is profound, because the livelihoods of the majority of rural people are intrinsically linked and most often dependent on river ecology (Poulsen, *et al.* 2003). Therefore, the integration of the knowledge of local people and science can significantly assist sustainable management of natural resources and increase the relevance of management decisions to local communities (Huntington, *et al.* 2004; Moller, *et al.* 2004; Chokkalingam, *et al.* 2005). In the context of this research, the profound local eco-livelihoods knowledge of residents of the Kolo Creek has been integrated into the understanding of the eco-livelihood consequences of inland river dredging.

The TELK of respondents about the respective dredging projects has been found to be related to time between events and its recording / reporting and that community involvement / participation in project enhances the quality of TELK of respondents about the project under study. This is based on water supply considerations, which affect all members of communities, as the effects of dredging on water quality are obvious. Generally, dredging had been perceived to be significantly detrimental to fish species and fishing in the Study Area. The rainy season is the preferred season of concession for dredging by respondents of this study. The knowledge of respondents of the Test communities about the dredging projects in their respective communities has been recognised as comparatively good. TK, TEK and TELK have been used to identify that the annual fishing festival that was (in May) constituted an environmental noise that affected the assessment results (rainy season at Otakeme R) that had been used in understanding the eco-livelihood consequences of inland river dredging.

In furtherance of understanding the eco-livelihood consequences of inland river dredging, fish CPUE, CPUH and species diversity have been demonstrated as sensitive metrics of the impact of inland river dredging in the Study Area. Fish trophic structures show that the Study Area is a highly degraded river habitat, with dredging contributing to the degradation.

Chapter 9 Conclusions and recommendations

9. 1 Background

This research has been designed to address two major issues, these are:

- ***Does in-land river dredging have impact on freshwater fisheries that could be of livelihood significance in rural communities of developing countries?; and***
- ***Can an eco-livelihood assessment (EcLA) approach appropriately measure the impacts of inland river dredging in areas where there is high dependence of livelihoods on common pool resources?***

Therefore, social and ecological surveys have been carried out in: two Test communities (Otuoke – Elebele / Otuoke Creek and Otuogidi – Kolo Creek); and two Reference communities (Elebele – Elebele / Otuoke Creek and Otakeme – Kolo Creek) to investigate the validity or otherwise of the research hypotheses. These hypotheses are as highlighted below:

- ***Eco-livelihood is a significant livelihood component in the Central Niger Delta (specifically the Study Area) and in similar areas in most developing countries;***
- ***Traditional eco-livelihoods knowledge (TELK) can provide useful baseline data for EA especially where eco-livelihood is a major livelihood source and baseline data are inadequate and unavailable;***
- ***Fisheries can be used as good indicators retrospectively in the assessment of the impacts of inland river dredging on the ecosystems that are of livelihood significance and***
- ***Eco-livelihood assessment (EcLA) is an appropriate EA tool in areas where the dependence on the ecosystem is a major livelihood component.***

Relevant literature has been reviewed, correspondences with relevant researchers have been done, and field work carried out in the Study Area (between January and August 2004). Furthermore, the quantitative data from the field work have been analysed with Microsoft spreadsheet and Statistical Package for Social Scientists (SPSS 11) to demonstrate that eco-livelihood assessment is an appropriate environmental assessment tool in an area where there is a high dependence of residents on CPRs and baseline data are unavailable or inadequate. To do otherwise could result in a deficient environmental assessment that ignores the livelihood priorities of those dependent on CPRs and the contribution that TK, TEK, and TELK could have made to the assessment.

The social survey has been used to access the TK, TEK and TELK of residents of the sample communities in the Study Area, which has been used to build the eco-livelihood baseline scenario. In addition, the social survey has been used in understanding the perception of residents of the Test communities (Otuoke – Elebele / Otuoke Creek and Otuogidi – Kolo Creek) about the consequences of dredging, as well as preferred practices that could have mitigated the impacts of dredging on these communities. Questionnaires have been administered face-t-face to 5% of those that are 20 years and above from all sample communities to obtaining TK and TELK of residents of the Study Area. In addition, an ecological survey has been conducted in the Study Area to retrospectively assess the impact of inland river dredging on inland river fisheries, which are of livelihood significance in the Study Area. The field work was carried out in the Study Area between January and August 2004.

9. 2 Conclusions

The conclusions below have been presented based on the results and analyses presented in Chapters 7 and 8. The conclusions of this research are presented in the light of the research hypotheses. It has been demonstrated in this study that EcLA is an appropriate, valid and adaptive environmental assessment approach that has a place in environmental assessment where baseline data are not available or inadequate, and dependence on CPR is common. Traditional EA relies on baseline data about physico-chemical parameters, but may omit livelihood issues. In contrast, EcLA includes livelihood considerations, and uses TK, TEK, and TELK to obtain baseline data in the retrospective assessment of anthropogenic impacts on the ecosystem that may be of livelihood consequences.

The social survey sampling has been shown to be non-biased for the age range of respondents when compared to the age profile of the study from results of the Nigeria’s 1991 census results. Sections 9.2.1 to 9.2.3 summarises the conclusions that apply to each of the four research hypotheses.

9.2. 1 Eco-livelihoods: a livelihood source

Eco-livelihood is a significant livelihood component in the Central Niger Delta (specifically the Study Area) and in similar areas in most developing countries

Generally, fishing, farming and petty trading and commerce are the major livelihood sources in the Study Area. Of these, fishing and farming have variable levels of dependence on CPRs. Surface water resources in the Study Area are under communal management and are of common pool value. Other major livelihood sources in the Study Area are: palm cutting; pensions; and formal economic sector; while: snail trapping; hunting; sand mining; canoe carving; lumbering; and menial jobs constitute minor livelihood sources in the Study Area.

There is a High / significant dependence on CPR in the Study Area. CPRs are “free” and access to this resource is open to all residents of the Study Area irrespective of age, educational qualification, gender, and duration of residency in the Study Area. The high dependence on surface water resources for livelihood in the Study Area has been identified as a livelihoods coping strategy due to lack of opportunities in the formal economic sector. Localised human or natural eco-livelihoods issues have been identified as the major factors that affect the productivity and the ecosystem services provided by surface water resources.

Irrespective of the variability in productivity of surface water resource, this resource continues to remain a viable CPR in the Study Area. Locally acquired and developed livelihood sustenance skills as well as knowledge and experience have been used by residents of the Study Area in wining livelihoods from CPRs. Multiple-livelihoods form adaptation strategy in the Study Area to coping with the complexity and variability associated with surface water resources as a CPR. Literature from other developing countries indicates that similar livelihood structures apply elsewhere.

9.2. 2 Baseline scenario based on TK and TELK

Traditional eco-livelihoods knowledge (TELK) can provide useful baseline data for EA especially where eco-livelihood is a major livelihood source and baseline data are inadequate and unavailable

River use profile based on river usage; fish diversity and abundance; fish species of commercial values; trend in fisheries; and eco-livelihoods issues that have occurred in the Study Area have been used to build the assessment baseline scenario of the Study Area. The TK, TEK and TELK of respondents from the sample communities have been used to build the baseline scenario of the Study Area. The TELK of residents of the Study Area have been recognised as reliable and consistent across all four sample communities. An average of 31.4% of respondents of this research have resided in the Study Area for a minimum of 35 years, which implies that this knowledge has been acquired over years of close contact, interaction, association and dependence on the local ecological systems.

9.2.2. 1 River use profile

The river usage across all sample communities in the Study Area has been presented based on the TK and TELK of respondents in the Study Area. Surface water is used for:

- ***Livelihood sustenance such as:***
- Fishing,
- Transportation and commerce,
- Lumbering,
- Sand mining, and
- Palm processing,
- ***Recreational and cultural usage such as:***
- Recreation, and
- Fishing festival (communities upstream of Otakeme in the Kolo Creek),
- ***General purpose such as:***
- Drinking water source,
- Domestic usage,
- Disposal of palm processing effluents, and
- Sewage and waste disposal.

River use profile represents the use (service) values of surface water as well as human pressure on this vital resource. The results of this research show that there is no statistical significant difference in the value residents of all sample communities derive from surface water, as well as the pressure that the human usage may have impacted on the productivity of surface water resource.

9.2.2. 2 Fish species and fishing

The TK, TEK, and TELK of residents have also been used to understand favourable and non-favourable fishing seasons. There has been a general consensus of residents of the Study Area that the flood recession season (between November and December) and the dry season (January to March) are the most suitable fishing seasons (inland river). In addition, the residents identified the rainy season (between June and August) and the flood season (between September and October) as the most unsuitable fishing season (inland river) in the Study Area. This shows that the abundance and diversity of fish species in surface water in the Study Area is dependent on the hydrological regime, which is a factor of seasonal flooding. Seasonal variation of fish productivity in the Study Area is dependent on the magnitude of seasonal flooding, and this information could be used in fishery management as well as help in planning environmental assessment in the Study Area and under similar circumstances or in similar areas.

Furthermore, the trend of fish abundance, diversity and the commercial value of fishing have been identified. There has been significant reduction in fish abundance and a reduction in diversity in fish catch by fishers in the Study Area which have been attributed to have negatively affected the commercial value of fishing as a livelihood source. However, fishing continues to constitute a major livelihood source in the Study Area despite the decline in fish abundance, and declining commercial significance of fishing. The present trend in fisheries based on Fishers' TELK shows that the Study Area is adversely degraded and this has been demonstrated by the ecological survey results (see section 8.4.2 for the details).

Fish abundance, diversity and the commercial value of fish species is consistent across all sample communities based on the TELK of fishers in the Study Area. A total of 37 fish species has been recognised by fishers in the Study Area as species of relatively high abundance based on fish catch. 16 of the 37 species have been categorised as species of major abundance (regularly fished), and 21 are of lesser abundance (minor abundance in fish catches). In addition, 23 species have been recognised as being of high commercial value; 13 of these species have comparatively higher commercial value, while the other 10 have been identified as species of relatively low commercial value.

Alestes spp, *Citharinus spp*, and *Tilapia spp*; while *Gymnarchus niloticus*, *Clarias spp* and *Heterotis niloticus* are the three most abundant fish species and species of highest commercial value respectively in the Study Area. Generally, there has been consistency in the information obtained regarding fish abundance, diversity and commercial value of fish species using ranking and perceptions of fishers as metrics. The TELK of fishers in the Study Area has shown consistency in information across all sample communities in:

- Identifying, favourable and unfavourable fishing seasons;
- Trends in fishing (fish abundance, diversity and commercial importance of fishing);
- Fish species abundance and diversity and
- Fish species of commercial value.

Therefore, TELK is a reliable and valid information source for building the baseline scenario to gain an understanding of the status of fishery resources in the Study Area, in which fishing constitutes a major livelihood source, and where baseline data are inadequate or unavailable. The reliability of TELK have further been buttressed by using this information and knowledge source in understanding environmental issues that have occurred and or are part of the ecological attributes of the Study Area. These events or issues have been identified as eco-livelihood issues in the context of this research.

9.2.2. 3 Eco-livelihood issues

Water hyacinth, tree stumps and other tree parts (in the surface water), waste and sewage disposed into the surface water, crude oil pollution, flooding, shallow depth of the rivers, seasonal changes associated with early rains, effluents from palm processing, lumbering, impacts of upstream dams, the fishing festival upstream (Kolo Creek only), inland river dredging (Test communities only) are the eco-livelihood issues that have been identified by these respondents. The eco-livelihood issues identified by the respondents from the Study Area have been based on their knowledge and experience (TELK), based on long-term residence in the Study Area. These issues have both ecological and livelihood consequences.

In the context of this research, there is consistency of the perception of the impacts of these eco-livelihood issues across all sample communities. Inland river dredging represents the Test issue while the upstream fishing festival is an environmental noise. The TELK of respondents has been used to justify the selection criteria for Test and Reference communities which have shown that inland river dredging is the eco-livelihood event that distinguishes Test and Reference communities, while an upstream fishing festival in the Kolo Creek constitutes an environmental noise that has affected the result of the ecological survey during the rainy season at Otakeme (Reference community along the Kolo Creek).

The TELK of respondents has further been used to understand issues associated with the respective dredging projects under study. The knowledge of respondents of the Test communities about the respective projects has been rated as good, and dependent on the time between the project phase and when the information has been recorded (as in this case the survey). In addition, community participation has been identified as a factor that helps the degree of reliability of information obtained about the project of interest. Generally, inland river dredging has a negative impact on fishing and fisheries in the Study Area, however, the rainy season has been recognised as the concession season during which the impacts of dredging would be less than in other seasons. The mitigation approaches that have been proposed by residents of the Test communities are:

- Water supply;
- Financial compensation;
- Employment of residents of host communities;
- Educational support;

- Clearing of water hyacinth;
- Preference of alternative source of sand for land reclamation (No inland river dredging scenario); Dredging to remove navigational obstruction;
- Preference for shorter duration of dredging;
- Preference of dredging sites away from communities;
- Preference for dredging along (rather than across) channels;
- Road construction and
- Community participation

Agreement on the timing of dredging operations, the nature of concessions to affected communities and the proposed mitigation approaches of respondents could be used in planning dredging projects aimed at equitable development. Such good knowledge of respondents could also be explored in planning environmental assessment and management in areas where livelihoods are dependent on the CPR and baseline data are unavailable or inadequate.

9.2. 3 Eco-livelihood assessment of inland river dredging

Fisheries can be used as good indicators retrospectively in the assessment of the impacts of inland river dredging on the ecosystems that are of livelihood significance

and

Eco-livelihood assessment (EcLA) is an appropriate EA tool in areas where the dependence on the ecosystem is a major livelihood component.

Fishing represents a major livelihood source in the Study Area; hence the use of fish species as indicator for the EcLA of inland river dredging in the Study Area has been justified. Fish species abundance, diversity and trophic structure (percentage: omnivores; carnivores; herbivores; invertivores and detritivores) have been successfully used in showing the eco-livelihoods impacts of dredging. CPUE, CPUH and species diversity have been demonstrated as very sensitive metrics in the retrospective assessment of the eco-livelihood significance of inland river dredging as well as the effect of the environmental noise (impact of upstream fishing festival).

The trophic structure as represented by the percentage composition of omnivores, carnivores, herbivores, invertivores, and detritivores shows that the Study Area is a heavily degraded area. The significant differences in percentage of omnivores and invertivores between Test and Reference communities imply that the Test communities are relatively more degraded than the Reference communities. Therefore, fish species is an appropriate indicator in the retrospective assessment of eco-livelihoods consequences in areas where fishing is a major livelihood source and baseline data are unavailable or inadequate.

The TELK of residents of the Study Area has been adequately used in understanding the eco-livelihoods baseline scenario as well as the environmental noise (the upstream fishing festival in the Kolo creek) that has affected the results of one of the ecological sampling seasons in one of the Reference communities (Otakeme). Generally, the integration of TELK and the scientific assessment tool (EcA) has been demonstrated in this research as appropriate (relevant) for the retrospective assessment of the eco-livelihood impacts of inland river dredging in the Study Area. However, there are limitations to the application of this adaptive approach; these limitations should be taken into consideration whenever or wherever this approach is intended for use (see section 9.2.4).

9.2. 4 Research constraints and limitation of eco-livelihoods assessment

Ecological sampling has been carried out during three of the five identified fishing seasons. Therefore the ecological survey result may be criticised as non-representative of the non-sampling seasons (the flood and flood recession seasons). The exclusion of these seasons has not been deliberate but it has been done in an attempt to carry out the ecological survey within the limit of available funds and time.

Furthermore, available finance and time have limited the social survey to focus on 5% of the target population (residents of the Study Area that are 20 years and above). A higher proportion of respondents would have improved and increased the validity of the results. In addition, administering questionnaires face-to-face increased the cost of the research regarding time. However, the benefits of the value of the information / knowledge acquired directly through interview administered questionnaires cannot be overemphasised.

EcLA has a place in environmental assessment and management for equitable development, particularly in areas where livelihoods are strongly dependent on CPRs, such as rural communities in the developing World. Moreover, EcLA has been demonstrated as being an appropriate tool in the retrospective assessment of inland river dredging. However, the application of EcLA in industrialised countries and in places where livelihoods are not linked to CPRs may have limitations. Therefore, EcLA should be carefully adapted and modified to suit the socio-economic and or livelihoods scenarios, and the existing knowledge base, in these countries.

9. 3 Recommendations and further research

Based on the outcomes of this research, the recommendations below have been identified:

- Livelihood pattern should form the basis for planning development projects if the benefits of developments are to become equitable, particularly to residents of rural communities in developing countries and whose livelihoods are eco-dependent;
- TELK should be used in areas where baseline data are unavailable or inadequate to build a baseline scenario, as well as for planning for sustainable development. This knowledge source is long-term and has been developed from close inter-dependence on the local ecosystem;
- EcLA should be used as both a post project (retrospective) assessment approach to understanding post project impacts, as well as pre-project assessment in rural areas where livelihoods are dependent on CPRs; and
- The TELK of inland river fishers should be used in preparing a catalogue to identify inland river fish species in the Study Area. This catalogue could be used: as educational materials in schools specifically in the Study Area (and Ogbia LGA in general); in environmental assessment for new projects; as well as in fisheries management.

Achieving equitable development may appear a daunting task but commitment from environmental professionals and managers could help make this a reality. Commitment in research to understanding local livelihood and eco-livelihood consequences may be an area for consideration. The areas identified below are research issues that require further investigation:

- Environmental assessments in rural areas, where livelihoods depend on the environment, should actively involve local residents to assess local eco-livelihood. Community involvement could make such research more relevant to those whose livelihood may be impacted by development projects;
- Documentation of TELK in the Study Area, as well as the use of this knowledge source in the management of CPRs, could make development more equitable. A comprehensive system could be developed to test the level of reliability of TELK in rural communities where dependence of livelihoods on CPRs is common. This could be used to strengthen the justification for the use of TELK in environmental assessment and management;
- There is the need for the monitoring of livelihood patterns and distribution in the Study Area as well as in similar rural areas in the Developing World. Results from such studies can be used to update information on the dependence of rural people on CPRs and the relationship between rural communities and the environment;

- The TELK of fishers should be investigated on its merit and used to develop a comprehensive inland river fishery data base. This can be done by the distribution of log books to local fishers for the purpose of recording their respective daily fish catch. This information could be used as a baseline for environmental assessment as well as fishery management;
- TK, TEK, and TELK could be used to develop eco-livelihood risk ranking conceptual models that will represent the quantitative impacts of environmental issues that are of eco-livelihood significance;
- The eco-livelihood consequences of the disposal of dredged material on disposal sites as well on terrestrial habitats in the Study Area could be investigated; and
- There is the need for the evaluation of the impacts of development projects on CPRs. such research findings could be used to establish a compensation mechanism for the cost of anthropogenic impacts on those depending on these resources for their livelihoods.

References

Abakerli, S. (2001). "A critique of development and conservation policies in environmentally sensitive regions in Brazil." Geoforum **32**. 551-565.

Abam, T. K. S. (2001). "Regional hydrological research perspectives in the Niger Delta." Hydrological Sciences **46**(1): 13-25.

Abam, T. K. S. and Akagbue, C. O. (1986). "Construction and performance of river bank protection structure in the Niger Delta." Bulletin of the International Association of Engineering Geology **23**(4): 499-506.

Adams, S. M. (2003). "Establishing causality between environmental stressors and effects on aquatic ecosystems." Human and Ecological Risk Assessment **9**(1): 17-35.

Adams, S. M., Greeley, M. S., and Ryon, M. G. (2000). "Evaluating effects of contaminants on fish health at multiple levels of biological organisation: Extrapolation from lower to higher levels." Human and Ecological Risk Assessment **6**: 15-27.

Adolph, B., Butterworth, J., Conroy, C., and Morris, M. (2001). Common Pool Resources in Semi-arid India Problems and Potentials. Natural Resources Institute (NRI), Chatham, UK. Synthesis Report CRIDA / CWS / AKRSP (I) WRM Ltd. / MSU / NRI Common Pool Resources Research Project Report No. 4 (NRI Report No. 2650).

Agarwal, A. (1997). "Environmental pollution due to urbanisation in developing countries." New Scientist **154**(4): 51-54.

Ahmad, A. (1993). "Environmental impact assessment in the Himalayas: An ecosystem approach." AMBIO **22**(1): 4-9.

Akinluyi, T. O., and Odeyemi, O. (1984). "Human waste disposal and the faecal pollution of the River Niger Delta waters." Water International **9**: 37-41.

Akpoghomeh, A., and Okorobia, A.M. (1999). Chapter Eight: Population Profile. In The land and People of Bayelsa State: Central Niger Delta. Alagoa, E. J. Onyoma Research Publications, Choba Port Harcourt, Nigeria.

