Identifying key threats and conservation requirements for the Critically Endangered Yangtze finless porpoise

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Declaration

I, Lisa Mogensen, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:

Abstract

Evidence-based conservation is the most effective way to preserve biodiversity. However, for many species robust long-term data sets are not available and so the process of selecting effective interventions is poorly-informed and at risk of being ineffective. The Critically Endangered Yangtze finless porpoise (*Neophocaena asiaeorientalis*), a unique freshwater cetacean endemic to the Yangtze River, China, is subject to numerous anthropogenic threats that have led to significant population decline in recent decades. Conservation of this species has been severely limited by a poor understanding of the causes of population decline. By using four novel lines of analysis on already existing data sets, this study firstly assessed whether there is currently a sufficient evidence base to inform conservation of this species. This process established conservation-relevant conclusions and identified key remaining knowledge gaps without having to use valuable resources and time to gather further data. Subsequently, boat-based mapping studies have revealed conservation-relevant spatial and temporal patterns relating to potential threat presence and YFP habitat use on multiple spatial scales, whilst extensive interview-based surveys with fishers have been used to gather detailed information on patterns in illegal fishing gear use and YFP bycatch, as well as conservation-relevant socio-economic data. In addition, longitudinal interview data has provided an invaluable insight into changes in human-wildlife interactions and high-risk human behaviours over time. Lastly, an interview survey with key stakeholders involved in Yangtze finless porpoise conservation has demonstrated that evidence-based conservation is not being applied to this species, meaning that interventions are not targeted to key causes of decline and there is a risk of conservation complacency and extinction of a second Yangtze River cetacean. The multi-disciplinary research presented here has demonstrated how the conservation process for data-poor endangered species can be improved by increasing the knowledge base surrounding potential threats and causes of direct and indirect mortality, which has wider application for other at-risk species.

Impact Statement

- This research has generated £15,000 funding for vital research into a Critically Endangered species.
- The methods used here have potential for wider applications to other species requiring conservation attention.
- The research presented here has both academic implications and wider impacts outside of academia for direct conservation of the studies target species.
- This research has been presented at the 2018 European Conference on Conservation Biology (ECCB) in Jyvaskyla, Finland.
- The conclusions of this study will be presented at a workshop with local managers and stakeholders involved in conservation of the study species in China.

Evidence-based conservation is the most effective way to improve the application of interventions aimed at preserving biodiversity. By using the Critically Endangered Yangtze finless porpoise, a unique freshwater cetacean, as a prominent case study, the research presented here has demonstrated how the conservation of data-poor endangered species around the world can be improved by increasing the knowledge base surrounding potential threats and causes of major mortality. The impacts of this study are both global (research methods applicable to conservation of other endangered species) and more localised and specific (conservation of this specific species within China).

Firstly, the understanding of some key threats to this species is improved using four lines of analysis on already existing data sets that have been combined and used in novel ways to extract conservation-relevant information. This has demonstrated that in cases where a data deficiency is preventing evidence-based conservation, it is vital to critically evaluate the information content of available data sets, even if they were not originally collected for conservation purposes. This approach could be useful to improve conservation-relevant knowledge of many other data-poor species and can be applied to other conservation-based academic research.

Following on, this study then demonstrates the interaction of a Critically Endangered unique cetacean with potential threats on multiple spatial scales and establishes the seasonal changes in species distribution and interaction with threats using a rapid simultaneous threat-species boat-based survey technique. This technique could be applied to research on other cetacean species. Further to this, the use of local ecological knowledge as a technique to gather conservation-relevant data is applied to improve the knowledge of the interaction of this species with one of the known causes of mortality: fishing bycatch. This method also has potential for wider application to other species and systems.

This study has additionally assessed the current reserve network for the Yangtze finless porpoise for the first time, both through boat-based surveys but also through an appraisal of the management and design of the reserves themselves. The results demonstrated here can directly be applied to improve the allocation and management of protected areas aimed at conserving the Yangtze finless porpoise in China and hopefully improve prospects for this species. In addition, all the results presented in this study are relevant to in-country conservation efforts for this species.

The main results of this study have been presented at the 2018 ECCB conference. In addition, all the information from this study will be disseminated within a workshop attended by prominent Yangtze finless porpoise stakeholders, policy makers, and managers in October 2018 in China, with the hope that key gaps and areas for improvement of in-situ Yangtze finless porpoise conservation can be addressed and a second Yangtze River cetacean extinction can be avoided. Further to this, most of the results presented here will be published in peer-reviewed academic publications for dissemination to interested academic parties.