Al Bakri, D., Wickham, J., and Chowdhury, M. (1999). "Biophysical demand and sustainable water resources management: an Australian perspective." Hydrological Sciences **44**(4): 517-528.

Alagoa, E. J. (1999). The Land and People of Bayelsa Sate: Central Niger Delta. Onyoma Research Publications, Choba, Port Harcourt, Nigeria.

Albert, J.-J., and Laë, R. (2003). "Impact of fishing on fish assemblages in tropical lagoons: the example of the Ebrie lagoon, West Africa." Aquatic Living Resources **16**: 1-9.

Alderman, H., and Paxson, C. (1992). Do the Poor Insure? A Synthesis of the Literature on Risk and Consumption in Developing Countries. Research Program in Development Studies, Princeton University, Discussion Paper 164.

Aldridge, D. C. (2000). "The impacts of dredging and weed cutting on a population of freshwater mussels (Bivalvia: Unionidae)." Biological Conservation **95**: 247-257.

Alho, R. (1992). "The accuracy of environmental impact assessments: Skew prediction errors." AMBIO **21**(4): 322-323.

Allan, D. J., Erickson, D.L., and Fay, J. (1997). "The influence of catchment land use on stream integrity across multiple spatial scales." Freshwater Biology **37**: 149-161.

Allison-Oguru, E. A., Zuofa, K., and Berepubo, N.A. (1999). Chapter 23: Agriculture. In The land and People of Bayelsa State: Central Niger Delta. Alagoa, E. J. Onyoma Research Publications, Choba Port Harcourt, Nigeria.

Almeida, O. T., Lorenzen, K., and McGrath, D.G. (2002). Impact of co-management agreements on the exploitation and productivity of floodplain lake fisheries in the lower Amazon. Proceedings of the ninth international conference of the IASCP. http://dlc.dlib.indiana.edu/documents/dir0/00/00/07/82/dlc-00000782-00/almeidao080502.pdf

Alton, C. C. and Underwood, P. B. (2003). "Let us make assessment more accessible." Environmental Impact Assessment Review **23**: 141-153.

Anaya, J. (1996). Indigenous Peoples in International Law. Oxford University Press, New York, USA.

Anderson, I. (1992). "Ecological risk assessment of Transgenic Organisms: Sweden." AMBIO **21**(7): 483-486.

Angaye, G. S. (1999). Chapter 22: Industry and Trade. In The Land and People of Bayelsa State: Central Niger Delta. Alagoa, E. J. Onyoma Research Publications, Choba, Port Harcourt, Nigeria.

Anwar, S. K., Sastri, M. V., Rama Rao., K., Venkateshwarlu, D., and Srinivas, K. (2001). Common Pool Resources in Semi-arid India: Andhra Pradesh Regional Report. Natural Resources Institute (NRI), United Kingdom. NRI Report No. 2648. 64.

ARRC NEWS. (2005). Improving streams and rivers for aquatic life: riffles and pools, and streamside plants. Arizona Regional Resource Center (ARRC) NEWS. http://www.pwri.go.jp/team/kyousei/jpn/news/extra/extra_p03.pdf 25/04/ 2005

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S., Janssen, B.O., Levin, S., Maler, K.G., Perring, C., and Pimental, D. (1995). "Economic Growth, Carrying Capacity, and the Environment." Science **268**: 520-521.

Arthington, A. H., Lorenzen, K., Pusey, B.J., Abell, R., Halls, A.S., Winemiller, K.O., Arrington, D.A., Baran, E. (2003). River fisheries: ecological basis for management and conservation. Sustaining Livelihoods and Biodiversity in the New Millennium, Phnom Penh, Kingdom of Cambodia. 11-14 February 2003.

Ashley, C. and Carney, D. (1999). Sustainable Livelihoods: Lessons from early Experience. Department for International Development (DFID), London.

Augspurger, C. (1996). "Editor's note." Ecology **77**: 1698.

Ault, J. S., Bohnsack, B.A., and Meester, G.A. (1998). "A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in Florida Keys." Fishery Bulletin **96**(3): 395-414.

Ault, J. S., Lindeman, K.C., and Clarke, D.G. (1998). FISHFATE: Population dynamics models to assess risks of hydraulic entrainment by dredges. DOER Technical Notes Collection (TN DOER-E-4), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dots/doer 12/02/2003.

Baines, G. (2003). Traditional Environmental Knowledge from the Marovo Area of the Solomon Islands. International Development and Research Centre, Canada. http://web.idrc.ca/en/ev-43101-201-1-DO_TOPIC.html. 12/02/2005.

Balchand, A. N. and Rasheed, K. (2000). "Assessment of short term environmental impacts on dredging in tropical estuary." Terra et Aqua **79**(June).

Balirwa, J. S., Chapman, C. A., Chapman, L. J., Cowx, I.G., Geheb, K., Kaufman, L., Lowe-McConnell, R.H., Seehausen, O., Wanink, J.H., Welcomme, R. L., and Witte, F. (2003).

"Biodiversity and fishery sustainability in Lake Victoria Basin: An unexpected marriage?" Biological Science **53**(8): 703-716.

Balon, E. K., and Holcík, J. (1999). "Gabcíkovo river barrage system: The ecological disaster and economic calamity for the inland delta of the middle Danube." Environmental Biology and Fisheries **54**: 1-17.

Baran, E. (2000). Biodiversity of estuarine fish fauna in West Africa. The International Center for Living Aquatic Resources Management (ICLARM) Quarterly. 23(23) 4. 1-9 (October-December 2000).

Barbier, E. B., Burges, J.C., and Folke, C. (1994). Paradise Lost? The Ecological Economics of Biodiversity. Earthscan, London, UK.

Barker, R., and Cross, N. (2003). Documenting Oral History in African Sahel. International Development Research Centre, Canada. http://web.idrc.ca/en/ev-43109-201-1-DO_TOPIC.html. http://web.idrc.ca/en/ev-43109-201-1-DO_TOPIC.html 15/03/2005.

Barnthouse, L. W., and Stahl, R.G. Jr., (2002). "Quantifying natural resource injuries and ecological service reductions: Challenges and opportunities." Environmental Management **30**(1): 1-12.

Barret, B. F. D., and Therivel, R. (1991). Environmental Policy and Impact Assessment in Japan. Routledge, Chapman, and Hall, New York.

Barsh, R. L. (1997). "Forests, indigenous people, and biodiversity." Global Biodiversity **7**(1): 20-23.

Bates, A. D. (1998). Clear Water Revival, Dredging for a Better Environment - Development in Dredging Plant Methods to Minimise Environmental Impact. Summary of Presentation at CEDA Regional Seminar, University of Liverpool, A.D. Bates Partnership and Inland waters Consultant.

Beanlands, G. E., and Duinker, P.N. (1983). An Ecological Framework for Environmental Impact Assessment in Canada. Institute for Resource and Environment Studies, Dalhousie University, Halifax, Nova Scotia, and Federal Environmental Assessment Resource Office, Hull, Quebec.

Beck, T., and Ghosh, M.G. (2000). Common property resource and the poor: Findings from West Bengal. Economic and Political Weekly. 35(35) 147-153.

Beck, T., and Ghosh, M.G. (2001). "Building on poor people's capacities: the case of common property resources in India and West Africa." World Development **29**(1): 119-133.

Becker, C. D., and Ghimire, K. (2003). "Synergy between traditional ecological knowledge and conservation science supports forest preservation in Ecuador." Conservation Ecology **8**(1): 1. [online] URL: http://www.consecol.org/vol8/iss1/art1. 23/10/2004.

Bella, D. A. (2002). "Salmon and complexity: Challenges to assessment." Human and Ecological Risk Assessment **8**(1): 55-73.

Belovsky, G. E. (2002). "Ecological stability: Reality, misconceptions, and Implications for risk assessment." Human and Ecological Risk Assessment **8**(1): 99-108.

Berkes, F. (1977). "Fishery resource use in a sub-Arctic Indian community." Human Ecology **5**(4): 289-309.

Berkes, F. (1999). Sacred Ecology: Traditional ecological knowledge and resource management. Taylor and Francis, Philadelphia.

Berkes, F., and Colding, J., and Folke, C. (2000). "Rediscovery of traditional ecological knowledge as adaptive management." Ecological Applications **10**(5): 1251-1262.

Bielawski, E. (1992). "Inuit Indigenous knowledge and science in the Arctic." Northern Perspectives **20**(1): 8.

Biswas, A. K. (1997). Water Resources: Environmental Planning, Management and Development. McGraw Hill, New York.

Blanchard, A. L., and Feder, H.M. (2003). "Adjustment of benthic fauna following sediment disposal at a site with multiple stressors in Port Valdez, Alaska." Marine Pollution Bulletin **46**: 1590-1599.

Bojorquez-Tapia, L. A., and Juarez, L., and Cruz-Bello, G. (2002). "Integrating fuzzy logic, optimization, and GIS for ecological impact assessment." Environmental Management **30**(3): 418-433.

Bolund, P., and Hunhammar, S., (1999). "Ecosystem services in urban areas." Ecological Economics **29**: 293-301.

Booth, A., and Jacobs, H.M. (1990). "Ties that bind: native American beliefs as a foundation for environmental consciousness." Environmental Ethics **12**: 27- 43.

Booth, D. B., and Karr, J.R., Schauman, S., and Konrad, C.P. (2004). "Reviving Urban streams: land use, hydrology, biology, and human behaviour." Journal of the American Water Resources Association **4**(5): 1351-1364.

Bosseche Van Den, J. P., and Bernacsek, G.M. (1990). Source book for the inland fishery resources of Africa Vol. 2. Committee for Inland Fisheries of Africa (CIFA) Technical Paper, No 84. 25pp.

Bray, R. N. (1998). "A review of the past and a look to the future." Terra et Aqua **70**(March).

Bray, R. N., Bates, A.D., and Land, J.M. (1998). Dredging A Handbook for Engineers. John Wiley and Sons, Inc, New York.

Brehmer, M. L. (1965). "Turbidity and siltation as forms of pollution." Journal of Soil and Water Conservation **20**: 132-133.

Brigden, A. J. (1996). "Used dredged spoil as a topsoil substitute for derelict land reclamation." The Dock and Harbour Authority **77**(869): 85 – 89.

Brightbill, R. A., and Bilger, M.D. (1999). Fish-community composition in Cowanesque river upstream and downstream of the Cowanesque dam Tioga county, Pennsylvania, 1989. U.S. Army Corps of Engineers, Lemoyne, Pennsylvania, USA. Open-File Report 99-208. 20.

Brody, H. (1981). Maps and dreams: Indians and the British Columbia frontier. Douglas and McIntyre, Toronto, Ont., Canada.

Brookes, A. (1988). Channelized Rivers: Perspective for Environmental Management. John Wiley and Sons, Chichester UK.

Brookes, A. (1989). Alternative Channelization Procedures. Alternatives in Regulated River Management. Gore, J. A., and Petts, G.E. CRC Press, Inc., Boca Raton Florida**:** 139-162.

Bryman, A., and Cramer, D. (2005). Quantitative data analysis with SPSS 12 and 13. Routledge Taylor and Francis Group, London, UK.

BSEDPA. (1998). Report on the ecological tour of Bayelsa State. Bayelsa State Environment and Development Planning Authority (BSEDPA), Yenagoa, Nigeria.

Budds, J. (1999). The role of environmental education in addressing environmental problems in Squatter settlements: Case study of Igarape do Quarenta Manaus, Brazil. Institute of Latin America Studies, University of London, London. MSc. Thesis.

Burt, T. N., and Hayes, D.F. (2005). "Framework for research leading to improved assessment of dredge generated plumes." Terra et Aqua **98**: 20-31.

Canter, L. W. (1996). Environmental Impact Assessment. McGraw-Hill, Inc., London.

Capp, J. C., and Jorgensen, C. (1997). Traditional knowledge: Don't leave home without it. Paper presented at the 62nd North American Wildlife and Natural Resources Conference, Washington DC.

Capra, F. (1982). The turning point: science, society and the rising culture. Bantam Books, Toronto, Ont., Canada.

Carney, D. (1998). Sustainable Rural Livelihoods: What contribution can we make? Russell Press Ltd., Nottingham, UK.

Carpenter, K. E., and Brampton, A.H. (1996). Maintenance and enhancement of saltmarshes: Draft Project Record – Volume 1. National Rivers Authority (NRA) R and D Note 567/1/SW.,

Castillo, A. (2000). "Ecological information system: Analyzing the communication and utilization of scientific information in Mexico." Environmental Management **25**(4): 383-392.

CEDA. (1999). Dredging: the facts. Central Dredging Association (CEDA), Al Deft, The Netherlands. 6.

Chambers, R. (1978). "Identifying research priorities in water development." Water Supply and Management **2**: 389-398.

Chambers, R., and Conway, G. R. (1992). Sustainable Livelihoods: Practical Concepts for the 21st Century. Institute of Development Studies, DP296.

Chapman, P. M. (1992). "Regulatory uses of aquatic toxicology (pitfalls and opportunities)." Canada Technical Report on Fisheries and Aquatic Science **1863**: 2-12.

Chen, D., Duan, X., Liu, S., and Shi, W. (2003). Status and management of fishery resources of the Yangtze river. Proceedings of the Second International Symposium on the Management of Large Rivers (Sustaining Livelihoods and Biodiversity in the New Millennium), Phnom Penh, Kingdom of Cambodia, Food and Agriculture Organisation of the United Nations and the Mekong River Commission.

Chen, M. (1991). Coping with seasonality and drought. Sage Publication, New Delhi.

Chiesura, A., and De Groot, R. (2003). "Critical natural capital: a socio-cultural perspective." Ecological Economics **44**(1): 219-231.

Chokkalingam, U., Kurniawan, I., and Ruchiat, Y. (2005). "Fire, livelihoods, and environmental change in the middle Majakam Peatlands, East Kalimantan." Ecology and Society **10**(1): 26 [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art26/.

CIRIA (1994). Environmental Assessment. Construction Industry Research and Information Association (CIRIA) Special Publication 96, Westminster, London.

CIRIA. (1997). Inland dredging - Guidance on Good Practice. Construction Industry Research and Information Association (CIRIA), Westminster, London. 181.

Coates, D., Bovin, T., Darwall, W.R.T., Friend, R., Hirsch, P., Poulsen, A.F., Quirós, R., Visser, T.A.M., and Wallace, M. (2003). Review information, knowledge and policy. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, Phnom Penh, Kingdom of Cambodia, Food and Agriculture Organisation of the United Nations and the Mekong River Commission.

Colorado, P. (1988). "Bridging Western and native science." Convergence **21**: 213.

Conroy, C. (2002). PRA tools used for research into common pool resources. Socio-economic Methodologies for Natural Resources Research. Best Practice Guidelines. Natural Resources Institute (NRI), Chatham, UK.

Conroy, C., and Patterson, R.T. (2000). A Review of literature on silvipasture management and development on common lands in semi-arid region. BAIF / NRI Goat Research Project, Report No.3.

Conroy, C., and Rangnekar, D.V. (2000). Livestock and the Poor in Rural India, with Particular Reference to Goat-Keeping. BAIF/NRI, BAIF/NRI Goat Project Report Number 1.

Crisman, T. L., Chapman, L.J., and Kaufman, L.S. (2003). Conservation Ecology, and Management of African Fresh Waters. University Press of Florida, Florida, USA.

Cruikshank, J. (2001). "Glaciers and climate change: perspectives from oral tradition." Artic **54**(4): 377-393.

CSIR. (2005). North West community creates awareness of indigenous knowledge systems among youth. Council for Scientific and Industrial Research (CSIR).

http://www.csir.co.za/plsql/ptl0002/PTL0002_PGE038_ARTICLE?ARTICLE_NO=7285638 3/06/2005

Daily, G. C., Söderqvist, T., Aniyar, S., Arrow, K., Dasgupta, P., Ehrlich, P.R., Folke, C., Jansson, A., Jansson, P., Kautsky, N., Levin, S., Lubchenco, J., Mäler, K., Simpson, D., Starrett, D., Tilman, D., and Walker, B., (2000). "The value of nature and the nature of value." Science **289**: 395-396.

Dale, V. H., and Beyeler, S.C. (2001). "Challenges in the development and use of ecological indicators." Ecological Indicators **1**: 3-10.

De Groot, R. (1992). Functions of Nature. Wolters-Noordhoff, Groningen, Netherlands.

De Groot, R., Van der Perk, J., Chiesura, A., and Van Vliet, A. (2003). "Importance and threat as determining factors for critical of natural capital." Ecological Economics **44**(1): 187-204.

De Groot, R., Wilson, M., and Boumans, R. (2002). "A typology for the description, classification and valuation of Ecosystem functions, Goods and Services." Ecological Economics **41**(3): 367-567.

DFID. (2000). Sustainable Livelihoods Guidance Sheets. Department for International Development (DFID), London, UK.

Dickerson, D., Reine, K., Nelson, D., and Dickerson. C. Jr.,. (1995). Assessment of sea turtle abundance in six south Atlantic US channels. Army Engineer Waterways Experiment Station, Vicksburg, MS. EL-95-5.

Dickerson, D. D., Reine, K. J., and Clarke, D. G. (1998). "Economic impacts of environmental windows associated with dredging operations,". U.S. Army Engineer Research and Development Center, Vicksburg, MS. DOER Technical Notes Collection (TN DOER-E3). www.wes.army.mil/el/dots/doer 12/02/2005.

Diep, L., Ly, S., and Van Zalinge, N.P. (1998). Catch Statistics of the Cambodian Freshwater Fisheries. Mekong River Commission.

Doberstein, C. P., Karr, J.R., and Conquest, L.L. (2000). "The effect of fixed-count subsampling on macroinvertebrate biomonitoring in small streams." Freshwater Biology **44**: 355-371.

DPR. (2002). Environmental Guidelines and Standard for the Petroleum Industry in Nigeria. Department of Petroleum Resources (DPR), Lagos, Nigeria.

Edwards-Jones, G., Edwards-Jones, E.S., and Mitchell, K. (1995). "A comparison of contingent valuation methodology and ecological assessment as techniques for incorporating ecological goods into land-use decisions." Journal of Environmental Planning and Management **38**(2): 215-230.

Egborge, C. E. (1980). Environmental pollution problems of small communities in the Niger Delta. Water and Waste Engineering in Africa, Kaduna, Nigeria, Proceedings of the 6th, Conference of the Water, Engineering and development Centre (WEDC), Loughborough University of Technology UK, 24 - 28 March.

Ekins, P., Simon, S., Deutsch, L., Folke, C., and De Groot, R. (2003). "A framework for the practical application of the concepts of critical natural capital and string sustainability." Ecological Economics **44**(1): 165-185.

Ellen, R., and Harris, H. (1996). Concepts of Indigenous environmental knowledge in scientific and developmental studies literature: A critical assessment. East-West Environmental Linkages Network Workshop 3, Canterbury 8-10 May 1996.

Ellery, W. N., and McCarthy, T.S. (1994). "Principles for the sustainable utilisation of the Okavango Delta ecosystem, Botswana." Biological Conservation **70**: 159-168.

Ellery, W. N., and McCarthy, T.S., (1998). "Environmental change over two decades since dredging and excavation of the lover Boro River, Okavango Delta, Botswana." Journal of Biogeography **24**: 361-378.

Environment Agency. (2005). Fluvial Trent Strategy. Environmental Agency Midlands Region, Nottingham. 148.

Environment Canada. (1997). Evaluating the Environmental Impact of Dredging Burnaby Lake. Environment Canada (EC), North Vancouver, B.C. 107.

Farrington, J. and Lomax, J. (2001). "Rural Development and the 'New Architecture of Aid': Convergence and Constraints." Development Policy Review **19**(4): 533-544. http://www.blackwell-synergy.com/loi/dpr

Feit, H. (1986). James Bay Cree Indian management and moral considerations of fur bearers. In Native people and renewable resource management, Edmonton, Aha., Canada, Alberta Society of Professional Biologists.

Fenge, T. (1997). "Ecological change in the Hudson Bay Bioregion: A traditional ecological knowledge perspective." Northern Perspectives **25**: 1.

Fernadez-Gimenez, M. E. (2000). "The role of Mongolian Nomadic Pastoralists' ecological Knowledge in rangeland management." Ecological Applications **10**(5): 1318-1326.

Field, A. (2005). Discovering statistics using SPSS. SAGE Publications Ltd., London, UK.

Folke, C. (2004). "Traditional knowledge in social–ecological systems." Ecology and Society **9**(3): 7. [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art7/.

Folke, C., Hammer, M., Costanza, R., and Jansson, A. (1994). Investing in natural capital - why, what, and how? Investing in Natural Capital. In: Jansson, A., Hammer, M., Folke, C., and Costanza, R. Island Press, Washington, DC. USA**:** pp: 1 - 20.

Fore, L. S., Karr, J.R., and Wisseman, R.W. (1996). "Assessing invertebrate responses to human activities: Evaluating alternative approaches." Journal of the North American Benthological Society **15**(212-231).

Forese, R., and Pauly, D., (Editors). (2005). FishBase. World Wide Web electronic publication. www.fishbase.org

Forrest, S. (2000). Indigenous knowledge and its representation within Western Australian's new curriculum framework. The Australian Indigenous Education Conference, Fremantle, 3 - 7 April 2000.

Freeman, M. M. R. (1992). "The nature and utility of traditional ecological knowledge." Northern Perspectives **20**(1): 8.

Friends of the Earth. (2000). Dubious Development: How the World Bank's Private Arm is Failing the Poor and the Environment. Friends of the Earth, Washington, DC. 24.

Gadgil, M., and Berkes, F. (1991). "Traditional resources management systems." Resource management and Optimization **8**(3-4): 127–141.

Gadgil, M., Berkes, F., and Folke, C. (1993). "Indigenous knowledge for biodiversity conservation." Ambio **22**(2-3): 151-156.

Gadgil, M., Seshagiri, P.R., Utkarsh, G., Pramod, P., and Chhatre, A. (2000). "New meanings for old knowledge: the people's biodiversity registers program." Ecological Applications **10**(5): 1307-1317.

Ganasan, V., and Hughes, R.M. (1998). "Application of an index of biological integrity (IBI) to fish assemblages of the rivers Khan and Kshipra (Madhya Pradesh), India." Freshwater Biology **40**: 367-383.

Garibaldi, A., and Turner, N (2004). "Cultural keystone species: implications for ecological conservation and restoration." Ecology and Society **9**(3): 1. [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art1.

Gebhards, S. (1973). Effects of channelization on fish. In Panel of Stream Channelization and Trout Fisheries (White, R.J. ed.). Trout. 14(14) 23-24.

George, C. (1999). "Testing for sustainable development through environmental assessment." Environmental Impact Assessment Review **19**: 175-200.

Ghimire, S., McKey, D., and Aumeeruddy-Thomas, Y. (2004). "Heterogeneity in ethnoecological knowledge and management of medicinal plants in the Himalayas of Nepal: implications for conservation." Ecology and Society **9**(3): 6. [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art6/.

Gilchrist, G., Mallory, M., and Merkel, F. (2005). "Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds." Ecology and Society **10**(1): 20. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art20/.

Gilkinson, K. D., Fader, G.B.J., Gordon Jr., D.C., Charron, R., McKeown, D., Roddick, D., Kenchington, E.L.R., MacIsaac, K., Bourbonnais, C., Vass, P., and Liu, Q. (2003). "Immediate and long-term impacts of hydraulic clam dredging on an offshore sandy seabed: effects on physical habitat and processes of recovery." Continental Shelf Research **23**: 1315-1336.

Giller, P. S., and Malmqvist, B. (2001). The Biology of Streams and Rivers. Oxford University Press., New York, USA.

Gobo, A. E., and Abam, T.K.S. (1991). "The floods In the Niger Delta: The case of Ndoni." The Journal of Meteorology **16**(163): 293-299.

Gore, J. A., and Petts, G.E. (1989). Alternatives in Regulated River Management. CRC Press, Inc., Boca Raton Florida.

Gough, C., Castells, N., and Funtowicz, S. (1998). "Integrated Assessment: An emerging methodology for complex issues." Environmental Modelling and Assessment **3**: 19-29.

Grigalunas, T., Opaluch, J.J., and Luo, M. (2001). "The economic costs of fisheries from marine sediment disposal: case study of Providence, RI, USA." Ecological Economics **38**: 47-58.

Gunn, A., Arlooktoo, G., and Kaomayak, D. (1988). The contribution of ecological knowledge of Inuit to wildlife management in the Northwest Territories. In Traditional knowledge and renewable resource management. Freeman, M. M. R. and Carbyn, L. N., ed. Occasional Publication, Boreal Institute for Northern Studies, Edmonton, Aha., Canada.

Gupta, A. K., Oza, A., Pastakia, A., Saxena, R., Desai, U., and Underwood, B. (2001). Common Pool Resources in Semi-arid India: Gujarat Regional Report. Natural Resources Institute (NRI Report No. 2649). 96.

Gupta, A. K., Sinha, R., Koradia, D., Patel, R., Parmar, M., Rohit, P., Patel, H., Patel, K., Chand, V.S., James, T.J., Chandan, A. Patel, M., Prakash, T.N., and Vivekanandan, P. (2003). "Mobilizing grassroots' technological innovations and traditional knowledge, values and institutions: articulating social and ethical capital." Futures **35**: 975-987.

Gutierrez, M. A. R. (1994). Utilizacion de la istiofauna como indicadora de la integridad biotica de losRios Gouche and Guanare Estado Portuguesa, Venezuela. Universidad National Experimental de los Llanos Occidentales "Ezequiel Zamora", Guanare, Venezuela. Cited in Karr, J. R., and Rossano, E.M. (2001). "Applying public health lessons to protect river health." Ecology and Civil Engineering Society 4(1): 3-18.

Hardin, G. (1963). "The tragedy of the commons." Science **162**: 1243-1248.

Hartmann, W., Dugan, P., Funge-Smith, S., Hortle, K.G., Kuemlangan, B., Lorenzen, K., Marmulla, G., Mattson, N., and Welcomme, R. (2003). People and fisheries management. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries (Sustaining Livelihoods and Biodiversity in the New Millennium), Phnom Penh, Kingdom of Cambodia, Food and Agriculture Organisation of the United Nations and Mekong River Commission.

Harvard Center for Risk Analysis. (2005). The CEA Register. Harvard Center for Risk Analysis, Harvard School of Public Health, Boston MA USA. http://www.hsph.harvard.edu/cearegistry/glossary.html

Hay, C. J., Van Zyl, B.J., and Steyn, G.J. (1996). "A quantitative assessment of the biotic integrity of the Okavango River, Namibia, based on fish." Water South Africa **22**(3): 263-284.

Hernández-Cornejo, R., Koedam, N., Luna, A.R., Troell, M., and Dahdouh-Guebas, F. (2005). "Remote sensing and ethnobotanical assessment of the mangrove forest changes in the Navachiste-San Ignacio-Macapule lagoon complex, Sinaloa, Mexico." Ecology and Society **10**(1): 16 [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art16/.

Hobson, G. (1992). "Traditional knowledge is science." Northern Perspectives **20**(1): 3.

Hoggarth, D. D. (1999). Management Guidelines for Asian Floodplain Fisheries: A spatial, hierarchical and integrated strategy for adaptive co-management. Food and Agriculture Organisation (FAO), Rome. Fisheries Technical Paper 384/2 FAO.

Hossain, S., Eyre, B.D., and McKee, L.J. (2004). "Impacts of dredging on dry season suspended sediments concentration in Brisbane estuary, Queensland, Australia." Estuarine, Coastal and Shelf Science **61**: 539-545.

HRW. (1999). The Price of Oil: Corporate responsibilities and Human Rights Violations in Nigeria's Oil Producing Communities. Human Right Watch (HRW), New York, USA. http://www.hrw.org/reports/1999/nigeria/

Hughes, F. M. R., and Rood, S.B. (2001). Floodplains in habitat Conservation Managing the Physical Environment. John Wiley and Sons Limited, New York USA.

Hughes, F. M. R., Colston, A., and Mountford, J.O. (2005). "Restoring riparian ecosystems: the challenge of accommodating variability and designing restoration trajectories." Ecology and Society **10**(1): 12 [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art12/.

Hugueny, B., Camara, S., Samoura, B., and Magassouba, M. (1996). "Applying an index of biotic integrity based on fish assemblages in a West African river." Hydrobiologia **331**: 71-78.

Huitric, M. (2005). "Lobster and conch fisheries of Belize: a history of sequential exploitation." Ecology and Society **10**(1): 21 [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art21/.

Huntington, H. P. (2000). "Using traditional ecological knowledge in science: methods and applications." Ecological Applications **10**(5): 1270-1274.

Huntington, H. P., Brown-Schwalenberg, P.K., Frost, K.J., Fernandez-Gimenez, M.E., Norton, D.W., and Rosenberg, D.H. (2002). "Observation on Workshop as a means of improving communication between holders of traditional and scientific knowledge." Environmental Management **30**(6): 778-792.

Huntington, H. P., Callaghan, T.V., Gearheard, S.F., Krupnik, I. (2004). "Matching traditional and scientific observations to detect environmental change: a discussion on arctic terrestrial ecosystems." AMBIO Special Report **13**: 18-23.

Ibarra, A. A., Reid, C., and Thorpe, A. (2000). "The political economy of marine fisheries development in Peru, Chile and Mexico." Journal of Latin American Studies **32**: 503-527.

Ikomi, R. B. (1996). "Studies on the growth pattern, feeding habits and reproductive characteristics of the Mormyrid *Brienomyrus longianalis* (Boulenger 1901) in the upper Warri River, Nigeria." Fisheries Research **26**: 187-198.

IUCN. (1980). World conservation strategy. IUCN (International Union for the Conservation of Nature and Natural Resources), UNEP (United Nations Environment Programme), and WWF (World Wildlife Fund), Morges, Switzerland.

Iyengar, S., and Shukla, N. (1999). Regeneration and Management of Common Property Land Resources (CLPRs) in India: A Review. Gujarat Institute of Development Research, Ahmedabad. Working Paper No 110.

Jackson, L. E., Janis, C.K., and William, S.F. (2000). Evaluation Guidelines for Ecological Indicators. U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC. EPA/620/R-99/005. 107.

Jodha, N. S. (1986). "Common property resources and rural poor in dry regions of India." Economic and Political Weekly **31**(27): 1169-1181.

Jodha, N. S. (1990). Rural Common Property Resources: Contribution and Crisis. Economic and Political Weekly. 30(30) A65 - A78.

Jodha, N. S. (1996). Management of Common Property Resources in selected dry areas of India. Natural Resource Economics: Theory and Applications in India. Kerr. Oxford and IBH Publication Co. Pvt. Ltd., New Delhi, India.

Jodha, N. S. (2000). Waste Lands Management in India: Myths, Motives and Mechanisms. Economic and Political Weekly. February 5(February 5) 466-473.

Johannes, R. E. (1992). Integrating traditional ecological knowledge and management with environmental assessment. Natural Resources Institute, Winnipeg, Man., Canada.

Johnson, M. (1992). "Dene traditional knowledge." Northern Perspectives **20**(1): 5.

Johnson, M. (2003a). Research on Traditional Environmental Knowledge: Its Development and Its Role. The International Development Research Centre, Canada. http://web.idrc.ca/en/ev-43097-201-1-DO_TOPIC.html. 22nd April 2005.

Johnson, M. (2003b). Traditional Environmental Knowledge of the Dene: A Pilot Project. International Development Research Centre, Canada. http://web.idrc.ca/en/ev-43099-201-1-DO_TOPIC.html.

Johnson, M. (2005). Research on Traditional Environmental Knowledge: Its Development and Its Role. The International Development Centre (IDRC) Canada. http://www.eepsea.org/en/en-43097-201-1-DO_TOPIC.html 02/02/2005

Johnson, M., and Ruttan, R. (1991). Dene traditional environmental knowledge: pilot project. Dene Cultural Institute, Hay River, NWT, Canada.

Jooste, S., and Claassen, M. (2001). "Rationale for an ecological risk approach for South African water resource management." Water South Africa **27**(3): 283-292.

Kapp, K. M. (2003). "How long does it take? Estimation methods for developing e-learning, learning circuits." Online Journal of Anerican Society of Training and Development **July 2003**. http://www.learningcircuits.org/2003/jul2003/kapp.htm

Karr, J. R. (1981). "Assessment of biotic integrity using fish communities." Fisheries **6**(6): 21-27.

Karr, J. R. (1991). "Biological integrity: a long-neglected aspect of water resource management." Ecological Applications **1**: 66-84.

Karr, J. R. (2000). Health, integrity and biological assessment: The importance of whole things. in Ecological Integrity: Integrating Environment, Conservation, and Health. Pimentel, P., Westra, L., and Noss, R.F., editors. Island Press, Washington, DC USA.

Karr, J. R. (2003). Biological Integrity and Ecological Health. in Fundamentals of Toxicology. (Newman, M. C., and Unger, M.A. ed.,). Lewis, Publishers, Boca Raton, Florida, USA.

Karr, J. R., and Chu, E.W. (1999). Restoring life in running waters: Better biological monitoring. Island Press, Washington DC.

Karr, J. R., and Chu, E.W. (2002). Biological Monitoring: Essential Foundation for Ecological Risk Assessment. University of Washington, Seattle WA 98195.

Karr, J. R., and Dudley, D.R. (1981). "Ecological perspective on water quality goals." Environmental Management **5**: 55-68.

Karr, J. R., and Kimberling, D.N. (2003). "A terrestrial arthropod index of biological integrity for Shrub-steep." Northwest Science **77**(3): 202-213.

Karr, J. R., and Rossano, E.M. (2001). "Applying public health lessons to protect river health." Ecology and Civil Engineering Society **4**(1): 3-18.

Karr, J. R., and Yoder, C.O. (2004). "Biological assessment and criteria improve total maximum daily load decision making." Journal of Environmental Engineering **130**: 594-604.

Karr, J. R., Fausch, K.D., Angermeier, P.L., Yant, P.R., and Schlosser, I.J. (1986). "Assessment of biological integrity in running waters: A method and its rationale." Natural History Survey: Special Publication No. 5. Champaign, Illinois.

Kay, J. J. (1991). "A Nonequilibrium Thermodynamic Framework for Discussing Ecosystem Integrity." Environmental Management **15**: 483-495.

Keeler, A. G., and McLemore, D. (1996). "The value of incorporating bioindicators in economic approaches to water pollution control." Ecological Economics **19**: 237-245.

Kikula, I. S. (1999). "Lessons from twenty-five years of conservation and seven years of research initiatives in Kondoa Highlands of central Tanzania." AMBIO **28**(5): 444-449.

Kirkpatrict, C., and Lee, N. (1997). Sustainable Development in a Developing World: Integrating Environmental Assessment with Socio-Economic Appraisal. Cheltenham: Edward Elgar.

Kleynhans, C. J. (1999). "The development of a fish index to assess the biological integrity of South African rivers." Water South Africa **25**(3): 265-278.

Klubnikin, K. A., C., Cherkasova, M., Shishin, M., and Fotieva, I. (2000). "The sacred and the scientific: traditional ecological knowledge in Siberian River conservation." Ecological Applications **10**(5): 1296-1306.

Kolsky, P. (1998). Storm drainage: an engineer guide to the low-cost evaluation of system performance. Biddles, Guildford and King'sLynn.

Koranteng, K. A., Ofori-Dason, P.K. and Entsua-Mensah, M. (2000). "Fish and fisheries of the Muni lagoon in Ghana, West Africa." Biodiversity and Conservation **9**: 487-499.

Koziell, I. (1998). Biodiversity and sustainable rural livelihoods. Department for International Development's Natural Resources Advisers' Conference, London, UK, Department for International Development (DFID). July 1998.

Kurien, J. (2000). "Traditional ecological knowledge and ecosystem sustainability: new meaning to Asian coastal proverbs." Ecological Applications **10**(5): S2-S5.

Kwak, S. J., Yoo, S.H., and Shin, C.O. (2002). "A multivariate index for assessing environmental impacts of regional development projects: A case study of Korea." Environmental Management **29**(2): 301-309.

Laë, R. (1994). "Effects of drought, dams and fishing pressure on the fisheries of the Central Delta of the Niger River." International Journal of Ecology and Environmental Sciences **20**: 119-128.

Laë, R., Williams, S., Malam Massou, A., Morand, P., and Mikolasek, O. (2003). Review of the present state of the environment, fish stocks and fisheries of the river Niger (West Africa). Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries (Sustaining Livelihoods and Biodiversity in the New Millennium), Phnom Penh, Kingdom of Cambodia, Food and Agriculture organisation of the United Nations and the Mekong River Commission.

Landers, D. H., Bangay, G., Sisula, H., Colborn, T., Liljelund, L.-E. (1995). "Airbone contaminants in the Artic: what we need to know." The Science of the Total Environment **160/161**: 841-848.

Landis, W. G., Matthews, R.A., and Matthews, G.B. (1995). "A Contrast of Human Health Risk and Ecological Risk Assessment: Risk assessment for an Organism Versus a Complex Nonorganismal Structure." Human and Ecological Risk Assessment **1**(5): 485-488.

Lee, N., and George, C. (2000). Environmental Assessment in Developing and Transitional Countries. John Wiley and Sons, Ltd, Chichester, UK.

LegCo. (2001). Impact of Dredging and Reclamation on the Marine Environment. LegCo Panel Environmental Affairs,

Lemly, A. D. (1997). "Risk assessment as an environmental management tool: Consideration for fresh wetlands." Environmental Management **21**(3): 343-358.

Lévêque, C. (1995). "Role and consequences of fish diversity in the functioning of African freshwater ecosystems: a review." Aquatic Living Resources **8**: 59-78.

Little, A. D. (1973). Channel Modification: An Environmental, Economic and Financial Assessment. Cited in Brookes, A. (1989). Alternative Channelization Procedures. Alternatives in Regulated River Management. J. A. Gore, and Petts, G.E. Boca Raton Florida, CRC Press, Inc.: 139-162. Report to the Council on Environmental Quality, Executive Office of the President, Washington D.C.

Lorenzen, K., and Arthington, A.H. (2003). Ecological basis for management and conservation. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, Phnom Penh, Cambodia Kingdom, Food and Agriculture Organisation of the United Nations and the Mekong River Commission.

Lubke, R. A., Reavell, P.E., and Dye, P.J. (1984). "The effects of dredging on the macrophyte vegetation of the Boro River, Okavango Delta, Botswana." Biological Conservation **30**: 211-236.

Lyons, J., Navarro-Perez, S., Cochran, P.A., Santana, C.E., and Guzman-Arroyo, M. (1995). "Index of biotic integrity based on fish assemblages for the conservation for streams and rivers in west-central Mexico." Conservation Biology **9**: 569-584.

Maass, J., Balvanera, P., Castillo, A., Daily, G. C., Mooney, H.A., Ehrlich, P., Quesada, M., Miranda, A., Jaramillo, J.V., García-Oliva, F., Martínez-Yrizar, A., Cotler, H., López-Blanco, J., Pérez-Jiménez, A., Búrquez, A., Tinoco, C., Ceballos, G., Barraza, L., Ayala, R., and Sarukhán, J (2005). "Ecosystem services of tropical dry forests: insights from long-term ecological and social research on the Pacific Coast of Mexico." Ecology and Society **10**(1): 17. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art17/.

Mackinson, S. (2001). "Integrating local and scientific knowledge: An example in fisheries science." Environmental Management **27**(4): 533-545.

Makhdoum, M. F. (2002). "Degradation Model: A Quantitative EIA Instrument, Acting as a Decision Support System (DSS) for Environmental Management." Environmental Management **30**(1): 151-156.

Mauro, F., and Hardison, P. (2000). "Traditional knowledge of indigenous and local communities: International debate and policy initiatives." Ecological Applications **10**(5): 1263-1269.

McCauley, R. W. (1977). "Laboratory methods for determining temperature preference." Journal of the Fisheries Research Board of Canada **34**(749-752).

McDonnell, R. (1992). "Assessing the impacts: The UK Situation." AMBIO **21**(2): 188-191.

McGregor, G. R. (1993). "A multivariate approach to the evaluation of the climatic regions and climatic resources of China." Geoforum **24**(4): 357-380.

Miller, G. T., Jr. (2002). Living in the Environment: principles, connections,a nd solutions. Brooks/Cole Thomas Learning, Stamford, USA.

Moller, H., Berkes, F., Lyver, P.O., and Kislalioglu, M. (2004). "Combining sciences and traditional ecological knowledge: monitoring populations for co-management." Ecology and Society **9**(3): 2 [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art2.

Morley, S. A., and Karr, J.R. (2002). "Assessing and restoring the health of urban streams in the Puget Sound Basin." Conservation Biology **16**(6): 1498-1509.

Moses, B. S., Udoidiong, O.M., and Okon, A.O. (2002). "A statistical survey of the artisanal fisheries of south-eastern Nigeria and the influence of hydroclimatic factors on catch and resource productivity." Fisheries Research **57**: 267-278.