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Contents

1 Chapter 1: Introduction 1

1.1 Conservation of threatened species – evidence-based vs. precautionary approaches 2

1.2 What data are needed to conserve threatened taxa? 3

1.2.1 Understanding and quantifying decline in a population 4

1.2.2 Improved data collection and analysis of poorly studied species 5

1.3 The plight of freshwater cetaceans 5

1.3.1 Freshwater cetaceans under threat 5

1.3.2 Conservation of freshwater cetaceans 8

1.4 Yangtze River cetaceans 9

1.4.1 The Yangtze River – a heavily modified ecosystem 9

1.4.2 The precautionary tale of the Yangtze River dolphin (baiji) 10

1.4.3 The Yangtze finless porpoise – a taxon under severe threat 10

1.4.4 Biology and ecology of the Yangtze finless porpoise 14

1.4.5 Overview of potential threats to the YFP 15

1.4.6 YFP research; past, present, and future 21

1.4.7 YFP conservation research requirements 25

1.5 Objectives 27

1.5.1 Overarching Research Questions 27

2 Chapter 2: Evidence-based conservation versus the precautionary principle: determining the current evidence base from existing data to inform Yangtze finless porpoise conservation 29

2.1 Abstract 29

2.2 Introduction 30

2.2.1 Conservation of data poor species: precautionary or evidence-based approach? 30

2.2.2 The YFP: precautionary or evidence-based approach? 30

2.2.3 Current evidence base around threats to YFP 31

2.2.4 How is sustainable removal from a population quantified? 32

2.2.5 Understanding landscape scale and finer scale interactions of YFP with potential threats and reported YFP mortalities 36

2.2.6 Investigating YFP reproductive success 38

2.2.7 Research Questions 38

2.3 Methods 39

2.3.1 Estimating sustainable loss in YFP: does available mortality data explain population decline? 41

2.3.2 Can we associate key threats with increased YFP mortality? 44

2.3.3 Investigating patterns in the overlap of fishing activity and YFP presence across the river 53

2.3.4 Is YFP reproduction stable and uniform across the Yangtze River? 54

2.4 Results 58

2.4.1 Is YFP mortality sustainable, and does current data explain current level of anthropogenic mortality? 58
2.4.2 Can we associate key threats with increased YFP mortality? 59
2.4.3 Patterns in the overlap of fishing activity and YFP presence across the river 61
2.4.4 Is reproduction observably stable and uniform across the Yangtze River? 62
2.5 Discussion 63
2.5.1 Quantifying sustainability of anthropogenic mortality from the YFP population 63
2.5.2 Can we associate specific threats with YFP mortality based on current information? 65
2.5.3 Localised spatial patterns in fishing gear use across-river 66
2.5.4 What can we infer about YFP reproduction from past YFP populations? 67
2.6 Conclusions 74
3 Chapter 3: Spatio-temporal overlap of Yangtze finless porpoise presence and potential threats in Poyang Lake 79
3.1 Abstract 79
3.2 Introduction 80
3.2.1 Why do we need to understand spatial and temporal patterns of species and threat occurrence? 80
3.2.2 Identifying key habitat and conservation areas for cetacean species 81
3.2.3 Threat mapping as a conservation tool 82
3.2.4 Current understanding of spatial and temporal distribution of YFP 83
3.2.5 Present understanding of spatial and temporal distribution of potential threats to YFP 84
3.2.6 Poyang Lake: a highly seasonal key YFP habitat 85
3.2.7 Research questions 86
3.3 Methods 87
3.3.1 Seasonal YFP distribution and threat mapping surveys 87
3.3.2 Post-survey processing and mapping methods 89
3.3.3 YFP detection probability 90
3.3.4 Encounter rate 91
3.3.5 Quantifying overlap of YFP and threats spatially and temporally 92
3.4 Results 93
3.4.1 How does YFP distribution vary spatially and seasonally? 93
3.4.2 YFP Encounter Rates 95
3.4.3 How are threats distributed spatially and temporally? 100
3.4.4 Distance to threat analysis 105
3.5 Discussion 106
3.5.1 Habitat preference and seasonal variability of YFP distribution in Poyang Lake 106
3.5.2 Seasonal variability in threat distribution and YFP overlap in Poyang Lake 107
3.5.3 Current reserve placement within Poyang Lake 109
3.5.4 Wider implications of this study and this survey methodology 111