Muller, A., and Vickers, M. (1996). Communication in a Common Pool Resource Environment with Probabilistic Destruction. Department of Economics, McMaster University, Working Paper, 96-106.

Mulvihill, P. (1988). Integration of the state and indigenous systems of wildlife management: problems and possibilities. School of Urban and Regional Planning, Faculty of Environmental Studies, University of Waterloo, Waterloo, Ont., Canada.

Munns, W. R., Jr., and MacPhail, R. (2002). "Extrapolation in human health and ecological risk assessments: Proceedings of a symposium." Human and Ecological Risk Assessment **8**(1): 1-5.

Murray, L. A. (1994). Progress in England and Wales on the development of beneficial uses of dredged material. Conference on Dredging, 13-16 November.

Nabhan, G. P. (1997). Cultures of habitat: on nature, culture, and story. Counterpoint, Washington D.C., USA.

Nadasdy, P. (1999). "The politics of TEK: Power and the "integration" of knowledge." Arctic Anthropology **36**(1): 1-18.

Nakashima, D. (1990). Application of native knowledge in EIA: Inuit eiders and Hudson Bay oil. Canadian Environmental Assessment Research Council, Hull, Que., Canada.

National Research Council (2000). Ecological Indicators for the Nation. National Academy Press, Washington, DC USA.

NDBDA. (1980). Report on the Investigation of Possible Flood Protection Measures in Nun and Forcados Rivers Area by the Flood Protection Delegation (Democratic People's Republic of Korea). Niger Delta Basin Development Authority (NDBDA), Port Harcourt, Nigeria.

NDBDA. (1992). Estimated Rainfall (mm) at Peramabiri, Nigeria, from 1948 to 1992. Niger Delta Basin Development Authority (NDBDA), Port Harcourt, Nigeria.

NDES. (1997). Niger Delta Environmental Survey Phase 1 Report. Niger Delta Environmental Survey (NDES), Lagos, Nigeria.

Neefjes, K. (2000). Environments and Livelihoods: Strategies for Sustainability. Oxfam Publishing, Oxford, United Kingdom.

Neiland, A. E., Weeks, J., Madakan, S.P., and Ladu, B.M.B. (2000). "Inland fisheries of the North East Nigeria including the upper River Benue, Lake Chad and Nguru-Gashua wetlands II. Fisheries management at village level." Fisheries Research **48**: 245-261.

Nepal, S. K. (2002). "Involving indigenous peoples in protected area management: comparative perspectives from Nepal, Thailand, and China." Environmental Management **30**(6): 748-763.

Njiru, M., Othina, A., and Cowx, I.G. (2002). Lake Victoria invasion by water hyacinth a blessing for Lake Victoria fisheries. Management and Ecology of Lake and Reservoir Fisheries. in Cowx, I. G. Blackwell Science, Oxford, UK.

NPC. (1997). Census 1991 Final Results. National Population Commission (NPC), Abuja, Nigeria. OFFICIAL GAZETTE No. 25, VOL. 84 Rivers State.

NRA. (1994). Water - Nature's Precious Resource. An Environmental Sustainable Water Resources Development Strategy for England and Wales. National Rivers Authority (NRA), Bristol.

Nunan, F., Grant, U., Bahiigwa, G., Bajracharya, P., Pritchard, D., and Vargas, M.J. (2002). Poverty and the environment: a study of the poverty-environment indicators with case studies from Nepal, Nicaragua and Uganda. Department for International Development (DFID), London. 70.

Nwankwo, D. I. (1996). "Notes on the effects of human induced stressors in parts of the Niger Delta, Nigeria." Polish Ecological Studies **22**(1-2): 71-78.

NYSDEC. (2005). Key to Aquatic Macroinvertebrates. New York State Department for Environmental Conservation (NYSDEC). http://www.dec.state.ny.us/website/dow/stream/ 19 / 05 / 2005

Oberdorff, T., and Hughes, R.M. (1992). "Modification of an index of biotic integrity based on fish assemblages to characterize rivers of the Seine-Nomadic Basin, France." Hydrobiologia **228**: 117-130.

O'Brien, M. H. (1995). "Ecological Alternatives Assessment Rather than Ecological Risk Assessment: considering Options, Benefits, and Hazards." Human and Ecological Risk Assessment **1**(4): 357-366.

Ohimain, E. I. (2004). "Environmental impacts of dredging in the Niger Delta." Terra et Aqua **97**: 9-19.

Ohimain, E. I., Imoobe, T.O.T., and Benka-Coker, M.O. (2005). "The impact of dredging on macrobenthic invertebrates in a tributary of the Warri River, Niger Delta." African Journal of Aquatic Sciences **30**(1): 49-54.

Okagbue, C. O. (1989). "Geotechnical and environmental problems of the Niger Delta." Bulletin of the International Association of Engineering Geology.

Okpanefe, M. O. (1991). "A method of monitoring fishery status." Fisheries Research **11**(2): 171-175.

Olaniyi, B. (2003). Communities Reject Dredging of the River Niger. The Punch. Lagos, Nigeria. 1 & 8.

Olokesusi, F. (1992). "Environmental impact assessment in Nigeria: Current situation and directions for the future." Journal of Environmental Management **35**: 163-171.

Olsson, P., and Folke, C. (2001). "Local ecological knowledge and institutional dynamics for ecosystem management: a study of Lake Racken watershed, Sweden." Ecosystems **4**: 85-104.

O'Neill, R. V., Gardner, R.H., Barnthouse, L.W., Suter, G.W. II, Hildebrand, S.G., and Gehrs, C.W. (1982). "Ecosystem risk analysis: a new methodology." Environmental Toxicology and Chemistry. **1**: 167-177.

Orfanids, S., Panayotidis, P., and Stamatis N. (2003). "An insight to the ecological evaluation index (EEI)." Ecological Indicators **3**: 27-33.

Osherenko, G. (1988). Sharing power with native users: co-management regimes for Arctic wildlife. Canadian Arctic Resources Committee, Ottawa, Ont., Canada. CARC Policy Paper 5.

Osman, M., Mishra, P. K., Mishra, A. K., Dixit, S., Ramachandran, K., Singh, H. P., Rama Rao, C. A., and Korwar, G. R. (2001). Common Pool Resources in Semi-arid India: a review of dynamics, management and livelihood contributions. Natural Resources Institute (NRI), Kent, United Kingdom.

Otobo, A. J. T. (1977). The biology of the clupeid fishes in Lake Kainji, Nigeria. Obafemi Awolo University (Formerly University of Ife), Ile-Ife. 272. PhD.

Otobo, A. J. T. (1995). The ecology and fishery of the Pygmy herring Sierrathrissa leonensis Thys Van Den Audenaerade, 1969 (Clupeidae) in the Nun River and Taylor Creek of the Niger Delta. University of Port Harcourt, Port Harcourt, Nigeria. 207. Ph.D.

Oyadongha, S. (2001). Economic Activities on the Rise in Bayelsa. Vanguard, All Africa Global Media. Lagos, Nigeria. http://209.225.9.134/stories/2001o5o3oo40.htm 26/05/2001

Oyegun, C. U. (1999). Chapter 3: Climate, Relief and Drainage. In The land and People of Bayelsa State: Central Niger Delta. Alagoa, E. J. Onyoma Research Publications, Choba Port Harcourt, Nigeria.

Paci, C., Tobin, A., and Robb, P. (2002). "Reconsidering the Canadian Environmental Impact Assessment Act a place for traditional environmental knowledge." Environmental Impact Assessment Review **22**: 111-127.

Pagel, J. E. (1995). "Quandaries and Complexities of Ecological Risk Assessment: Viable Options to Reduce Humanistic Arrogance." Human and Ecological Risk Assessment **1**(4): 376-391.

Parr, W., Mainstone, C.P., and Morgan, N. (1998). Nutrient budget for the upper reaches of the Hampshire Avon. Water Resources Council, Medmenham. CO 4426/3. 58.

Pavlikakis, G. E., and Tsihrintzis, V.A. (2000). "Ecosystem management: A review of a new concept and methodology." Water Resources Management **14**: 257-283.

Pennekamp, J. G. S., and Quaak, M.P. (1990). "Impact on the environment of turbidity caused by dredging." Terra et Aqua **42**: 10-20.

Perry, C. (2002). A Structured Appeoach to Presenting Theses: Notes for Students and their Supervisors. Post Graduate Workshop. http://www.scu.edu.au/schools/gcm/ar/art/cperry.pdf 28/10/2005.

Pierotti, R., and Wildwat, D. (2000). "Traditional ecological knowledge: the third alternative (Commentary)." Ecological Applications **10**(5): 1333-1340.

Potvin, C., Owen, C.T., Melzi, S., and Beaucage, P. (2005). "Biodiversity and modernization in four coffee-producing villages of Mexico." Ecology and Society **10**(1): 18 [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art18/.

Poulsen, A. F., Hartman, W., and Mattson, N. (2003). The role of local communities in the generation of fisheries information of fisheries information based on ecosystem approach. The Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, Phnom Penh, Cambodia Kingdom, Food and Agriculture Organisation of the United Nations and Mekong River Commission.

Pringle, C., Vellidis, G., Heliotis, F., and Bandacu, D. (1993). "Environmental problems of the Danube Delta." American Scientist **81**: 350-361.

PTF. (1999). Environmental Impact Assessment of the Proposed Dredging of the Lower Niger Waterway. Petroleum (Special) Trust Fund (PTF), Wuse, Abuja, Nigeria. Draft Report. 557.

Quinn, C. H., Huby, M., Kiwasila, H., and Lovett, J.C. (2003). "Local perceptions of risk to livelihood in semi-arid Tanzania." Journal of Environmental Management **68**: 111-119.

Rapport, D. J. (2002). "The health of ecology and the ecology of health." Human and Ecological Risk Assessment **8**(1): 205-213.

Rapport, D. J., and Whitford, W. G. (1999). "How ecosystems respond to stress. Common properties of arid and aquatic systems." Biological Science **49**: 193-203.

Rapport, D. J., Costanaza, R., and McMichael, A.J. (1998a). "Assessing ecosystem health: Challenges at the interface of social, natural and health sciences." THREE **13**: 397-402.

Rapport, D. J., Gaudet, C., and Karr, J. R. (1998b). "Evaluating landscape health: Integrating societal goals and biophysical processes." Journal of Environmental Management **35**(1): 1-15.

Rapport, D. J., Regier, H. A., and Hutchinson, T. C. (1985). "Ecosystem behaviour under stress." American Naturalist **125**: 617-640.

Reed, W., Burchard, J., Hopson, A.J., Jennes, J., and Yaro, I. (1967). Fish and Fisheries of Northern Nigeria. Ministry of Agriculture Northern Nigeria, Zaria, Nigeria.

Reine, K., and Clark, D. (1998). Entrainment by hydraulic dredges - A review of potential impacts. Technical Note Dredging Operations and Environmental Research (DOER)-E1. U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Reine, K. J., Dickerson, D.D., and Clarke, D.G. (1998). Environmental windows associated with dredging operations. DOER Technical Notes Collection (TN DOER-E2). U.S. Army Engineering Research and Development Centre, Vicksburg, MS. www.wes.army.mil/el/dots/doer

Riddell, J. (2000). "Dredging: opportunities and challenges for 2000 and beyond." International Journal of Public Works, Ports and Waterways Development **78**(March).

Rigby, D., Howlett, D., and Woodhouse, P. (2000). A Review of Indicators of Agricultural and Rural Livelihood Sustainability, Sustainability Indicators for Natural Resource Management and Policy, Working Paper No. 1. Development and Project Planning Centre, University of Bradford, UK / University of Fort Hare, South Africa Economic Policy Research Centre, Makere, Uganda/Institute for Development Policy and Management and Centre for Agricultural, Food and Resource Economics, University of Manchester, UK.,

Roberts, M., and Giya, G. (2002). "Beyond the development workshop" - New approaches to government and community-based learning in Ethiopia. Report of the Conference held on 28th and 29th January 2002, Queen of Sheba Hotel, Addis Ababa.

Robinson, J. E., and Newell, R.C., Seiderer, L.J., and Simpson, N.M. (2005). "Impact of aggregate dredging on sediment composition and associated benthic fauna at an offshore dredge site in the southern North Sea." Marine Environmental Research **60**: 51-68.

Robinson, R. F., and Richardson, C.A. (1998). "The direct and indirect effects of suction dredging on a razor clam (*Ensis arcuatus*) population." ICES Journal of Marine Science **55**(970-977).

Roche, C. (1999). Impact Assessment for Development Agencies Learning to Value Change. An Oxfam Publication, London, UK.

Rosenberg, D. M., Bodaly, R.A., and Usher, P.J. (1995). "Environmental and social impacts of large-scale hydro-electric development: who is listening?" Global Environmental Change **5**: 127-148.

Roth, N. E., Allan, J.D., and Erickson, D.E. (1996). "Landscape influences on stream biotic integrity assessed at multiple spatial scales." Landscape Ecology **11**: 141-156.

Royer, T. V., Robinson, C.T., and Minshall, G.W. (2001). "Development of macroinvertebrate-based index for bioassessment of Idaho Rivers." Environmental Management **27**(4): 627-636.

RSPB (1995). The New Rivers and Wildlife Handbook. The Royal Society for the Protection of Birds (RSPB), National Rivers Authority (NRA) and Royal Society for Nature Conservation (RSCN).

Saith, A. (1992). The Rural Non-Farm Economy: Processes and Policies. International Labour Office, World Employment Programme, Geneva.

Salk, M. S., Tolbert, V.R., and Dickerman, J.A. (1999). "Guidelines and techniques for improving the NEPA process." Environmental Management **23**(4): 467-476.

Sallenave, J. (1994). "Giving traditional ecological knowledge its rightful place in environmental impact assessment." Northern Perspectives **22**(1): 8. http://www.carc.org/pubs/v22no1/know.htm 06/11/2002.

Sankoh, O. A. (1996). "An Evaluation of the Analysis of Ecological Risk Method in Environmental Impact Assessment." Environmental Impact Assessment Review **16**: 183-188.

Sarch, M. T. (2001). "Fishing and farming at Lake Chad: Institutions for access to natural resources." Journal of Environmental Management **62**: 185-199.

Sarch, M.-T., and Allison, E.H. (2002). Fluctuating fisheries in Africa's inland waters: well adapted livelihoods, maldapted management. Fisheries Management Science Programme, Department for International Development (DFID), London, UK. Project R7336. 1-11.

Satia, B. P. (1990). National review for aquaculture development in Africa: Nigeria. Food and Agriculture Organisation (FAO), Fish Girel: 770.29. 191.

Schiemer, F., Guti, G., Keckeis, H., and Staras, M. (2003). Ecological status and problems of the Danube river and its fish fauna: a review. Sustaining Livelihoods and Biodiversity in the New Millennium, Phnom Penh, Kingdom of Cambodia. 11 - 14 February 2003.

Schiller, A., Hunsaker, C.T., Kane, M.A., Wolfe, A.K., Dale, V.H., Suter, G.W. II., Russell, C.S., Pion, G., Jensen, M.H., and Konar, V.C. (2001). "Communicating ecological indicators to decision makers and the public." Conservation Ecology **5**(1): 19. [online] URL: http://www.consecol.org/vol15/iss1/art19. 03/04/2003.

Sikoki, F. D., and Otobotekere, A.J.T. (1999). Chapter 24: Fisheries. In The Land and People of Bayelsa State: Central Niger Delta. Alagoa, E. J. Onyoma Research Publications, Port Harcourt, Nigeria**:** 411.

Sillitoe, P., Dixon, P., and Barr, J. (2002). Indigenous Knowledge Methodology. (Anthropology Department, University of Durham and Centre for Land Use and Water Resources Research University of Newcastle) for Department for International Development (DFID), London.

Singh, N., and Gilman, J. (1999). "Making livelihoods more sustainable." International Social Science Journal **51**(4): 539-545.

Soussan, J. (1998). Water / Irrigation and Sustainable Rural Livelihoods. Department for International Development's Natural Resources Advisers' Conference, London UK, Department for International Development (DFID).

SPDC. (2000). Ecological Map of the Niger Delta. Shell Petroleum Development Company. http://www.shellnigeria.com/frame.asp?page=map 13/12/2000

Stevenson, M. G. (1996). "Indigenous knowledge and environmental assessment." Artic **49**(3): 178-291.

Stolpe, N. E. (2001). Trawling and dredging effects; an industry perspective. NAS / NRC Committee on Ecosystem Effects of Fishing: Phase 1. Effects of Bottom Trawling on Seafloor Habitats., New England Aquarium.

Su, S. H., Pearlman, L.C., Rothrock, J.A., Iannuzzi, T.J., and Finley, B.L. (2002). "Potential long-term ecological impacts caused by disturbance of contaminated sediments: A case study." Environmental Management **29**(2): 234-249.

Swales, S. (1989). The Use of In stream Habitat Improvement Methodology in Mitigating the Adverse Effects of River Regulation on fisheries. Alternatives in Regulated River Management. Gore, J. A., and Petts, G.E. CRC Press, Inc., Boca Raton, Florida.

Tabuti, J. R. S., Dhillion, S.S., and Lye, K.A. (2003). "Ethnoveterinary medicines for cattle (Bos indicus) in Bulamogi county, Uganda: plant species and mode of use." Journal of Ethnopharmacology **88**: 278-286.

Tamuno, P. B. L. (2001). Flood mitigation: a case study from Bayelsa State, Nigeria. Water, Engineering and Development Centre (WEDC), Loughborough University, Loughborough, UK. 161. MSc Thesis.

Tamuno, P. B. L., Howard, G., and Smith, M.D. (2003a). "Ecological risk assessment (ERA): How appropriate for developing countries?" Environmental Informatics Archives **1**: 204-212.

Tamuno, P. B. L., Ince, M.E., and Howard, G. (2003b). Understanding vulnerability in the Niger floodplain. Towards the Millennium Development Goals ~ Actions for Water and Environmental Sanitation, Abuja, Nigeria, Water, Engineering and Development Centre (WEDC), Loughborough, UK.

Tamuno, P. B. L., Smith, M.D., and Howard, G., (2003c). Dredging good practices: are these achievable where baseline data are unavailable? Water a Tool for Sustainable Development, Cape Town, South Africa, International Water Association (IWA) Regional Conference, 14th - 18th September 2003.

Tengö, M., and Belfrage, K (2004). "Local management practices for dealing with change and uncertainty: a cross-scale comparison of cases in Sweden and Tanzania." Ecology and Society **9**(3): 4. [online] URL: http://www.ecologyandsociety.org/vol9/iss3/art4.

Terano, T., Asai, K., and Sugeno, M. (1997). "The ecological component of environmental impact assessments: A critical review of British environmental assessments." Journal of Environmental Planning and Management **40**: 157-171.

This Day. (2002). Audu Makes Case for Dredging the Niger. THISDAYOnline.com. http:www.thisdayonline.com/archive/2002/02/09/20020209sta07.html 18th February 2002 - 10/10/02.

Thorne, R. J., St., and Willaims, W.P. (1997). "The response of benthic invertebrates to pollution in developing countries: A multimetric system of bioassessment." Freshwater Biology **37**(671-686).

Timoney, K. (2002). "A dying Delta? A case study of a wetland paradigm." Wetlands **22**(2): 282-300.

Toth, F., and Hizsnyik, E. (1998). "Integrated environmental assessment methods: Evolution and applications." Environmental Modelling and Assessment **3**: 193-207.

Trebaol, L. (2003). "EIA of the Adjarala hydroelecteric project (Togo-Benin): the aquatic environment component." AJEAM-RAGEE **5**: 55-65.

Treweek, J. (1995). "Ecological impact assessment." Impact Assessment **13**: 289-315.

Troyer, M. E. (2002). "A spatial approach for integration and analyzing indicators of ecological and human condition." Ecological Indicators **2**: 211-220.

Tunstall, S. (2000). "Public perceptions of the environmental changes to the Thames Estuary in London, U.K." Journal of Coastal Research **16**(2): 269-277.

Turner, N. J., Ignace, M.B., and Ignace, R. (2000). "Traditional ecological knowledge and wisdom of Aboriginal peoples in British Columbia." Ecological Applications **10**(5): 127-1287.

Turner, R. E. (1997). "Wetland loss in the northern Gulf of Mexico: Multiple working hypothesis." Estuaries **20**: 1-13.

Turner, R. K., Adger, W.N., and Brouwer, R. (1998). "Ecosystem services value, research needs, and policy relevance: a commentary." Ecological Economics **25**: 61-65.

Twong, T., Bugenyi, F.W.B., and Wanda, F. (1995). "The potential for further proliferation of water hyacinth in Lakes Victoria, Kyoga and Kwania and some urgent aspects of research." African Journal of Tropical Hydrobiology and Fisheries **6**: 1-10.

U.S. EPA. (1998). EPA's contaminated sediment management strategy. Office of Water, United States Environmental Protection Agency (U.S. EPA), Washington DC. EPA-823-R-97-006.

U.S. EPA. (2000). Stressor Identification Guidance Document. Office of Research and Development, United States Environmental Protection Agency (U.S. EPA), Cincinnati, Ohio, USA. EPA-822-B-00-025.

UK Marine. (2002a). Environmental impacts of maintenance dredging and disposal. UK Marine Special Areas of Conservation (SACs) Project, http://www.ukmarinesac.org.uk/activities/ports/ph5_2.htm 23/10/02.

UK Marine. (2002b). Dredging: Removal of Benthic Animals. UK Marine Special Areas of Conservation (SACs) Project, http:///www.ukmarinesac.org.uk/activities/ports/ph5_2_2.htm 23/10/02.

UK Marine. (2002c). Dredging and Disposal: Suspended Sediments and Turbidity. UK Marine Special Areas of Conservation (SACs) Project, http://www.ukmarinesac.org.uk/activities/ports/ph5_2_3.htm 23/10/2003.

UK Marine. (2002d). Dredging and Disposal: Organic matter and nutrients. UK Marine Special Areas of Conservation (SACs) Project, http://www.ukmarinesac.org.uk/activities/ports/ph5_2_4.htm 23/10/2002.

UK Marine. (2002e). Dredging and Disposal: Contaminated sediments. UK Marine Special Areas of Conservation (SACs) Project, http://www.ukmarinesac.org.uk/activities/ports/ph5_2_5.htm 23/10/2002.

UK Marine. (2002f). Means of avoiding, minimising and assessing the potential impacts of maintenance dredging and promoting benefits. UK Marine Special Areas of Conservation (SACs) Project, http://www.ukmarinesac.org.uk/activities/ports/ph5_3.htm 23/10/2002.

UNCSD. (1997). Country Profile - Nigeria: Implementation of Agenda 21: Review of Progress Made Since The United Nations Conference On Environment and Development, 1992. UNCSD (United Nations Commission on Sustainable Development), New York, USA. http://www.un.org/esa/earthsummit/nigeria.htm 24/12/2000.

UNEP. (1998). Report of the fourth meeting of the conference of the parties to the convention on biological diversity. United Nations Environmental Programme (UNEP), Nairobi, Kenya.

United Nations. (2002). Report of the World Summit on Sustainable Development. The United Nations, New York, USA.

USACE. (2002). Dredged Material Management Plan for the Port of New York and New Jersey: Final Implementation Report. US Army Corps of Engineers, New York District, New York, NY.

USAEWES. (1989). Environmental Effects of Dredging: Technical Notes. US Army Engineer Waterways Experiment Station (USAEWES), Environmental Laboratory, Vicksburg, MS. EEDP-01-16. 8.

Van der Wal, D., Pye, K., and Neal, A. (2002). "Long-term morphological change in the Ribble Estuary, northwest England." Marine Geology **189**: 249-266.

Van Zalinge, N., Degen, P., Pongsri, C., Jensen, N.J.G., Nguyen, V.H., and Choulamany, X. (2003). The Mekong river system. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries (Sustaining Livelihoods and Biodiversity in the New Millennium), Phnom Penh, Kingdom of Cambodia, Food and Agriculture Organisation of the United Nations and Mekong River Commission.

Van Zalinge, N., Thuok, N., and Tana, T.S. (1998). Where there is water, there is fish? Fisheries issues in the Lower Mekong Basin from a Cambodian perspective. Seventh Common Propert Conference of the International Association for the Study of Common Property, Vancouver, Canada 10 - 14 June 1998. http://www.indiana.edu/~iascp/Final/zalingeo.pdf

Vandecasteele, B., De Vos, B., and Tack, M.G. (2002). "Heavy mental contents in surface soils along the Upper Scheldt river (Belgium) affected by historical upland disposal of dredged materials." The Science of the Total Environment **290**: 1-14.

Vitousek, P. M., Mooney, H. A., and Lubchenco, J. (1997). "Human domination of the earth's ecosystems." Science **277**: 464-499.

Von Geusau, L. A. (2003). Regional Development in Northern Thailand: Its Impacts on Highlanders. International Development Research Centre, Canada. http://web.idrc.ca/en/ev-43110-201-1-DOC_TOPIC.html.

Wang, L., Lyons, J., Kanehl, P., and Gatti, R. (1997). "Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams." Fisheries **22**(6): 6-12.

Wang, M. S., Fang, J.K., and Bowen, W.M. (2000). "An integrated framework for public sector environmental management in developing countries." Environmental Management **25**(5): 463-476.

Wang, X. (2001). "Integrating water-quality management and land-use planning in a watershed context." Journal of Environmental Management **61**: 25-36.

Ward, J. V., Tockner, K., and Schiemer, F. (1999). "Biodiversity of floodplain river ecosystems: Ecotones and connectivity." Regulated Rivers: Research and Management **15**: 125-139.

Warren, D. M., and Rajasekaran, B. (1993). "Putting local knowledge to good use." International Agricultural Development **13**(4): 8–10.

Watson, A., Alessa, L., and Glaspell, B. (2003). "The relationship between traditional ecological knowledge, evolving cultures, and wilderness protection in the circumpolar north." Conservation Ecology **8**(1): 2.[online] URL: http://www.consecol.org/vol8/iss1/art2.

WCED (1987). Our Common Future. WCED (World Commission on Environment and Development) . Oxford University Press, London.

Welcomme, R. L. (1983). River Basins. Food and Agricultural Organisation (FAO), Rome. FAO Fishery Technical Paper 262. 60.

Welcomme, R. L. (2001). Inland fisheries: ecology and management. Blackwell Science New Publishing Books, Blackwell, Oxford, UK.

Whitfield, A. K., and Elliott, M. (2002). "Fishes as indicators of environmental and ecological changes within estuaries: a review of progress and some suggestions for the future." Journal of Fish Biology **61**: 229-250.

Whitfield, A. K., and Paterson, A.W. (2003). "Distribution patterns of fishes in a freshwater deprived Eastern Cape estuaries, with particular emphasis on the geographical headwater region." Water South Africa **29**(1): 61-67.

Wilber, C. G. (1971). Turbidity **-** Animals. In Marine Ecology Vol 2. Wiley-Interscience, London. **2:** 1181-1189.

Wolf, C. P., Emerhi, E.A., and Okosi, P.H. (2005). Community Impact Assessment of the Lower Niger River Dredging. Urobho Historical Society. http://www.waado.org/Environment/Wetlands/Dredging/LowerNiger.htm 17/02/2005

Wolfe, J., Bechard, C., Cizek, P. and Cole, D. (1992). Indigenous and Western knowledge and resource management systems. University of Guelph, Guelph, Ont., Canada. Rural Reportings, Native Canadian Issues Series, 1.

Wolfe, J., Bechard, C., Cizek, P., and Cole, D. (1992). "Indigenous and Western knowledge and resource management systems." Rural Reporting **Native Canadian Issues, Series, 1**.

Woodhouse, P. (2000). Environmental Degradation and Sustainability. In: Poverty and Development in the 21st Century. Allen, T., and Thomas, A. (Editors). Oxford University Press, Oxford**:** Chapter 7: 141 - 162 (22 pages).

Woodrow, W. (1998). Beneficial use of dredgings – plusses and minuses for the coastal ecology. In: Beneficial Use of Dredged Material, Proceedings of a one day seminar, at HR Wallingford, Wednesday 14 October, 1998.

World Bank (1995a). Defining an environmental development strategy for the Niger Delta. World Bank, Washington DC, USA.

World Bank. (1995b). The Niger Delta: A Stakeholder Approach to Environmental Development. World Bank, Washington DC. African Region, Number 53.

World Bank. (1997). IDA in Action 1994-1996, the Pursuit of Sustained Poverty Reduction. World Bank, Washington, DC.

World Bank (1999). India: Livestock Sector Review: Enhancing Growth and Development. The World Bank and Allied Publishers, New Delhi.

Yozzo, D. J., Wilber, P., and Will, R.J. (2004). "Beneficial use of dredged material for habitat creation, enhancement, and restoration in New York - New Jersey Habor." Journal of Environmental Management **73**: 39 - 52.

Appendices

Appendix 1 List of publications

S/No.	Publication	Status
1.	Tamuno, P.B.L., Howard, G. and Smith, M.D. (2003). Ecological risk assessment (ERA): How appropriate for developing countries? Environmental Informatics Archives 1: 204-212	Journal publication
2.	Tamuno, P.B.L., Ince, M.E., and Howard, G. (2003) Understanding vulnerability in the Niger floodplain. Towards the Millennium Development Goals ~ Actions for Water and Environmental Sanitation, Abuja, Nigeria, Water, Engineering and development Centre (WEDC), Loughborough, UK	Conference publication
3.	Tamuno, P.B.L., Smith, M.D., and Howard, G. (2003). Dredging good practices: are these achievable where baseline data are unavailable? Water a Tool for Sustainable Development. Cape Town, South Africa, International Water Association (IWA) Regional Conference, 14th – 18th September 2003	Conference presentation
4.	Tamuno, P.B.L., Smith, M.D., and Howard, G.. Dredging good practices: are these achievable where baseline data are unavailable? Journal of Environmental Management (Submitted October 2005).	Submitted - awaiting comments from reviewers and editor

Appendix 2 Description of ecological assessment approaches

Approach	Advantages	Limitations
Laboratory testing	Test conducted under controlled conditions; Causality can be determined for single stressor and effects; Standardised, simple, and cost effective; Used to validate possible relationships observed in field and in laboratory studies; Screening and hazard ranking of chemicals	Lacks ecological realism; Not all potential causal factors can be tested; Usually does not predict indirect effects (i.e., mediated through food chain); Cumulative and synergistic effects not accounted for; Usually limited to chemical stressors
Field studies and observation	Identify biological/ecological impairments; Represent natural environmental conditions; Provide indications of potential causality; Gradient, indicator, and trend analysis; Best study to address causality; Provide ecologically relevant endpoints used in environmental management	Causal factors cannot be experimentally tested and controlled; factors co-occur and co-vary; Some studies logistically demanding and expensive; Can encounter high variability in system variables due to both natural and anthropogenic causes
Combinations of laboratory, field, and experimental	Used to validate field studies; Provides integrated approach for establishing causality; Field data provide indications of possible associations while laboratory studies can help identify specific causes; Can use experimental hypothesis testing to investigate causality	Subject to same limitations characteristic of individual laboratory, field or experimental studies; and Can be expensive
Simulation Modelling	Can integrate all major biotic and abiotic factors influencing components of ecosystem Describes interactions between biological components and influential parameters; Help to focus and prioritise research issues which can be experimentally tested Potential causal mechanisms can be tested and examined against each other (sensitivity analysis); Less expensive than field or experimental studies; Permits studies over longer time periods than field or experimental studies; Provide ecologically relevant endpoint used in environmental management	Risk of incomplete and inaccurate estimates of input model parameters; Spurious correlation can occur; Highly simplified model may omit important influential factors, very difficult to interpret and outputs may not be valid; Assumed causal associations underlying basic model processes may be inaccurate leading to unreliable predictions; Feedback systems such as density-dependent processes may be difficult to accurately simulate
Statistical Association	Statistical association suggests possible causal relationship; Relatively inexpensive and rapid; Some tests (regression models) allow for control of some treatment variables while testing for significance of the primary variables of interest.	Statistical correlation does not imply causality; Most field and some experimental studies are not designed for statistical hypothesis testing; Most field and some experimental studies cannot be replicated or controlled; Many environmental factors can co-occur and co-vary; High intrinsic natural variability and signal-to-noise ratio influences significance testing
Eco-epidemiological	Not subject to limitations of most other approaches; Based on strength or weight-of-evidence Integrates a diversity of information into a coherent whole; Can be used within the ecological assessment process; Based on principles of human epidemiology	Some causal criteria are based on subjective judgments; and Some evidence are not based on quantitative data or hypothesis testing

(Adams, 2003)

Appendix 3 Fishing gears used in the Central Delta

Gear	Description
Net - Clap nets	Clap nets vary in size from about 50cm to more than 2 metres across the mouth. Smaller clap nets are used mainly by children. They are used either alone with certain large traps and fish fences and are commonly used during the dry season to catch fish in isolated pools or swamps.
Net – Seine net	Seine nets are usually between 10 and 70 metres in size; the mesh size varies from 10 to 30 mm; the distance between the head and footropes is about 40 cm, and the sticks to which these ropes are attached are around 1.5 metres apart. These nets are used from sandbanks in rivers during the dry season and in swamps at most times of the year. The cost of seine nets depends upon the length of the net. Large seine nets are usually operated by two men. They catch most kinds of fish and are an extremely effective gear
Net - Cast or throw nets	They are more effective for capturing more fish than any other single gear type. The size of cast net varies according to individual fishers' preference and the type of fish which it is intended to catch. Children often use a net of about 3 metres diameter and 10mm mesh size, while the largest ones are between 6 and 9 metres diameter. The mesh size varies but is usually about 20 mm. Great skill is required to throw a cast net in such a way that it will unfold in the form of a large circle and cover the greatest possible area. They are usually thrown to depths of up to four metres. The cost of the cast net depends on its size and can be used at all season.
Net – Beach Seine net	Large Beach Seine nets are frequently used in the main rivers and swamps during the dry season. The nets are usually patchwork affairs made from a variety of webbing of different mesh and twine sizes. The majority are about 200 metres long and 6 metres deep; the meshes vary between 20 and 50 mm. Large Beach Seine nets are usually operated by between six and ten men. Experiments with properly designed seine nets have given satisfactory results in the rivers and swamps and the introduction of well made Beach Seine nets may increase the catch efficiency in most places.
Nylon Gill nets	Many Gill nets have no floats or sinkers. Gill nets are set in strategic places where moving fish will become entangled in them. Gill Nets are made from the cheapest available twine size. They are more effective at night than day. Gill Nets are used for all season, primarily in small creeks and swamps and they catch most types of fish. In most cases, many of the fishes that are caught by Gill Nets set all night are often almost rotten or are partly eaten away by other small fish.
Drifting Gill nets	The mesh sizes of Drifting Gill Nets vary between 50 and 100 mm, and are mounted by running the head and footropes through the top and bottom rows of meshes respectively. A few small floats are fastened at wide intervals and the footropes are also leaded that the nets have slight negative buoyancy and will drift along the bottom. Drifting Gill Nets are set in places where the river has a sandy bottom that is devoid of obstacles. The Drifting Gill Nets are best used during the dry season when the current is slower.
Lift nets	The frame of the Lift net is made from cane and wood and is roughly oval in shape, about 6 metres long and 4 metres across. The net is usually of about 10 mm mesh size. Lift nets are used at night, as fishermen claim that fish can see the net and avoid it during daylight. The peak of the usage of the Lift net in the Niger Delta is the dry season, which is usually operated from stationary canoes. Anchored either in a natural or in an artificial-created backwater and baits are usually used to attract fishes. Many local fishers criticise the use of the Lift nets, based on the premise that there is indiscriminate catching of so many juvenile fish which may result in fish population depletion.
Cross-Channel Lift nets	The Cross-Channel Lifts nets are used across the connecting channels between rivers and swamps or across small creeks where current is gentle. The mesh size of this net type is usually about 12 mm, but may sometimes be larger near the edges. This net type is commonly used during flood recession or when flood just begins to rise. In most cases they catch chiefly small fishes. However, large fishes are occasionally caught, especially on rising river level as they enter the swamps to spawn.
Rod and Line Fishing	All Lines are made from nylon multifilament twine. Most fishers begin their fishing career as young children using a metre or two of twine and a small hook fixed to a light fishing pole or rod. This fishing method accounts for a significant part of the catch of small fish with the aid of a bait. This method is most productive during the first month or two after flood recession.
Spring-loaded Set Line	This is commonly used along the river bank. Baits are used and the lines are commonly tied to flexible tree branches.
Drifting Baited Hooks	This consist of a single large hooks, usually 30 mm in diameter, are attached to calabashes and floated down the river at most times of the year except during the highest flood. Small fishes are most often used as bait, which are preferably alive.
Single-hook Setlines	Large baited hooks attached to a few metres of heavy twine are used in most places. The lines are usually attached to clumps of grass on the river bank or to fallen trees. Naturally this gear captures most type of predator fishes.
Bottom-Set Longline	Bottom-set longlines are set chiefly near the banks of rivers at high water level and in midstream during the dry season. They are usually made of several hundred hooks of between 8 and 12 mm diameter. The snoods are 8 to 15 cm long and attached to the mainline at intervals of between 60 and 100 cm. These lines are usually set in the afternoon and lifted again the following morning. When operated by day, they are inspected each hour, the hooked fish removed, the hooks re-baited where necessary and the lines re-set.
Traps – Fish Fences	They are used either alone, or in combination with other types of traps and nets, especially in swampy areas and in places where there is a wide floodplain. In the simplest form, a fish fence is simply erected across the connecting channel between swamp and the river during flood recession, hence preventing the fish from returning to the river.
Traps - Cross-river Fish Traps	These traps can be set from the bank of the main stream when the current is at its slackest. At other times they are usually sited in backwaters or relatively sheltered paces. The operator of this type of trap usually works other gear as well, or sometimes farms on a riverside plot of land, as these traps require attention only once daily to remove the caught fish.
Traps - Fish Shelter	They are made of a triangular plot of branches staked firmly in the river bed and with the apex of the triangle upstream. Each shelter is about 10 metres and 4 metres across the base. As many as 10 such shelter is operated by the same group of fishers.
Wounding gear – Spears	Fish spears are sometime used alone, but they are generally used in conjunction with the flimsy nets and weak lines of local fishers and a few fishers go out without a spear in their canoe. When large fish is caught by net or line it is usually first speared before being boated, lest it break the gear and escape. Spears are used extensively at night in conjunction with torches and flares to capture fishes, are as well used at shores of rivers or in lakes to capture littoral fishes (Surface feeding fishes) and throughout all freshwater areas.
Wounding – Machetes / Cutlass	Machetes / Cutlass are used in shallow shores of weedy river beds and in clear waters of used at night with the aid of a source light

Source: Modified from (Reed, *et al.*1967; Sikoki and Otobotekere, 1999) 145 – 177and 311 – 314 respectively.

Appendix 4 Questionnaire for Fishers

Name of Community: …………………………………………………………………………………….

Fishing area(s): ……………………………………………………………………………………...

Section A

1. Name of respondent (Optional): ……………………………………………………………….
2. Local Government Area: ……………………………………………………………………..
3. Sex

Male		Female	

4. What is your highest educational qualification? **(Tick only one)**

First School Leaving Certificate	Secondary School Certificate	Bachelor Degree	Master Degree	PhD	None	Others, please specify

5. Age (in years):

Tick as appropriate

20 – 25	26 – 30	31 – 39	40 – 49	50 – 65	Above 65

6. How long have you been living in this community (in years)? **(Tick only one)**

Less than 5	5 – 9	10 – 19	20 - 25	26 – 29	30 – 39	40 - 50	Above 50

7. How long have you been a fisher man/woman (in years)? **(Tick only one)**

Less than 5	5 – 9	10 – 19	20 - 25	26 - 29	30 – 39	40 - 50	Above 50

8. What category of fisher are you?

Full-time		Part-time		Others (specify)	

9. On an average, how many days in the week do you go fishing?

1 day	2 days	3 days	4 days	5 days	6 days	7 days

10. What is the estimate of the average time you spend fishing daily?

< 2 hrs	2 – 4 hrs	4 – 6 hrs	6 – 8 hrs	8 – 10 hrs	10 – 12 hrs	> 12 hrs

Section B

Is fishing your major source of income? If No go to 2, if Yes go to 3 **(Tick only one)**

Yes		No	

What is your major source of income? **(Tick only one)**

Farming	Fishing	Trading / Commerce	Pensions	Civil Servant	Others, please Specify below

…………………………………………………………………………………………………

3. What is/are your other source(s) of income? **(Tick as appropriate)**

Farming	Fishing	Trading / Commerce	Pensions	Civil Servant	None	Others, please specify below

(a)…………………………………………. (b)…………………………………………….

4. Please use the table below to list the five most abundant fish species within the river catchments of your community in descending order of abundance?

Fish species abundance (frequency of catch)
a.
b.
c.
d.
e.

5. List other fish species in your fishing area

Fish species abundance
a.
b.
c.
d.
e.

6. What species of fish is of the most economic value? Please list in order of decreasing economic value.

Fish species (Economic value)
a.
b.
c.
d.
e.