3.6 Conclusions 112
4 Chapter 4: Fishing for answers: drivers of Yangtze finless porpoise bycatch and illegal fishing behaviour in artisanal fisheries in the Yangtze drainage 113
4.1 Abstract 113
4.2 Introduction 114
4.2.1 Why do we need to understand cetacean bycatch? 114
4.2.2 The importance of LEK and socio-economic knowledge to manage sustainable fisheries and bycatch 115
4.2.3 The impact of conservation on local communities 116
4.2.4 Current understanding of Yangtze finless porpoise bycatch 117
4.2.5 Research Questions 119
4.3 Methods 120
4.3.1 Study area 120
4.3.2 Sampling design and interviewee selection 120
4.3.3 Pilot interview survey 124
4.3.4 Ethical considerations 124
4.3.5 Data analysis 124
4.4 Results 128
4.4.1 Interview statistics 128
4.4.2 Characterising fishing practices in the Yangtze River and Poyang Lake 128
4.4.3 Spatial variation in fishing gear use in Poyang Lake 132
4.4.4 Temporal patterns in fishing activity 134
4.4.5 Has catch or income changed over time? 136
4.4.6 Drivers of illegal or potentially lethal gear use 138
4.5 Discussion 140
4.5.1 Characterising fishing activity and Yangtze finless porpoise bycatch 140
4.5.2 Understanding the effect of fish stock decline on YFP 142
4.5.3 Understanding drivers of illegal fishing behaviour 143
4.5.4 How does this information translate into effective bycatch mitigation? 144
4.5.5 LEK as a method of assessing bycatch and fishing practices 146
4.6 Conclusions 146
5 Chapter 5: Use it or lose it: the use and misuse of evidence-based conservation and mitigation selection in the management of a Critically Endangered species 149
5.1 Abstract 149
5.2 Introduction 150
5.2.1 How do we optimise conservation outcomes? 150
5.2.2 The importance of evidence-based conservation 151
5.2.3 Current YFP conservation efforts 153
5.2.4 Research Questions 156
5.3 Methods 157
5.3.1 Assessment of current research efforts 157

5.3.2 Stakeholder interview survey 157
5.4 Results 161
5.4.1 Is there sufficient YFP based conservation research? 161
5.4.2 The use of evidence-based conservation for the YFP 164
5.4.3 Fish stock management and enforcement of mitigation in the Yangtze River (fisheries bureaus only) 171
5.5 Discussion 174
5.5.1 Are current YFP research goals appropriate? 174
5.5.2 Are conservation decisions for the YFP based on evidence? 175
5.5.3 Perceived YFP conservation successes and shortfalls 177
5.6 Conclusions 179
6 Discussion 181
6.1 Bycatch and fishing-based mitigation options for the Yangtze finless porpoise 183
6.1.1 Quantifying maze net (MiHunZhen) use in Poyang Lake 184
6.2 Vessel strike mitigation options for the Yangtze finless porpoise 184
6.3 Other recommendations for improving YFP conservation efforts 186
6.4 Are current reserves and interventions sufficient to protect YFP in-situ? 186
6.4.1 Is zoning within YFP reserves appropriate for cetacean conservation? 188
6.4.2 Is enforcement sufficient in YFP reserves? 189
6.4.3 Conflict within YFP reserves 190
6.4.4 Genetic and inbreeding issues within YFP reserves 191
6.4.5 Are current YFP reserves appropriate for cetacean conservation? 191
6.5 Overall conclusion 194
7 References 195
8 Appendices 242
8.1 Appendix A – chapter 2 242
8.2 Appendix B – chapter 3 257
8.3 Appendix C – chapter 4 259
8.4 Appendix D – chapter 4 270

List of Figures

Figure 1.1: Range of the YFP within the Yangtze River and two appended lakes of Poyang and Dongting. Map made in ArcMap (ESRI, 2014). 12

Figure 1.2: Diagrammatic representation of the progress made in taxonomically grouping the family Phocoenidae over time (top to bottom) 13

Figure 1.3: Location of eight in-situ and four semi-natural (numbered 1-4, bold text) cetacean reserves in the Yangtze River basin 26

Figure 2.1: Interview locations targeted during the 2008 survey from Yichang (west) to the river mouth at Shanghai (east). Numbers in brackets provide number of interviews conducted in each location in the survey. Map made in ArcMap (ESRI, 2014). 48

Figure 2.2: Number of fisher interviews in counties around Poyang Lake and the central Yangtze River region interview in 2011/12 survey. Map made in ArcMap (ESRI, 2014). 52

Figure 2.3: Stratification method for categorising distance from the bank,. Image adapated from Zhao *et al.* (2008) 54