7. How would you rate the present fish species diversity in the river catchments of your community based on your experiences? On a scale of -2 to +2, in which -2 highly reduced diversity, +2 very highly increased diversity and 0 no change in diversity.

Fish species diversity				
-2	-1	0	+1	+2

8. How would you rate the present fish abundance of the river catchments within your community based on your experience? On a scale of -2 to +2, in which -2 highly reduced abundance, +2 very highly increased abundance and 0 no change in abundance.

Fish abundance				
-2	-1	0	+1	+2

9. How would you rate the present economic importance of fishery in the river catchments within your community based on your experience? On a scale of -2 to +2, in which -2 highly reduced economic values, +2 very highly increased economic value and 0 no change in economic value.

Fish – economic significance				
-2	-1	0	+1	+2

10. What month(s) of a typical year is fishing (fresh water rivers) most viable?

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.

11. What is/are the factors that favour fishing (fresh water rivers) in your community and their relative rating? Where 1 is least supporting and 5 most supporting

Factors supporting fishing activities	Relative rating				
	1	2	3	4	5
a.					
b.					
c.					
d.					
e.					

Could you please give reasons for your answer in 10 and 11

………
………
………
………
………………………………………………………………………………………

12. What month(s) of a typical year is fishing (fresh water rivers) least viable?

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.

13. What are the factors limiting/constraining fishing (fresh water rivers) in your community and their relative rating? Where 1 is least supporting and 5 most supporting

Factors limiting fishing activities	Relative rating				
	1	2	3	4	5
a.					
b.					
c.					
d.					
e.					

Could you please give reasons for your answer in 13 and 14?

………
………
………
………
………………………………………………………………………………………

14. Could you remember of any event in the past that has constrained fishing (fresh water rivers) in your community?
………
………
………………………………………………………………………………………………

15. How would you rate fisheries diversity, abundance and economic significant in the river catchments within your community? Where -2 to -1 ranges from highly depleting to lowly depleting; 0 no significant changes, and +1 to +2 ranges from lowly increasing to highly increasing.

	-2	-1	0	+1	+2
Diversity					
Abundance					
Economic significant					

Could you please explain your response to 15 above?
………
………
………

Section C

1. Please use the table below and list the typical annual River usage profile of your community. Details would be written on a separate sheet of paper

Activity	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.

2. Can you please remember any major changes (natural or by man) that significantly altered the annual River usage profile of your community. Time and frequency of occurrence; nature of alteration; duration of alteration; livelihoods consequence of alteration

………
………
………
………
………
……………………………………………………………………………………

3. Please use the table below to identify and rate environmental issues problems that have occurred in your community, on a scale of -2 to +2, with -2 as most detrimental and +2 most beneficial to your community generally, and 0 as neutral (No impact).

Environmental issue	Relative rating				
	-2	-1	0	+1	+2
a.					
b.					
c.					
d.					
e.					

4. Based on your response in 4 above. How would you describe these environmental issues?

Environmental issues	Occurrence (historical)	Relative duration of impact		
		Short term (< 1 yr)	Medium term (1 – 5 yrs)	Long term (> 5 yrs)
a.				
b.				
c.				
d.				
e.				

5. Further description of the environmental issues.

Environmental issues	Description
a.	
b.	
c.	
d.	
e.	

Section D

1. Has the river near your community been dredged before? If yes go to 2 if no Thank you.

Yes		No	

2. When was the river dredged?

Year(s)	Time of the year	Duration

3. What company dredged the river?

……………………………………………………………………………………………………

4. Did you work with this company during the dredging process? Did any woman work with the dredging company?

5. Did any member of your family work for the dredging company? If yes how many?

6. How was the dredged material (“waste”) disposed?

………
………
…………………………………………………………………………………

7. How do you perceive Inland River dredging (impact on fishing)?

Perception				
Very beneficial	Beneficial	Neutral	Detrimental	Very detrimental

Based on your response in 7 above, please explain/justify

………
………
………
………
…………………………………………………………………………………….

8. How do you think Inland River dredging could be carried out to increase its benefits to your community? (Good practices)

………
………
………
………
……………………………………………………………

Thank you

Appendix 5 Questionnaire for Non-fishers

Name of Community: ……………………………………………………………………………….

Section A

1. Name of respondent (Optional): ………………………………………………………….

2. Local Government Area: ……………………………………………………………….

3. Sex

Male		Female	

4. What is your highest educational qualification? **(Tick only one)**

First School Leaving Certificate	Secondary School Certificate	Bachelor Degree	Master Degree	PhD	None	Others, please specify

5. Age (in years):

Tick as appropriate

20 – 25	26 – 30	31 – 39	40 – 49	50 – 64	Above 65

6. How long have you been living in this community (in years)? **(Tick only one)**

Less than 5	5 – 9	10 - 19	20 – 25	26 – 29	30 – 39	40 – 49	Above 50

7. What is your major source of income? **(Tick only one)**

Farming	Fishing	Trading / Commerce	Pensions	Civil Servant	Others, please Specify below

………………………………………………………………………………………………….

8. What is/are your other source(s) of income? **(Tick as appropriate)**

Farming	Fishing	Trading / Commerce	Pensions	Civil Servant	None	Others, please specify below

……………………………………… (b)……………………………………………………..

Section B

1. Please use the table below and list the typical annual River usage profile of your community. Details would be written on a separate sheet of paper

Activity	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.

2. Can you please remember any major changes (natural or by man) that significantly altered the annual River usage profile of your community. Time and frequency of occurrence; nature of alteration; duration of alteration; livelihoods consequence of alteration

………
………
………
………
………
…………………………………………………………………………………

3. Please use the table below to identify and rate environmental issues problems that have occurred in your community, on a scale of -2 to +2, with -2 as most detrimental and +2 most beneficial to your community generally, and 0 as neutral (No impact).

Environmental issue	Relative rating				
	-2	-1	0	+1	+2
a.					
b.					
c.					
d.					
e.					

4. Based on your response in 3 above. How would you describe these environmental issues?

Environmental issues	Occurrence (historical)	Relative duration of impact		
		Short term (< 1 yr)	Medium term (1 – 5 yrs)	Long term (> 5 yrs)
a.				
b.				
c.				
d.				
e.				

5. Further description of the environmental issues.

Environmental issues	Description
a.	
b.	
c.	
d.	
e.	

Section C

1. Has the river near your community been dredged before? If yes go to 2 if no Thank you.

Yes		No	

2. When was the river dredged?

Year(s)	Time of the year	Duration

3. What company dredged the river?

……………………………………………………………………………………………………….

4. Did you work with this company during the dredging process? Did any woman work with the dredging company?

5. Did any member of your family work for the dredging company? If yes how many?

6. How was the dredged material (“waste”) disposed?

………
………
……………………………………………………………………………………

7. How do you perceive Inland River dredging (impact on fishing)?

Perception				
Very beneficial	Beneficial	Neutral	Detrimental	Very detrimental

Based on your response in 7 above, please explain/justify

………
………
………
………
………………………………………………………………………………………

8. How do you think Inland River dredging could be carried out to increase its benefits to your community? (Good practices)

………
………
………
………
…………………………………………………………

Thank you

Appendix 6 Gender distribution of respondents (Study Area)

Gender

Sample Communities			Frequency	Percent
Elebele	Valid	Female	29	35.8
		Male	52	64.2
		Total	81	100.0
Otuoke	Valid	Female	25	24.3
		Male	78	75.7
		Total	103	100.0
Otakeme	Valid	Female	42	33.3
		Male	84	66.7
		Total	126	100.0
Otuogidi	Valid	Female	37	34.3
		Male	71	65.7
		Total	108	100.0

Appendix 7 Age distribution of respondents (Study Area)

Age in Years

Sample Communities			Frequency	Percent
Elebele	Valid	20 to 29 years	11	13.6
		30 to 39 years	27	33.3
		40 to 49 years	22	27.2
		50 to 59 years	14	17.3
		60 years and above	7	8.6
		Total	81	100.0
Otuoke	Valid	20 to 29 years	33	32.0
		30 to 39 years	33	32.0
		40 to 49 years	20	19.4
		50 to 59 years	7	6.8
		60 years and above	10	9.7
		Total	103	100.0
Otakeme	Valid	20 to 29 years	62	49.2
		30 to 39 years	34	27.0
		40 to 49 years	15	11.9
		50 to 59 years	8	6.3
		60 years and above	7	5.6
		Total	126	100.0
Otuogidi	Valid	20 to 29 years	40	37.0
		30 to 39 years	30	27.8
		40 to 49 years	17	15.7
		50 to 59 years	13	12.0
		60 years and above	8	7.4
		Total	108	100.0

Appendix 8 Years residency of respondents (Study Area)

Years Residency

Sample Communities			Frequency	Percent
Elebele	Valid	Less than 5 years	2	2.5
		5 and 19 years	23	28.4
		20 and 34 years	22	27.2
		35 and 49 years	20	24.7
		50 years and above	14	17.3
		Total	81	100.0
Otuoke	Valid	Less than 5 years	2	1.9
		5 and 19 years	20	19.4
		20 and 34 years	46	44.7
		35 and 49 years	21	20.4
		50 years and above	14	13.6
		Total	103	100.0
Otakeme	Valid	Less than 5 years	9	7.1
		5 and 19 years	37	29.4
		20 and 34 years	56	44.4
		35 and 49 years	17	13.5
		50 years and above	7	5.6
		Total	126	100.0
Otuogidi	Valid	Less than 5 years	3	2.8
		5 and 19 years	32	29.6
		20 and 34 years	40	37.0
		35 and 49 years	20	18.5
		50 years and above	13	12.0
		Total	108	100.0

Appendix 9 Educational qualifications of respondents (Study Area)

Educational Qualification

Sample Communities			Frequency	Percent
Elebele	Valid	None	17	21.0
		Primary School Certificate	38	46.9
		Secondary School Certificate	23	28.4
		NCE and National Diploma	2	2.5
		Higher Degree	1	1.2
		Total	81	100.0
Otuoke	Valid	None	11	10.7
		Primary School Certificate	32	31.1
		Secondary School Certificate	49	47.6
		NCE and National Diploma	9	8.7
		Degree and Higher National Diploma	2	1.9
		Total	103	100.0
Otakeme	Valid	None	8	6.3
		Primary School Certificate	40	31.7
		Secondary School Certificate	67	53.2
		NCE and National Diploma	6	4.8
		Degree and Higher National Diploma	4	3.2
		Higher Degree	1	.8
		Total	126	100.0
Otuogidi	Valid	None	14	13.0
		Primary School Certificate	31	28.7
		Secondary School Certificate	57	52.8
		NCE and National Diploma	5	4.6
		Degree and Higher National Diploma	1	.9
		Total	108	100.0

Appendix 10 Livelihoods options (Study Area)

Livelihood Options

Sample Communities		Frequency	Percent
Elebele	Unemployed	1	1.2
	1	19	23.5
	2	37	45.7
	3	22	27.2
	4	2	2.5
	Total	81	100.0
Otuoke	Unemployed	2	1.9
	1	19	18.4
	2	45	43.7
	3	31	30.1
	4	6	5.8
	Total	103	100.0
Otakeme	Unemployed	5	4.0
	1	26	20.6
	2	56	44.4
	3	32	25.4
	4	6	4.8
	5	1	.8
	Total	126	100.0
Otuogidi	Unemployed	2	1.9
	1	23	21.3
	2	49	45.4
	3	29	26.9
	4	4	3.7
	5	1	.9
	Total	108	100.0

Appendix 11 Fishing as livelihoods category (Study Area)

Fishing - LS

Sample Communities		Frequency	Percent
Elebele	Highly dependent on CPR	18	22.2
Otuoke	Highly dependent on CPR	40	38.8
Otakeme	Highly dependent on CPR	48	38.1
Otuogidi	Highly dependent on CPR	42	38.9

Appendix 12 Palm cutting as livelihood category (Study Area)

Palm Cutting - LS

Sample Communities		Frequency	Percent
Elebele	Moderately Dependent on CPR	15	18.5
Otuoke	Moderately Dependent on CPR	15	14.6
Otakeme	Moderately Dependent on CPR	13	10.3
Otuogidi	Moderately Dependent on CPR	21	19.4

Appendix 13 Farming as livelihoods category (Study Area)

Farming - LS

Sample Communities		Frequency	Percent
Elebele	Dependent on CPR	64	79.0
Otuoke	Dependent on CPR	75	72.8
Otakeme	Dependent on CPR	93	73.8
Otuogidi	Dependent on CPR	88	81.5

Appendix 14 Trading and commerce as livelihoods category (Study Area)

Trading / Commerce - LS

Sample Communities		Frequency	Percent
Elebele	Neutrally dependent on CPR	34	42.0
Otuoke	Neutrally dependent on CPR	44	42.7
Otakeme	Neutrally dependent on CPR	54	42.9
Otuogidi	Neutrally dependent on CPR	44	40.7

Appendix 15 Pension as livelihoods category (Study Area)

Pension - LS

Sample Communities		Frequency	Percent
Elebele	Non-dependent on CPR	1	1.2
Otuoke	Non-dependent on CPR	2	1.9
Otakeme	Non-dependent on CPR	3	2.4
Otuogidi	Non-dependent on CPR	1	.9

Appendix 16 Formal economic as livelihoods category (Study Area)

Formal Economic - LS

Sample Communities		Frequency	Percent
Elebele	Non-dependent on CPR and Stable	29	35.8
Otuoke	Non-dependent on CPR and Stable	29	28.2
Otakeme	Non-dependent on CPR and Stable	25	19.8
Otuogidi	Non-dependent on CPR and Stable	21	19.4

Appendix 17 Other livelihoods category (Study Area)

Others - LS

Sample Communities		Frequency	Percent
Elebele	Unemployed	1	1.2
	Highly dependent on CPR	6	7.4
	Moderately dependent on CPR	3	3.7
	Neutrally Dependent on CPR	1	1.2
Otuoke	Unemployed	2	1.9
	Highly dependent on CPR	10	9.7
	Moderately dependent on CPR	11	10.7
	Neutrally Dependent on CPR	4	3.9
Otakeme	Unemployed	5	4.0
	Highly dependent on CPR	14	11.1
	Moderately dependent on CPR	6	4.8
	Neutrally Dependent on CPR	6	4.8
Otuogidi	Unemployed	2	1.9
	Highly dependent on CPR	7	6.5
	Moderately dependent on CPR	2	1.9
	Neutrally Dependent on CPR	4	3.7

Appendix 18 Gender of fishers (Study Area)

Gender [Fishers]

Community ID			Frequency	Percent
Elebele	Valid	Female	4	22.2
		Male	14	77.8
		Total	18	100.0
Otuoke	Valid	Female	4	12.5
		Male	28	87.5
		Total	32	100.0
Otakeme	Valid	Female	1	2.8
		Male	35	97.2
		Total	36	100.0
Otuogidi	Valid	Female	5	16.7
		Male	25	83.3
		Total	30	100.0

Appendix 19 Livelihoods option of fishers (Study Area)

Livelihood Option [Fishers]

Community ID			Frequency	Percent
Elebele	Valid	2	8	44.4
		3	10	55.6
		Total	18	100.0
Otuoke	Valid	2	10	31.3
		3	18	56.3
		4	4	12.5
		Total	32	100.0
Otakeme	Valid	1	1	2.8
		2	10	27.8
		3	21	58.3
		4	3	8.3
		5	1	2.8
		Total	36	100.0
Otuogidi	Valid	1	1	3.3
		2	6	20.0
		3	20	66.7
		4	3	10.0
		Total	30	100.0

Appendix 20 Fishing as livelihoods source - fishers (Study Area)

Fishing - Livelihood Source [Fishers]

Community ID.		Frequency	Percent
Elebele	Highly dependent on CPRs	18	100.0
Otuoke	Highly dependent on CPRs	32	100.0
Otakeme	Highly dependent on CPRs	36	100.0
Otuogidi	Highly dependent on CPRs	30	100.0

Appendix 21 Palm cutting as livelihoods source – fishers (Study Area)

Palm Cutting - Livelihood Source [Fishers]

Community ID.		Frequency	Percent
Elebele	Moderately dependent on CPRs	3	16.7
Otuoke	Moderately dependent on CPRs	6	18.8
Otakeme	Moderately dependent on CPRs	4	11.1
Otuogidi	Moderately dependent on CPRs	11	36.7

Appendix 22 Farming as livelihoods source – fishers (Study Area)

Farming - Livelihood Source [Fishers]

Community ID.		Frequency	Percent
Elebele	Dependent on CPRs	14	77.8
Otuoke	Dependent on CPRs	28	87.5
Otakeme	Dependent on CPRs	25	69.4
Otuogidi	Dependent on CPRs	25	83.3

Appendix 23 Trading as livelihoods source – fishers (Study Area)

Trader - Livelihood Source [Fishers]

Community ID.		Frequency	Percent
Elebele	Neutrally dependent on CPRs	5	27.8
Otuoke	Neutrally dependent on CPRs	9	28.1
Otakeme	Neutrally dependent on CPRs	17	47.2
Otuogidi	Neutrally dependent on CPRs	9	30.0

Appendix 24 Pension as livelihoods source – fishers (Study Area)

Pension - Livelihood Source [Fishers]

Community ID.			Frequency	Percent
Elebele	Missing	9	18	100.0
Otuoke	Missing	9	32	100.0
Otakeme	Missing	9	36	100.0
Otuogidi	Missing	9	30	100.0

Appendix 25 Formal economic sector as livelihood source – fishers (Study Area)

Formal Economic Sector - Livelihood Source [Fishers]

Community ID.		Frequency	Percent
Elebele	None-dependent on CPRs and Stable	6	33.3
Otuoke	None-dependent on CPRs and Stable	7	21.9
Otakeme	None-dependent on CPRs and Stable	8	22.2
Otuogidi	None-dependent on CPRs and Stable	6	20.0

Appendix 26 Other livelihood sources – fishers (Study Area)

Other - Livelihood Source [Fishers]

Community ID.			Frequency	Percent
Elebele		Highly dependent on CPRs	2	11.1
Otuoke	Missing	9	32	100.0
Otakeme		Highly dependent on CPRs	7	19.4
		Moderately dependent on CPrs	2	5.6
		Neutrally dependent on CPRs	1	2.8
Otuogidi		Highly dependent on CPRs	2	6.7
		Neutrally dependent on CPRs	2	6.7

Appendix 27 Educational qualification of fishers (Study Area)

Educational Qualification [Fishers]

Community ID			Frequency	Percent
Elebele	Valid	None	5	27.8
		Primary School Certificate	8	44.4
		Secondary School Certificate	5	27.8
		Total	18	100.0
Otuoke	Valid	None	7	21.9
		Primary School Certificate	9	28.1
		Secondary School Certificate	12	37.5
		NCE, or National Diploma	4	12.5
		Total	32	100.0
Otakeme	Valid	None	3	8.3
		Primary School Certificate	11	30.6
		Secondary School Certificate	17	47.2
		NCE, or National Diploma	1	2.8
		Degree or Higher National Diploma	3	8.3
		Higher Degree	1	2.8
		Total	36	100.0
Otuogidi	Valid	None	5	16.7
		Primary School Certificate	8	26.7
		Secondary School Certificate	15	50.0
		NCE, or National Diploma	1	3.3
		Degree or Higher National Diploma	1	3.3
		Total	30	100.0

Appendix 28 Age range of fishers (Study Area)

Age in Years [Fishers]

Community ID			Frequency	Percent
Elebele	Valid	20 and 29 Years	1	5.6
		30 and 39 Years	4	22.2
		40 and 49 Years	7	38.9
		50 and 59 Years	3	16.7
		60 Years and above	3	16.7
		Total	18	100.0
Otuoke	Valid	20 and 29 Years	7	21.9
		30 and 39 Years	8	25.0
		40 and 49 Years	11	34.4
		50 and 59 Years	3	9.4
		60 Years and above	3	9.4
		Total	32	100.0
Otakeme	Valid	20 and 29 Years	10	27.8
		30 and 39 Years	15	41.7
		40 and 49 Years	6	16.7
		50 and 59 Years	3	8.3
		60 Years and above	2	5.6
		Total	36	100.0
Otuogidi	Valid	20 and 29 Years	7	23.3
		30 and 39 Years	9	30.0
		40 and 49 Years	6	20.0
		50 and 59 Years	5	16.7
		60 Years and above	3	10.0
		Total	30	100.0

Appendix 29 Years (range) of fishers (Study Area)

Years Resident in Years [Fishers]