Figure 2.4: Proportion of YFP observations and fishing gear use across the Yangtze river. Distance from bank that YFP were observed in the 2006 survey contrasted with distance from bank that two groups of fishing gear is used in the Yangtze. 62

Figure 3.1: USGS satellite imagery showing the change in extent of Poyang Lake between winter (left) and summer (right) 85

Figure 3.2: Detail of the route of boat based YFP and threat surveys on Poyang Lake in both winter and summer. Winter (low-water) and summer (high-water) lake extent demonstrate the seasonal difference in the lake size. Map made in ArcMap (ESRI, 2014). 89

Figure 3.3: Total number of all YFP detections at perpendicular distances from the survey vessel during the summer survey (top, n = 64 groups observed) and winter survey (top, n = 166 groups observed) in Poyang Lake. 91

Figure 3.4: Group size of observed YFP in both summer and winter surveys (summer survey n = 133, winter survey n = 334) and calves observed per group (summer survey n = 12, winter survey n = 27) 94

Figure 3.5: Distribution of YFP observations in Poyang Lake from the winter survey (left, number of groups = 148, total number of individuals = 334) and summer survey (right, number of groups = 52, total number of individuals = 133). Squares represent approximate 1km^2 areas covering a mid-line survey route following the centre of the northward and southward survey paths +300m to cover all observation points. Map made in ArcMap (ESRI, 2014). 97

Figure 3.6: Statistically significant hotspots of YFP presence observed during the winter (left) and summer (right) surveys. Hotspots were calculated using the Getis-Ord* statistic in ArcGIS. Map made in ArcMap (ESRI, 2014). 98

Figure 3.7: Distribution of YFP calf observations in Poyang Lake from the winter survey (left, number of groups with calves = 20, total number of individuals = 27) and summer survey (right, number of groups containing calves = 10, total number of individuals = 12) Squares represent approximate 1km^2 areas covering a mid-line survey route following the centre of the northward

and southward survey paths +300m to cover all observation points. Map made in ArcMap (ESRI, 2014). 99

Figure 3.8: Observed incidences of active fishing vessels or equipment in Poyang Lake during the winter (left) and summer (right) surveys within the 250m buffer. Map made in ArcMap (ESRI, 2014). 101

Figure 3.9: Statistically significant hotspots of fishing activity observed during the winter (left) and summer (right) surveys. Hotspots were calculated using the Getis-Ord* statistic in ArcGIS. Map made in ArcMap (ESRI, 2014). 102

Figure 3.10: Observed incidences of active sand mining vessels and sand mining activity in Poyang Lake during the winter surveys within the 250m buffer. Map made in ArcMap (ESRI, 2014). Map made in ArcMap (ESRI, 2014). 103

Figure 3.11: Statistically significant hotspots of sand-mining activity and vessels observed during the winter (left) and summer (right) surveys. Hotspots were calculated using the Getis-Ord* statistic in ArcGIS. Map made in ArcMap (ESRI, 2014). 104

Figure 3.12: Histograms of simulated null distributions from randomly generated distance data for each season and threat. Each histogram also shows the value of the observed mean distance from actual survey data for the corresponding season and threat, and asterisks (*) denote significant difference at the 99% confidence level. 105

Figure 4.1: Location and quantity of all fisher interviews in both Poyang lake and the Yangtze River mainstem section from Hukou – Anqing for the 2016 interview survey. **Note**: Xingzi, Duchang, Yongxiu, Poyang, and Yugan constitute Poyang Lake results, all others are for the Yangtze mainstem. Lake shown is summer extent to show proximity to the Lake. Map made in ArcMap (ESRI, 2014). 123

Figure 4.2: Groups of fishing gear used by fishers interviewed in this survey. **A**: Net based gear, **B**: pot/trap types gear, **C**: fixed gear, **D**: hook-based gear, **E**: electric fishing, **F**: cormorant fishing. 125

Figure 4.3: Fishing vessels used in the Yangtze River and Poyang Lake. **A**: small, open fishing boat, **B**: medium sized fishing vessel with shelter and sleeping quarters, and **C**: larger, sheltered vessels used for fishing and as more permanent accommodation. 128

Figure 4.4: Percentage of fishers using functional types of fishing equipment from Poyang Lake towns (Xingzi, Yongxiu, Poyang, Duchang, Yugan, N=176) and from H-A mainstem section towns (Anqing, Pengze, Wangjiang, Chizhou, Susong, Hukou, N=84). Asterisks indicate significant differences: 5% level (*), 1% level (**). 132

Figure 4.5: Spatial variation in percentage of fishermen using fishing gear types across major towns in Poyang Lake. Number of interviews represented in brackets. Note: fishers from Hukou not included as it could not be distinguished whether they fish in Poyang Lake or the H-A mainstem section. 133

Figure 4.6: Seasonality of fishing activity in the H-A mainstem section (n=76) and Poyang Lake (n=185) represented by the % of fishermen carrying out any fishing activity in each calendar month. † indicates months where fishing is banned for the entire month. †† indicates

months where fishing is banned from the 20th onwards ††† indicates months where fishing is banned up until the 20th of the month. Asterisks indicate significant differences between locations at the 5% level (*) and 1% level (**) (z-test for proportions using the chi-squared statistic). 135

Figure 4.7: Changes in perceptions of hook type fishing gear use (A) and electric fishing gear use (B) by the local community. Data are summarised information from respondents when asked what percentage of the local community uses electric fishing currently ("Now", n=209), 5 years ago ("5ya", n=212) and 10 years ago ("10ya" n=207) and for hook based fishing currently ("Now", n=228), 5 years ago ("5ya", n=227) and 10 years ago ("10ya" n=218). These years roughly equate to 2016, 2011, and 2006, respectively. Asterisks on B indicate significant differences within the same categories between years at the 5% level (*) and 1% level (**) e.g. "none" category between "10ya" and "now". For A, all years and all groups are significantly different, and so are not marked. For clarity, white arrows indicate decreasing trend in use (A) and increasing trend in use (B). 136

Figure 4.8 Boxplots of change in income and fish catch from 2005 to 2015 reported by fishers in interviews. Income: Mean yearly income for 2005 (n= 194), 2010 (n= 229), 2012 (n= 179), 2015 (n= 235) in RMB. Fish catch: mean estimated daily catch reported by fishermen for the previous year (equating to 2015, n=194), 5 years ago (2010, n=174) and 10 years ago (2005, n=147). † the "2012" data are from the 2011/12 interview survey. All other data are from the 2016 interview survey conducted for this study. * indicates significant differences between years – 2005 mean is significantly different to all other years. 137

Figure 4.9: Fisher responses to stock status of nine YFP prey-specific fish species in the Yangtze River (in order from top to bottom, n=212, n=227, n=218, n=216, n=238, n=238, n=231, n=232, n=243). 138

Figure 5.1: The IUCN-SSC Species Planning Conservation Cycle 151

Figure 5.2: Location of all in-situ (8) and semi-natural (4) YFP reserves in the Yangtze River (as of 2017). Map made in ArcMap (ESRI, 2014). 155

Figure 5.3: Noted causes of YFP decline (**A**, n=28) and the primary cause of decline (**B,** n=25, 3 answered with "Don't know", not shown) from all stakeholders interviewed. Stakeholder opinion on the best future mitigation option for YFP conservation (**C,** n = 26), compared to mitigation currently being conducted (**D**, n = 28). On (**D**), * denotes the top 2 noted causes of decline in (**A**). Values for all figures sum to more than 100% as many stakeholders noted >1 option and all options were included separately. 165

Figure 5.4: Stakeholder perception of the success of both in-situ and ex-situ (including semi-natural) reserves (N=28). A and B are both Likert scale data and C are categorical data. The percentage values shown in A and B are negative (left value, "completely unsuccessful" and "somewhat unsuccessful"), neutral (central value, "don't know"), and positive (right value, "somewhat successful" and "very successful") responses. Percentages and A and B are rounded up. 166

Figure 5.5: Perceived level of success of personal (**A**, n= 28) and overall (**B**, n= 28) YFP conservation efforts, perceptions of the sufficiency of local YFP efforts (**C**, n= 28), and perceived local YFP population trend (**D**, n= 28). The percentage values shown in A and B are negative (left value, “completely unsuccessful” and “somewhat unsuccessful”), neutral (central value, “don’t know”), and positive (right value, “somewhat successful” and “very successful”) responses. In A and B, percentages are rounded up. 167

Figure 5.6: (A) Sources of information for stakeholders perceptions of YFP population status (n = 26) and (B) Independent bodies that stakeholders communicate with about YFP (both giving and receiving information) (n = 28) 168

Figure 5.7: Types of illegal fishing gear noted by fisheries bureaus (n=17) 169

Figure 5.8: Reported barriers to conservation (A) and key factors for successful conservation (B) reported by all stakeholders (n=28). 171