Community ID			Frequency	Percent
Elebele	Valid	Less than 5 Years	1	5.6
		5 and 19 Years	4	22.2
		20 and 34 Years	7	38.9
		35 and 49 Years	3	16.7
		50 Years and above	3	16.7
		Total	18	100.0
Otuoke	Valid	5 and 19 Years	3	9.4
		20 and 34 Years	13	40.6
		35 and 49 Years	10	31.3
		50 Years and above	6	18.8
		Total	32	100.0
Otakeme	Valid	Less than 5 Years	2	5.6
		5 and 19 Years	10	27.8
		20 and 34 Years	17	47.2
		35 and 49 Years	4	11.1
		50 Years and above	3	8.3
		Total	36	100.0
Otuogidi	Valid	Less than 5 Years	1	3.3
		5 and 19 Years	6	20.0
		20 and 34 Years	8	26.7
		35 and 49 Years	9	30.0
		50 Years and above	6	20.0
		Total	30	100.0

Appendix 30 Years fishing (Study Area)

Years Fishing

Community ID			Frequency	Percent
Elebele	Valid	5 and 19 Years	8	44.4
		20 and 34 Years	9	50.0
		50 Years and above	1	5.6
		Total	18	100.0
Otuoke	Valid	5 and 19 Years	22	68.8
		20 and 34 Years	8	25.0
		35 and 49 Years	1	3.1
		50 Years and above	1	3.1
		Total	32	100.0
Otakeme	Valid	Less than 5 Years	1	2.8
		5 and 19 Years	18	50.0
		20 and 34 Years	14	38.9
		35 and 49 Years	2	5.6
		50 Years and above	1	2.8
		Total	36	100.0
Otuogidi	Valid	Less than 5 Years	2	6.7
		5 and 19 Years	14	46.7
		20 and 34 Years	11	36.7
		35 and 49 Years	2	6.7
		50 Years and above	1	3.3
		Total	30	100.0

Appendix 31 Category of fishers (Study Area)

Category of Fisher

Community ID			Frequency	Percent
Elebele	Valid	Part-time	17	94.4
		Full-time	1	5.6
		Total	18	100.0
Otuoke	Valid	Part-time	23	71.9
		Full-time	9	28.1
		Total	32	100.0
Otakeme	Valid	Part-time	28	77.8
		Full-time	8	22.2
		Total	36	100.0
Otuogidi	Valid	Part-time	23	76.7
		Full-time	7	23.3
		Total	30	100.0

Appendix 32 Average Day fishing per week (Study Area)

Fishing (Day/Wk)

Community ID			Frequency	Percent
Elebele	Valid	1 and 2 Days	2	11.1
		3 and 4 Days	6	33.3
		5 to 7 Days	10	55.6
		Total	18	100.0
Otuoke	Valid	1 and 2 Days	6	18.8
		3 and 4 Days	18	56.3
		5 to 7 Days	8	25.0
		Total	32	100.0
Otakeme	Valid	1 and 2 Days	9	25.0
		3 and 4 Days	19	52.8
		5 to 7 Days	8	22.2
		Total	36	100.0
Otuogidi	Valid	1 and 2 Days	6	20.0
		3 and 4 Days	15	50.0
		5 to 7 Days	9	30.0
		Total	30	100.0

Appendix 33 Average fishing hour per day (Study Area)

Fishing (Hrs/Day)

Community ID			Frequency	Percent
Elebele	Valid	0 to 3 Hours	5	27.8
		4 to 6 Hours	11	61.1
		7 to 9 Hours	2	11.1
		Total	18	100.0
Otuoke	Valid	0 to 3 Hours	11	34.4
		4 to 6 Hours	17	53.1
		7 to 9 Hours	4	12.5
		Total	32	100.0
Otakeme	Valid	0 to 3 Hours	4	11.1
		4 to 6 Hours	30	83.3
		7 to 9 Hours	2	5.6
		Total	36	100.0
Otuogidi	Valid	0 to 3 Hours	16	53.3
		4 to 6 Hours	14	46.7
		Total	30	100.0

Appendix 34 Fish diversity ad abundance based on TELK (Elebele)

		Abundance / Diversity					Others				
S/No.	**Fish species**	**5**	**4**	**3**	**2**	**1**	**0.5**	**Total Fishers**	**Total Rank**	**% Fishers**	**Relative Rank**
1	*Citharinus spp*	2	1	2			4	9	22	50.0	7.0
2	*Alestes spp*	5	4	1	1		2	13	47	72.2	14.8
3	*Tilapia spp*	5	1	2	4		2	14	44	77.8	13.9
4	*Gymnarchus niloticus*	2		1	1	1	7	12	19.5	66.7	6.2
5	*Distichodus spp*	1		1		3	4	9	13	50.0	4.1
6	*Clarias spp*		4	1	2	2	6	15	28	83.3	8.8
7	*Chrysichthys nigrodigitatus*			1	1	2	4	8	9	44.4	2.8
8	*Ophiocephalus obscurus*		1	1	1		7	10	12.5	55.6	3.9
9	*Heterotis niloticus*		1	1	1	2	7	12	14.5	66.7	4.6
10	*Synodontis spp*		1	3	2	2	2	10	20	55.6	6.3
11	*Marcusenius spp*	2	1		1	2	7	13	21.5	72.2	6.8
12	*Papyrocranus afer*		1	1	1		5	8	11.5	44.4	3.6
13	*Pareutropius sp*		1	3	2	2	3	11	20.5	61.1	6.5
14	*Labeo sp*						2	2	1	11.1	0.3
15	*Schilbe mystus*							0	0	0.0	0.0
16	*Petrocephalus spp*	1	2				2	5	14	27.8	4.4
17	*Micralestes spp*		1				1	2	4.5	11.1	1.4
18	*Mormyrus spp*						1	1	0.5	5.6	0.2
19	*Hepsetus odoe*						3	3	1.5	16.7	0.5
20	*Lates niloticus*						2	2	1	11.1	0.3
21	*Notopterus chitala*						1	1	0.5	5.6	0.2
22	Egbetuki - Unidentified			3		1		4	10	22.2	3.2
23	*Malapterurus electricus*						1	1	0.5	5.6	0.2
	Total	**18**	**19**	**21**	**17**	**17**	**73**	**165**	**316.5**	**916.7**	**100.0**

Appendix 35 Fish species diversity and abundance based on TELK (Otuoke)

		Abundance / Diversity					Others	Total Fishers	Total Rank	% Fishers	Relative Rank
S/No.	Fish species	5	4	3	2	1	0.5				
1	*Citharinus spp*	7	4		4		6	21	62	65.6	11.4
2	*Alestes spp*	8	5	1	6	1	8	29	80	90.6	14.7
3	*Tilapia spp*	3	4	4	1	4	6	22	52	68.8	9.6
4	*Gymnarchus niloticus*	4	5	3	3	1	14	30	63	93.8	11.6
5	*Distichodus spp*	5	2	3	2	8	6	26	57	81.3	10.5
6	*Clarias spp*	1	4	1	1	4	14	25	37	78.1	6.8
7	*Chrysichthys nigrodigitatus*	1	2	3	2	1	12	21	33	65.6	6.1
8	*Ophiocephalus obscurus*	2		3	4		9	18	31.5	56.3	5.8
9	*Heterotis niloticus*		3	9	2	3	10	27	51	84.4	9.4
10	*Synodontis spp*				2	1	6	9	8	28.1	1.5
11	*Marcusenius spp*				1	2	6	9	7	28.1	1.3
12	*Papyrocranus afer*		2	1		1	8	12	16	37.5	2.9
13	*Pareutropius sp*	1		3	2	3	3	12	22.5	37.5	4.1
14	*Labeo sp*				1		5	6	4.5	18.8	0.8
15	*Schilbe mystus*						1	1	0.5	3.1	0.1
16	*Petrocephalus spp*				1		2	3	3	9.4	0.6
17	Ekudu (Uidentified)					1	1	2	1.5	6.3	0.3
18	*Ctenopoma kingsleyae*						1	1	0.5	3.1	0.1
19	*Mormyrus spp*						3	3	1.5	9.4	0.3
20	*Hepsetus odoe*					2	6	8	5	25.0	0.9
21	*Lates niloticus*						12	12	6	37.5	1.1
22	*Trachinotus goreensis*						1	1	0.5	3.1	0.1
23	Omiozogboro (Uidentified)						1	1	0.5	3.1	0.1
24	*Malapterurus electricus*						2	2	1	6.3	0.2
	Total	**32**	**31**	**31**	**32**	**32**	**143**	**301**	**545**	**940.6**	**100.0**

Appendix 36 Fish species abundance and diversity (Otakeme)

		Abundance / Diversity					Others				
S/No.	Fish species	5	4	3	2	1	0.5	Total Fishers	Total Rank	% Fishers	Relative Rank
1	*Citharinus spp*	13	7	6	2	1	3	32	117.5	88.9	19.4
2	*Alestes spp*	6	11	4	4	3	3	31	98.5	86.1	16.3
3	*Tilapia spp*	10	3	7	4	3	4	31	96	86.1	15.8
4	*Gymnarchus niloticus*			4	1	2	22	29	27	80.6	4.5
5	*Distichodus spp*	4	4	3	8		4	23	63	63.9	10.4
6	*Clarias spp*		2	1	1	2	11	17	20.5	47.2	3.4
7	*Chrysichthys nigrodigitatus*		1	2	1	3	12	19	21	52.8	3.5
8	*Ophiocephalus obscurus*	3	1	1	3	4	12	24	38	66.7	6.3
9	*Heterotis niloticus*		1	1	3	4	14	23	24	63.9	4.0
10	*Synodontis spp*		1			3	9	13	11.5	36.1	1.9
11	*Marcusenius spp*		1	2	2	1	7	13	18.5	36.1	3.1
12	*Papyrocranus afer*				1		6	7	5	19.4	0.8
13	*Pareutropius sp*		1	1	1	6	9	18	19.5	50.0	3.2
14	*Labeo sp*					1	5	6	3.5	16.7	0.6
15	*Schilbe mystus*							0	0	0.0	0.0
16	*Petrocephalus spp*		1	3	2	2	7	15	22.5	41.7	3.7
17	Ekudu (Unidentified)				1		3	4	3.5	11.1	0.6
18	*Pantodon bucholzi*					1	1	2	1.5	6.7	0.2
19	*Xenomystus nigri*			1		1	7	9	7.5	25.0	1.2
20	*Protopterus annectens*					1	6	7	4.0	19.4	0.7
21	*Micralestes spp*						1	1	0.5	2.8	0.1
22	*Hepsetus odoe*						3	3	1.5	8.3	0.2
23	*Malapterurus electricus*						3	3	1.5	8.3	0.2
24	*Hydrocynus linaetus*						1	1	0.5	2.8	0.1
25	Gbagbakurukuru (Unidentified)						1	1	0.5	2.8	0.1
26	*Notopterus chitala*		1					1	4.0	2.8	0.7
27	Ogelegele (Uidentified)					1		1	1.0	2.8	0.2
28	*Ichthyborus monody*						1	1	0.5	2.8	0.1
	Total	**36**	**34**	**36**	**34**	**38**	**152**	**330**	**606**	**916.7**	**100.0**

Appendix 37 Fish diversity and abundance based on TELK (Otuogidi)

		Abundance / Diversity					Others	Total Fishers	Total Rank	% Fishers	Relative Rank
S/No.	**Fish species**	**5**	**4**	**3**	**2**	**1**	**0.5**				
1	*Citharinus spp*	9	7	2	1	1	5	25	84.5	83.3	17.2
2	*Alestes spp*	13	8	5		1	3	30	114.5	100.0	23.3
3	*Tilapia spp*	2	3	5	1	4	8	23	47	76.7	9.6
4	*Gymnarchus niloticus*		1			4	20	25	18	83.3	3.7
5	*Distichodus spp*	5	6	6	2	1	7	27	75.5	90.0	15.3
6	*Clarias spp*				2		9	11	8.5	36.7	1.7
7	*Chrysichthys nigrodigitatus*	1	2	3	7	2	9	24	42.5	80.0	8.6
8	*Ophiocephalus obscurus*				1	1	3	5	4.5	16.7	0.9
9	*Heterotis niloticus*			1	2	1	11	15	13.5	50.0	2.7
10	*Synodontis spp*			2	2	2	7	13	15.5	43.3	3.2
11	*Marcusenius spp*					1		1	1	3.3	0.2
12	*Papyrocranus afer*					1	7	8	4.5	26.7	0.9
13	*Pareutropius sp*			2	1	2		5	10	16.7	2.0
14	*Labeo sp*		2		1	3	2	8	14	26.7	2.8
15	*Schilbe mystus*					5	3	8	6.5	26.7	1.3
16	*Petrocephalus spp*			1	1	5		7	10	23.3	2.0
17	*Lates niloticus*					1	7	8	4.5	26.7	0.9
18	*Pantodon bucholzi*						1	1	0.5	3.3	0.1
19	*Xenomystus nigri*				1			1	2	3.3	0.4
20	*Mormyrus spp*						5	5	2.5	16.7	0.5
21	*Mugil cephalus*			1	2			3	7.0	10.0	1.4
22	*Hepsetus odoe*						6	6	3.0	20.0	0.6
23	*Protopterus annectens*						4	4	2.0	13.3	0.4
24	*Malapterurus electricus*						1	1	0.5	3.3	0.1
25	*Hydrocynus linaetus*					1	2	3	2.0	10.0	0.4
26	Ekudo (Unidentified)						2	2	1.0	6.7	0.2
	Total	**30**	**29**	**28**	**24**	**35**	**118**	**264**	**492**	**880.0**	**100.0**

Appendix 38 Relationship between metrics of fish diversity and abundance (Elebele)

Correlations

			Fish species DV-AB - Perception	Fish species DV-AB - Ranking
Kendall's tau_b	Fish species DV-AB - Perception	Correlation Coefficient	1.000	.617**
		Sig. (2-tailed)	.	.001
		N	17	17
	Fish species DV-AB - Ranking	Correlation Coefficient	.617**	1.000
		Sig. (2-tailed)	.001	.
		N	17	17

**. Correlation is significant at the .01 level (2-tailed).

Appendix 39 Relationship between metrics of fish abundance and diversity (Otuoke)

Correlations

		Fish species DV-AB - Perception	Fish species DV-AB - Ranking
Fish species DV-AB - Perception	Pearson Correlation	1	.817**
	Sig. (2-tailed)	.	.000
	N	17	17
Fish species DV-AB - Ranking	Pearson Correlation	.817**	1
	Sig. (2-tailed)	.000	.
	N	17	17

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 40 Relationship between metrics of fish diversity and abundance (Otakeme)

Correlations

			Fish species DV-AB - Perception	Fish species DV-AB - Ranking
Kendall's tau_b	Fish species DV-AB - Perception	Correlation Coefficient	1.000	.781**
		Sig. (2-tailed)	.	.000
		N	17	17
	Fish species DV-AB - Ranking	Correlation Coefficient	.781**	1.000
		Sig. (2-tailed)	.000	.
		N	17	17

**. Correlation is significant at the .01 level (2-tailed).

Appendix 41 Relationship between metrics of fish abundance and diversity (Otuogidi)

Correlations

			Fish species DV-AB - Perception	Fish species DV-AB - Ranking
Kendall's tau_b	Fish species DV-AB - Perception	Correlation Coefficient	1.000	.717**
		Sig. (2-tailed)	.	.000
		N	17	17
	Fish species DV-AB - Ranking	Correlation Coefficient	.717**	1.000
		Sig. (2-tailed)	.000	.
		N	17	17

**. Correlation is significant at the .01 level (2-tailed).

Appendix 42 Relationship between metrics of fish diversity and abundance (Study Area)

Correlations

			Fish species DV-AB - Perception	Fish species DV-AB - Ranking
Kendall's tau_b	Fish species DV-AB - Perception	Correlation Coefficient	1.000	.706**
		Sig. (2-tailed)	.	.000
		N	68	68
	Fish species DV-AB - Ranking	Correlation Coefficient	.706**	1.000
		Sig. (2-tailed)	.000	.
		N	68	68

**. Correlation is significant at the .01 level (2-tailed).

Appendix 43 Commercial value of fish species (Elebele)

		Commercial value					**Total Fisher**	**Total Rank**	**% Fishers**	**Relative Rank**
S/No.	**Fish species**	**5**	**4**	**3**	**2**	**1**				
1	*Citharinus spp*					3	3	3	16.7	1.1
2	*Alestes spp*					1	1	1	5.6	0.4
3	*Tilapia spp*				1		1	2	5.6	0.7
4	*Gymnarchus niloticus*	10	5				15	70	83.3	26.2
5	*Distichodus spp*			2	5	1	8	17	44.4	6.4
6	*Clarias spp*	5	6	1	2	2	16	58	88.9	21.7
7	*Ophiocephalus obscurus*	1		3	1	1	6	17	33.3	6.4
8	*Heterotis niloticus*	1	4	6	1		12	41	66.7	15.4
9	*Papyrocranus afer*	1	3	1	3	3	11	29	61.1	10.9
10	*Pareutropius sp*			1	1		2	5	11.1	1.9
11	*Lates niloticus*					1	1	1	5.6	0.4
12	*Chrysichthys nigrodigitatus*			2			2	6	11.1	2.2
13	*Emunu (Unidentified)*			1	1	1	3	6	16.7	2.2
14	*Synodontis spp*				1	1	2	3	11.1	1.1
15	*Marcusenius spp*					2	2	2	11.1	0.7
16	*Notopterus chitala*			1	1		2	5	11.1	1.9
17	*Bagrus spp*					1	1	1	5.6	0.4
Total		18	18	18	17	17	88	267	488.9	100.0

Appendix 44 Commercial value of fish species (Otuoke)

		Commercial value					Total Fisher	Total Rank	% Fishers	Relative Rank
S/No.	**Fish species**	**5**	**4**	**3**	**2**	**1**				
1	*Citharinus spp*			1	1	1	3	6	9.4	1.3
2	*Alestes spp*			1	1	2	4	7	12.5	1.5
3	*Tilapia spp*	1			1	1	3	8	9.4	1.7
4	*Gymnarchus niloticus*	25	4	2			31	147	96.9	30.9
5	*Distichodus spp*		2	4	5	2	13	32	40.6	6.7
6	*Clarias spp*	3	15	4	5	1	28	98	87.5	20.6
7	*Ophiocephalus obscurus*		2	1	5	2	10	23	31.3	4.8
8	*Heterotis niloticus*		6	12	4	4	26	72	81.3	15.1
9	*Papyrocranus afer*				1	2	3	4	9.4	0.8
10	*Pareutropius sp*				1		1	2	3.1	0.4
11	*Lates niloticus*	1	2	3	1	3	10	27	31.3	5.7
12	*Chrysichthys nigrodigitatus*	2	1	4	5	2	14	38	43.8	8.0
13	*Emunu (Unidentified)*						0	0	0.0	0.0
14	*Labeo sp*				1	2	3	4	9.4	0.8
15	*Mormyrus spp*				1	3	4	5	12.5	1.1
16	*Hepsetus odoe*					1	1	1	3.1	0.2
17	*Bagrus spp*					2	2	2	6.3	0.4
Total		32	32	32	32	28	156	476	487.5	100.0

Appendix 45 Commercial value of fish species (Otakeme)

		Commercial value								
S/No.	**Fish species**	**5**	**4**	**3**	**2**	**1**	**Total Fisher**	**Total Rank**	**% Fishers**	**Relative Rank**
1	*Citharinus spp*		2	1	3	3	9	20	25.0	3.8
2	*Alestes spp*			2	3	4	9	16	25.0	3.0
3	*Tilapia spp*	1	1	1	2	4	9	20	25.0	3.8
4	*Gymnarchus niloticus*	28	5				33	160	91.7	30.1
5	*Distichodus spp*	1	1	11	5	4	22	56	61.1	10.5
6	*Clarias spp*	3	3	10	3	2	21	65	58.3	12.2
7	*Ophiocephalus obscurus*		1	1	5	9	16	26	44.4	4.9
8	*Heterotis niloticus*	3	22	5	1		31	120	86.1	22.6
9	*Papyrocranus afer*				5	3	8	13	22.2	2.4
10	*Pareutropius sp*						0	0	0.0	0.0
11	*Lates niloticus*						0	0	0.0	0.0
12	*Chrysichthys nigrodigitatus*		1	1	8		10	23	27.8	4.3
13	*Emunu (Unidentified)*						0	0	0.0	0.0
14	*Protopterus annectens*			2		1	3	7	8.3	1.3
15	*Bagrus spp*			2			2	6	5.6	1.1
Total		36	36	36	35	30	173	532	480.6	100.0

Appendix 46 Commercial value of fish species (Otuogidi)