Figure 5.9: Status of nine YFP prey-specific fish stocks in the Yangtze River according to fisheries bureaus (n=17). These species are in the same order as the same figure from the same question asked to fishers (bottom – decreasing the least according to fishers, top – decreasing the most). 172

Figure 5.10: Status of nine YFP prey-specific fish stocks in the Yangtze River according to fishers (in order from top to bottom, n=212, n=227, n=218, n=216, n=238, n=238, n=231, n=232, n=243). From fisher interview data as shown in chapter 4 of this thesis. 172

Figure 5.11: Perceived success of alternative livelihood schemes by fisheries bureaus (n=13). The percentage values are negative (left value, “completely unsuccessful” and “somewhat unsuccessful”), neutral (central value, “don’t know”), and positive (right value, “somewhat successful” and “very successful”). The percentages are rounded to the nearest integer. 173

Figure 6.1: Google Earth imagery showing maze nets (MiHunZhen) in Poyang Lake. 184

Figure 6.2: Design of (A) Zhenjiang in-situ YFP reserve, (B) Hewangmiao reserve and (C) mainstem Hukou – Anqing reserve. Each shows the core zone (red), buffer zone (green) and experimental zone (blue). All photos taken from publicly available maps in-country. 188

Figure 6.3: Poster detailing the fishing ban from Taojiakancun village, Wucheng Township, Yongxiu County (永修县吴城镇陶家坎村) 190

List of Tables

Table 1.1: Global status of and threats to freshwater cetaceans. Information from the IUCN RedList website. All information correct as of May 2019. 7

Table 1.2: Published YFP population estimates to date 11

Table 1.3: Details of all potential threats, the observable and indirect effects of each, and any publications directly relating to each threat. 16

Table 1.4: Details of the four current semi-natural YFP reserves 24

Table 2.1: Previously gathered data sets relating to the YFP used in Chapter 2 40

Table 2.2: Interview locations and sample sizes from 2008 interview survey by Dr Samuel Turvey *et al*. 45

Table 2.3: Interview locations, quantity and number of reported YFP mortalities from 2011/12 interview survey 50

Table 2.4: Number of porpoises observed in the middle and lower section of the Yangtze in the 2006 YFDE after correction with a detection function. Taken from Zhao *et al.* (2008). 54

Table 2.5: Observed numbers of adults and calves in 3 sections of the Yangtze River on the 2006 and 2012 YFDE 56

Table 2.6: Annual PBR values calculated for 2006 and 2012 YFP population estimates, giving values when using both the cetacean generic and the YFP specific R_{max}. Values are annual loss rates based on formula [3] and [4]. 58

Table 2.7: Estimated annual loss from mainstem and total YFP populations to maintain stable 2006 population numbers (max. sustainable loss) or to result in actual 2012 population numbers (predicted actual loss). Calculated using formula [5]. 58

Table 2.8: Estimated annual loss rate for the mainstem YFP population for 2006 and 2012. Calculated using formula [5]. 59

Table 2.9: Beta-binomial model selection based on the Akaike Information Criterion corrected for small sample sizes (AICc), showing **Δ**6 set. Response variable is the proportion of interviewed fishers that had seen a dead YFP in the last 12 months. Results shown are Akaike Information Criterion corrected for small sample sizes (AICc), AICc scores (**Δ**AICc) and Akaike's weight (**ωi**) and the number of parameters for each candidate model. 60

Table 2.10: Beta-binomial and logit gaussian model averaged parameter estimates 60

Table 2.11: Beta-binomial model selection based on the Akaike Information Criterion corrected for small sample sizes (AICc), showing **Δ**6 set. Response variable is the proportion of interviewed fishers that had seen a dead YFP in the last 12 months. Shown results are Akaike Information Criterion corrected for small sample sizes (AICc), AICc scores (**Δ**AICc) and Akaike's weight (**ωi**) and the number of parameters for each candidate model. 61

Table 2.12: Proportion of calves in comparable species and sub-populations 68

Table 2.13: Mercury (T-Hg) concentrations in tissues of YFP samples compared to other porpoise and beluga populations. West Greenland is considered a relatively low contamination area, and the North, Baltic and Irish Seas are considered relatively high contamination areas. All concentrations in µg/g ww. 71

Table 2.14: Thresholds for physiological, clinical and neuropathological effects of mercury contamination in the brain (Krey, Ostertag & Chan, 2015). 71

Table 2.15: Current evidence base implicating the known or implied causes of mortality to YFP, including remaining data gaps 76

Table 3.1: YFP and threat mapping survey details 88

Table 3.2: Details of summer and winter YFP boat survey data 94

Table 3.3: Individual encounter rate (IER, individuals/km) during summer and winter Poyang Lake surveys for each section from north (Hukou) to south (Ruihong) Poyang Lake 95