S/No.	Fish species	Commercial value 5	4	3	2	1	Total Fisher	Total Rank	% Fishers	Relative Rank
1	*Citharinus spp*				3	4	7	10	23.3	2.3
2	*Alestes spp*		1		2	1	4	9	13.3	2.1
3	*Tilapia spp*		1	3	2	5	11	22	36.7	5.0
4	*Gymnarchus niloticus*	21	5	1			27	128	90.0	29.3
5	*Distichodus spp*	1	2	5	5	2	15	40	50.0	9.2
6	*Clarias spp*		7	6	4	1	18	55	60.0	12.6
7	*Ophiocephalus obscurus*					1	1	1	3.3	0.2
8	*Heterotis niloticus*	1	7	4	1	5	18	52	60.0	11.9
9	*Papyrocranus afer*						0	0	0.0	0.0
10	*Pareutropius sp*						0	0	0.0	0.0
11	*Lates niloticus*	6	2		3	2	13	46	43.3	10.5
12	*Chrysichthys nigrodigitatus*	1	4	8	7	2	22	61	73.3	14.0
13	*Emunu (Unidentified)*						0	0	0.0	0.0
14	*Mormyrus spp*			2		1	3	7	10.0	1.6
15	*Mugil cephalus*					1		1	0.0	0.2
16	*Hepsetus odoe*		1					4	0.0	0.9
17	*Synodontis spp*					1	1	1	3.3	0.2
Total		30	30	29	27	26	140	437	466.7	100.0

Appendix 47 Relationship between metrics of commercial value of species (Elebele)

Correlations

			Species ECONS - Ranking (Elebele)	Species ECONS - Percentage (Elebele)
Kendall's tau_b	Species ECONS - Ranking (Elebele)	Correlation Coefficient	1.000	.874**
		Sig. (2-tailed)	.	.000
		N	14	14
	Species ECONS - Percentage (Elebele)	Correlation Coefficient	.874**	1.000
		Sig. (2-tailed)	.000	.
		N	14	14

**. Correlation is significant at the .01 level (2-tailed).

Appendix 48 Relationship between metrics of commercial value of species (Otuoke)

Correlations

			Species ECONS - Ranking (Otuoke)	Species ECONS - Percentage (Otuoke)
Kendall's tau_b	Species ECONS - Ranking (Otuoke)	Correlation Coefficient	1.000	.904**
		Sig. (2-tailed)	.	.000
		N	14	14
	Species ECONS - Percentage (Otuoke)	Correlation Coefficient	.904**	1.000
		Sig. (2-tailed)	.000	.
		N	14	14

**. Correlation is significant at the .01 level (2-tailed).

Appendix 49 Relationship between metrics of commercial value of species (Otakeme)

Correlations

			Species ECONS - Ranking (Otakeme)	Species ECONS - Percentage (Otakeme)
Kendall's tau_b	Species ECONS - Ranking (Otakeme)	Correlation Coefficient	1.000	.906**
		Sig. (2-tailed)	.	.000
		N	14	14
	Species ECONS - Percentage (Otakeme)	Correlation Coefficient	.906**	1.000
		Sig. (2-tailed)	.000	.
		N	14	14

**. Correlation is significant at the .01 level (2-tailed).

Appendix 50 Relationship between metrics of commercial value of species (Otuogidi)

Correlations

		Species ECONS - Ranking (Otuogidi)	Species ECONS - Percentage (Otuogidi)
Species ECONS - Ranking (Otuogidi)	Pearson Correlation	1	.937**
	Sig. (2-tailed)	.	.000
	N	14	14
Species ECONS - Percentage (Otuogidi)	Pearson Correlation	.937**	1
	Sig. (2-tailed)	.000	.
	N	14	14

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 51 Relationship between metrics of commercial value of species (Study Area)

Correlations

			Species ECONS - Ranking (Kolo Creek area)	Species ECONS - Percentage (Kolo Creek area)
Kendall's tau_b	Species ECONS - Ranking (Kolo Creek area)	Correlation Coefficient	1.000	.915**
		Sig. (2-tailed)	.	.000
		N	56	56
	Species ECONS - Percentage (Kolo Creek area)	Correlation Coefficient	.915**	1.000
		Sig. (2-tailed)	.000	.
		N	56	56

**. Correlation is significant at the .01 level (2-tailed).

Appendix 52 Relationship between metrics of commercial value of species (Elebele / Otuoke Creek)

Correlations

			Species ECONS - Ranking (Elebele / Otuoke Creek)	Species ECONS - Percentage (Elebele / Otuoke Creek)
Kendall's tau_b	Species ECONS - Ranking (Elebele / Otuoke Creek)	Correlation Coefficient	1.000	.895**
		Sig. (2-tailed)	.	.000
		N	28	28
	Species ECONS - Percentage (Elebele / Otuoke Creek)	Correlation Coefficient	.895**	1.000
		Sig. (2-tailed)	.000	.
		N	28	28

**. Correlation is significant at the .01 level (2-tailed).

Appendix 53 Relationship between metrics of commercial value of species (Kolo Creek)

Correlations

			Species ECONS - Ranking (Kolo Creek)	Species ECONS - Percentage (Kolo Creek)
Kendall's tau_b	Species ECONS - Ranking (Kolo Creek)	Correlation Coefficient	1.000	.936**
		Sig. (2-tailed)	.	.000
		N	28	28
	Species ECONS - Percentage (Kolo Creek)	Correlation Coefficient	.936**	1.000
		Sig. (2-tailed)	.000	.
		N	28	28

**. Correlation is significant at the .01 level (2-tailed).

Appendix 54 Relationship between educational qualifications (Otuoke-Otuogidi)

Correlations

			Educational qualification (Otuoke)	Educational qualifications (Otuogidi)
Kendall's tau_b	Educational qualification (Otuoke)	Correlation Coefficient	1.000	1.000**
		Sig. (2-tailed)	.	.005
		N	6	6
	Educational qualifications (Otuogidi)	Correlation Coefficient	1.000**	1.000
		Sig. (2-tailed)	.005	.
		N	6	6

**. Correlation is significant at the .01 level (2-tailed).

Appendix 55 Relationship between impacts of dredging on fishing (Otuoke-Otuogidi)

Correlations

			Impact of dredging on fisheries - Otuoke	Impact of dredging on fisheries - Otuogidi
Kendall's tau_b	Impact of dredging on fisheries - Otuoke	Correlation Coefficient	1.000	.889*
		Sig. (2-tailed)	.	.037
		N	5	5
	Impact of dredging on fisheries - Otuogidi	Correlation Coefficient	.889*	1.000
		Sig. (2-tailed)	.037	.
		N	5	5

*. Correlation is significant at the .05 level (2-tailed).

Appendix 56 Relationship between mitigation preferences (Otuoke-Otuogidi)

Correlations

			Mitigation options (Otuoke)	Mitigation options (Otuogidi)
Kendall's tau_b	Mitigation options (Otuoke)	Correlation Coefficient	1.000	.486*
		Sig. (2-tailed)	.	.031
		N	13	13
	Mitigation options (Otuogidi)	Correlation Coefficient	.486*	1.000
		Sig. (2-tailed)	.031	.
		N	13	13

*. Correlation is significant at the .05 level (2-tailed).

Appendix 57 Catalogue of freshwater fish species (Study Area)

Local name	Scientist name
Epete / Aporu	*Citharinus spp*
Agbara	*Lates niloticus*
Apamu / Isongo	*Pantodon bucholzi*
Baracuda	*Acestrorhynchus sp*
Ebede	*Petrocephalus spp*
Ebelem	*Xenomystus nigri (Pez cuchillo Africano)*
Ebhe	*Marcusenius spp*
Ebiesene	*Protopterus annectens*
Ebiesene	*Protopterus annectens*
Edegere	*Micralestes spp*
Eferere	*Distichodus spp*
Egbetuki	*Unidentified*
Ekwei	*Phago loricatus*
Emunu	*Unidentified*
Epelepele	*Unidentified*
Epelia	*Trachinotus goreensis*
Epelia	*Trachinotus goreensis*
Epelia	*Trachinotus goreensis*
Esa	*Gymnarchus niloticus*
Esasam	*Ctenopoma kingsleyae*
Ewela	*Tilapia spp*
Gbagbakurukuru	*Unidentified*
Ibutu	*Labeo sp*
Obhari	*Papyrocranus afer*
Obhari	*Papyrocranus afer*
Obulo	*Ophiocephalus obscurus*
Obuya	*Mormyrus spp*
Ofio / Oduro	*Bagrus spp*
Ofuroma	*Mugil cephalus*
Ogbolokaka	*Heterotis niloticus*
Ogbolomo-obele	*Polycentropsis abbreviata*
Ogbuda	*Schilbe mystus*
Ogulo / Egbo	*Chrysichthys nigrodigitatus*
Ohabh	*Hydrocynus linaetus*
Okolobosigoin	*Ichthyborus monodi*
Okolokolo	*Alestes spp*
Okpoki / Opogoin	*Synodontis spp*
Okpokpozi	*Notopterus chitala*
Olari	*Pareutropius sp*
Omemde	*Mastacenblus loennbagi*
Omemde	*Mastacenblus loennbagi*
Omiozogboro	*Unidentified*
Omosi / Otikiri	*Malapterurus electricus*
Orim	*Hepsetus odoe*
Orobhobhi	*Clarias spp*
Oza	*Raiamas senegalensis*

Appendix 58 Summary of ecological survey (Elebele)

	FISH SPECIES (Scientific and Native names)																																			
	Aletes spp	*Distichodus spp*	*Heterotis niloticus*	*Citharinus spp*	*Tilapia spp*	*Bagrus spp*	*Mugil cephalus*	*Micralestes spp*	*Petrocephalus spp.*	*Marcusenius spp*	*Pareutropius sp*	*Phago loricatus*	*Synodontis spp*	*Chrysichthys nigrodigitatus*	*Hydrocynus linaetus*	*Pantodon bucholzi*	*Notopterus chitala*	*Bagrus spp*	*Acestrorhynchus sp.*	*Labeo sp*	*Ichthyborus monodi.*	*Xenomystus nigri (Pez cuchillo Africano)*	*Raiamas senegalensis*	*Hepsetus odoe*	*Polycentropsis abbreviata*											
Sampling day	OKOLOKOLO	EFERERE	OGBOLOKA	EPETE / APORU	EWELA	OGBUDA	OFUROMA	EDEGERE	EBEDE	EBHE	OLARI	EKWEI	OKPOKI / OPOGOIN	OGULO / EGBO	OHABH	APAMU / ISONGO	OKPOKOZI	ODURO / OFIO	BARACUDA	IGBUTU	OKOLOBOSIGOIN	EBELEM	OZA	ORIM	OGBOLOMO-OBELE	TOTAL FISH CATCH	TOTAL AATEMPT	FISHING DURATION (MIN.)	CATCH PER UNIT HOUR	CATCH PER UNIT EFFORT	SPECIES DIVERSITY	% OMNIVORES	% CARNIVORES	% INVERTIVORES	% HERBIVORES	% DETRITIVORES
1	24	0	0	21	0	0	0	31	34	14	14	0	0	2	0	1	5	0	0	0	0	0	0	0	0	146	46	416	21.1	3.2	9	53.4	3.4	43.2	0.0	0.0
2	25	1	0	2	1	0	0	3	0	13	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	50	29	286	10.5	1.7	8	64.0	0.0	32.0	2.0	2.0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12	213	0.3	0.1	1	0.0	0.0	0.0	0.0	100.0
4	25	1	1	10	1	0	0	24	70	4	5	0	0	2	0	2	0	0	0	0	0	0	0	0	0	145	45	233	37.3	3.2	11	42.1	0.0	55.9	0.7	1.4
5	23	0	0	7	0	0	0	8	3	10	5	0	3	1	0	0	0	0	0	0	0	0	0	0	0	60	34	288	12.5	1.8	8	65.0	0.0	35.0	0.0	0.0
6	41	1	0	10	1	0	0	19	4	11	9	0	0	8	0	0	0	0	0	0	0	0	0	0	0	104	51	331	18.9	2.0	9	75.0	0.0	23.1	1.0	1.0
$\bar{x}$	23.0	0.5	0.3	8.3	0.5	0.0	0.0	14.2	18.5	8.7	6.0	0.0	0.5	2.5	0.0	0.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.3	36.2	294.5	16.8	2.0	7.7	56.9	0.6	31.5	0.6	1.0

Appendix 59 Summary of ecological survey (Otuoke)

	FISH SPECIES (Scientific and Native names)																																			
	Aletes spp	*Distichodus spp*	*Heterotis niloticus*	*Citharinus spp*	*Tilapia spp*	*Bagrus spp*	*Mugil cephalus*	*Micralestes spp*	*Petrocephalus spp.*	*Marcusenius spp*	*Pareutropius sp*	*Phago loricatus*	*Synodontis spp*	*Chrysichthys nigrodigitatus*	*Hydrocynus linaetus*	*Pantodon bucholzi*	*Notopterus chitala*	*Bagrus spp*	*Acestrorhynchus sp.*	*Labeo sp*	*Ichthyborus monodi.*	*Xenomystus nigri (Pez cuchillo Africano)*	*Raiamas senegalensis*	*Hepsetus odoe*	*Polycentropsis abbreviata*											
Sampling day	OKOLOKOLO	EFERERE	OGBOLOKA	EPETE / APORU	EWELA	OGBUDA	OFUROMA	EDEGERE	EBEDE	EBHE	OLARI	EKWEI	OKPOKI / OPOGOIN	OGULO / EGBO	OHABH	APAMU / ISONGO	OKPOKOZI	ODURO / OFIO	BARACUDA	IGBUTU	OKOLOBOSIGOIN	EBELEM	OZA	ORIM	OGBOLOMO-OBELE	TOTAL FISH CATCH	TOTAL ATTEMPT	FISHING DURATION (MIN	CATCH PER UNIT HOUR	CATCH PER UNIT EFFOR	SPECIES DIVERSITY	% OMNIVORES	% CARNIVORES	% INVERTIVORES	% HERBIVORES	% DETRITIVORES
1	17	0	0	20	0	0	0	0	0	0	2	0	4	1	0	0	0	0	0	0	0	0	0	0	0	44	47	427	6.2	0.9	5	86.4	0.0	13.6	0.0	0.0
2	7	2	0	24	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	36	32	374	5.8	1.1	5	86.1	0.0	0.0	8.3	5.6
3	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	29	271	0.7	0.1	2	66.7	0.0	0.0	33.3	0.0
4	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	41	321	5.0	0.7	1	100.0	0.0	0.0	0.0	0.0
5	3	0	0	12	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	36	379	2.7	0.5	4	88.2	0.0	11.8	0.0	0.0
6	13	0	0	18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	32	30	256	7.5	1.1	3	96.9	0.0	3.1	0.0	0.0
$\bar{x}$	6.7	0.5	0.0	17.2	0.3	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	26.5	35.8	338.0	4.6	0.7	3.3	90.6	0.0	4.8	6.9	1.3

Appendix 60 Summary of ecological survey (Otakeme)

	FISH SPECIES (Scientific and Native names)																																			
	Aletes spp	*Distichodus spp*	*Heterotis niloticus*	*Citharinus spp*	*Tilapia spp*	*Bagrus spp*	*Mugil cephalus*	*Micralestes spp*	*Petrocephalus spp.*	*Marcusenius spp*	*Pareutropius sp*	*Phago loricatus*	*Synodontis spp*	*Chrysichthys nigrodigitatus*	*Hydrocynus linaetus*	*Pantodon bucholzi*	*Notopterus chitala*	*Bagrus spp*	*Acestrorhynchus sp.*	*Labeo sp*	*Ichthyborus monodi.*	*Xenomystus nigri (Pez cuchillo Africano)*	*Raiamas senegalensis*	*Hepsetus odoe*	*Polycentropsis abbreviata*											
Sampling day	OKOLOKOLO	EFERERE	OGBOLOKA	EPETE / APORU	EWELA	OGBUDA	OFUROMA	EDEGERE	EBEDE	EBHE	OLARI	EKWEI	OKPOKI / OPOGOIN	OGULO / EGBO	OHABH	APAMU / ISONGO	OKPOKOZI	ODURO / OFIO	BARACUDA	IGBUTU	OKOLOBOSIGOIN	EBELEM	OZA	ORIM	OGBOLOMO-OBELE	TOTAL FISH CATCH	TOTAL ATTEMPT	FISHING DURATION (MIN.)	CATCH PER UNIT HOUR	CATCH PER UNIT EFFORT	SPECIES DIVERSITY	% OMNIVORES	% CARNIVORES	% INVERTIVORES	% HERBIVORES	% DETRITIVORES
1	11	1	0	26	9	2	0	0	0	0	2	0	2	3	0	0	0	0	0	0	0	0	0	0	0	56	26	215	15.6	2.2	8	71.4	3.6	7.1	1.8	16.1
2	5	2	0	53	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	47	340	11.3	1.4	4	90.6	0.0	0.0	3.1	6.3
3	12	0	0	32	6	0	0	0	8	9	4	0	0	7	0	0	0	0	0	0	0	0	0	0	0	78	49	363	12.9	1.6	7	65.4	0.0	26.9	0.0	7.7
4	9	4	0	27	0	0	0	0	0	11	8	0	7	2	0	0	0	0	0	0	0	0	0	0	0	68	37	276	14.8	1.8	8	55.9	0.0	38.2	5.9	0.0
5	8	1	0	12	0	0	0	0	14	1	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	40	48	607	4.0	0.8	7	52.5	7.5	37.5	2.5	0.0
6	1	0	0	2	0	0	0	0	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	12	51	508	1.4	0.2	5	58.3	8.3	33.3	0.0	0.0
x̄	7.7	1.3	0.0	25.3	3.2	0.3	0.0	0.0	3.7	4.2	2.3	0.0	1.5	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.2	53.0	43.0	384.8	10.0	1.3	6.5	65.7	3.2	23.9	2.2	5.0

Appendix 61 Summary of ecological survey (Otuogidi)

	FISH SPECIES (Scientific and Native names)																																			
	Aletes spp	*Distichodus spp*	*Heterotis niloticus*	*Citharinus spp*	*Tilapia spp*	*Bagrus spp*	*Mugil cephalus*	*Micralestes spp*	*Petrocephalus spp.*	*Marcusenius spp*	*Pareutropius sp*	*Phago loricatus*	*Synodontis spp*	*Chrysichthys nigrodigitatus*	*Hydrocynus linaetus*	*Pantodon bucholzi*	*Notopterus chitala*	*Bagrus spp*	*Acestrorhynchus sp.*	*Labeo sp*	*Ichthyborus monodi.*	*Xenomystus nigri (Pez cuchillo Africano)*	*Raiamas senegalensis*	*Hepsetus odoe*	*Polycentropsis abbreviata*											
Sampling day	OKOLOKOLO	EFERERE	OGBOLOKA	EPETE / APORU	EWELA	OGBUDA	OFUROMA	EDEGERE	EBEDE	EBHE	OLARI	EKWEI	OKPOKI / OPOGOIN	OGULO / EGBO	OHABH	APAMU / ISONGO	OKPOKOZI	ODURO / OFIO	BARACUDA	IGBUTU	OKOLOBOSIGOIN	EBELEM	OZA	ORIM	OGBOLOMO-OBELE	TOTAL FISH CATCH	TOTAL ATTEMPT	FISHING DURATION (MIN	CATCH PER UNIT HOUR	CATCH PER UNIT EFFOR	SPECIES DIVERSITY	% OMNIVORES	% CARNIVORES	% INVERTIVORES	% HERBIVORES	% DETRITIVORES
1	47	0	0	4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54	44	240	13.5	1.2	5	94.4	1.9	0.0	0.0	3.7
2	0	0	0	11	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	14	81	626	1.3	0.2	3	78.6	14.3	0.0	0.0	7.1
3	1	0	0	0	0	1	0	0	2	0	0	0	0	13	0	0	0	3	0	0	0	0	0	0	0	20	16	235	5.1	1.3	5	70.0	0.0	10.0	0.0	0.0
4	6	1	0	8	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	18	39	115	9.4	0.5	5	77.8	5.6	0.0	5.6	11.1
5	1	1	0	44	0	1	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0	0	51	51	309	9.9	1.0	7	90.2	2.0	3.9	2.0	0.0
6	7	1	0	17	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	30	36	425	4.2	0.8	7	86.7	3.3	3.3	3.3	0.0
x̄	10.3	0.5	0.0	14.0	0.2	0.7	0.5	0.0	0.3	0.0	0.0	0.2	0.3	2.7	0.3	0.0	0.0	0.5	0.2	0.0	0.2	0.0	0.2	0.2	0.0	31.2	44.5	325.0	7.2	0.8	5.3	82.9	4.5	2.9	1.8	3.7