Table 3.4: Individual encounter rate (IER, individuals/km) during summer and winter Poyang Lake surveys within Longkou and Laoyemiao Reserves, and in the four sections outside of the reserves. The order of sections is roughly North – South. 96

Table 4.1: Reports of YFP bycatch in published literature, adapted from Turvey *et al.* (2013) 118

Table 4.2: Tally of fisher interviews conducted in towns centred around Poyang Lake and the Yangtze River mainstem from Hukou to Anqing 121

Table 4.3: Names of fishing gear types used in the Yangtze basin (interview locations vary year-to-year) and number of directly related YFP mortalities noted during fisher interview surveys in 2008, 2011/2012, and 2016. Values are not absolutes and only indicate types of gear that cause YFP mortality. 130

Table 4.4: Results of a GLMM investigating income and age as predictors of specific fishing gear type use 138

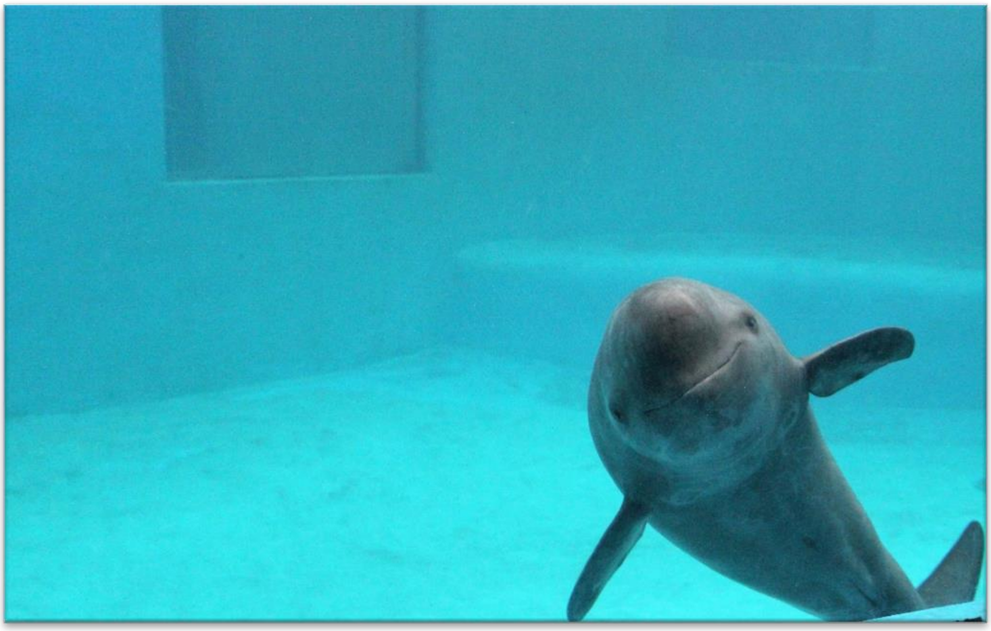
Table 5.1: Comparison of the types of published studies relating to YFP since 2008, grouped by category 162

Table 5.2: Comparison of the types of published studies relating to the baiji, or Yangtze River dolphin (*Lipotes vexillifer*) between 1980 and 2007 (the year it was declared functionally extinct), grouped by category 163

Table 6.1: Summary of potential threats to YFP in the same order as presented in chapter 1, listing the current understanding of each threat as a potential cause of YFP decline, whether each threat is being addressed in current mitigation efforts, and whether more information is needed. 182

Table 6.2: Appraisal of the current reserves within Poyang Lake based on cetacean reserve recommendations by Ross *et al.* (2011) 193

1 Chapter 1: Introduction



Yangtze finless porpoise housed in the IHB aquarium in Wuhan, China

1.1 Conservation of threatened species – evidence-based vs. precautionary approaches

Biodiversity is declining rapidly due to anthropogenic activities, driving ecosystem level change and species loss (Pimm *et al.*, 2014). Of those species for which data are available, an estimated 1,981 taxa are currently in a state of decline (WWF, 2016). Rate of biodiversity loss is showing no signs of slowing (Butchart *et al.*, 2010), and one-fifth of vertebrate taxa are now classified in one of the three formal IUCN threat categories (Hoffmann *et al.*, 2010). To counter this trend, rapid and effective interventions are required to target causes of decline and slow or reverse loss of biodiversity. Caughley's declining population paradigm (Caughley, 1994) outlines the process of species recovery; firstly, the reasons for population decline must be identified, after which these threats must be removed and a test population is released to ascertain whether removal of causes of mortality has been effected, and finally the area is restocked with the target species and the population monitored. Effective threat removal requires robust data to inform effective intervention choices, and ensure mitigation is appropriate to counter causes of decline. However, any uncertainty in the system translates into uncertainty in any management decision (Nisokhow & Reckhow, 1994; Regan *et al.*, 2005; Keith *et al.*, 2011). This risks failure of the intervention and therefore loss of resources and time as well as risking further loss of biodiversity. This has led to an increase in favour of evidence-based conservation (Sutherland *et al.*, 2004), whereby decisions are only made in the presence of robust scientific data to inform them to maximise the likelihood of success.

However, species conservation in practice often addresses situations that are already in or heading towards crisis, and urgent decisions often must be made based on limited reliable information. For example, one sixth of all species are considered "Data Deficient" (DD) by the IUCN Red List (IUCN, 2017; Bland *et al.*, 2014) and so their conservation status is not yet known. For many of these and other species, robust long-term population trend data are not available, and ecological, biological and conservation-related data have not been well quantified (Bland *et al.*, 2014). For example, reptiles are severely data deficient as a taxonomic group (Bland & Böhm, 2016), as are many plant (Good, Zjhra & Kremen, 2006; Sousa-Baena, Garcia & Townsend Peterson, 2014) and mammal species (Karanth *et al.*, 2003; Parsons *et al.*, 2015). Often in cases of data deficiency, species that are in rapid decline may be subject to delays in effective interventions due to a lack of robust data to inform an evidence based approach, which can lead to further population decline and risk of extinction (e.g. the Po'ouli, *Melamprosops phaeosoma*, Groombridge *et al.*, 2004). This is particularly problematic in many rapidly developing countries where awareness lags behind development and industrialisation is prioritised over conservation (e.g. Covert *et al.*, 2017; McShea *et al.*, 2018). Additionally, conservation in these situations is often made more difficult by the typical involvement of multiple stakeholders who can hold contradictory objectives or conservation values (Bode *et* *al.*, 2010; Yang *et al.*, 2017). Making conservation decisions is often further complicated by the presence of multiple threats that may be complex and poorly understood (Isaac & Cowlishaw, 2004; Bolten *et al.*, 2011). In addition, interventions are often at the cost of removing people or livelihoods as a perceived source of threats (Harihar, Veríssimo & Macmillan, 2015; Wright *et al.*, 2016) and each alternative course of management raises potential risks and resource burdens, so choices must be made wisely (Campbell *et al.*, 2002; Lacy *et al.*, 2017). This means that, although evidence-based conservation is the ideal to aim for, this approach to conservation of biodiversity is not always possible or the best choice given imminent risk of extinction and limited time to gather further data.

The precautionary principle, or precautionary approach, is generally understood to be an approach to dealing with uncertainty within systems (Cooney, 2004). The precautionary approach contrasts to evidence-based management methods in that it provides a case for selecting more immediate action without prior certainty that harm is occurring (van Asselt & Vos, 2004). For example, given a poorly studied, rapidly declining population, the precautionary approach would make the case for urgent, defensive intervention over delaying action until scientific certainties have been identified. It is therefore a more pro-intervention stance than an evidence-based approach would take. This conservation approach has led to a number of qualitative and quantitative approaches that take uncertainty into account whilst trying to make robust conservation decisions for conservation management (e.g. Regan *et al*. 2005; Gregory & Long 2009; Smith *et al.* 2011). These contrasting approaches have led to a dichotomy amongst conservation biologists in managing at-risk populations, with ongoing debate as to which will be more effective at countering global biodiversity decline (e.g. Thompson *et al.*, 2000; Cooney, 2004; Sutherland *et al.*, 2004; Gregory & Long, 2009). The precautionary approach has been widely applied to issues relating to fisheries management (FAO, 1996; Pan & Huntington, 2015), marine conservation (e.g. Carr & Raimondi 1999), and improving the conservation decision making process (Gregory & Long, 2009), yet acceptance of the precautionary approach as a tool in conservation is inconsistent and somewhat contentious (Cooney, 2004), posing a challenge to application of interventions for poorly-understood and at-risk species.

1.2 What data are needed to conserve threatened taxa?

Conservation relevant data required for effective intervention of a species can vary dependent on the species and system in question. At a minimum, detailed knowledge of biology and ecology of a species ensures that basic requirements of the species are met within any intervention design (e.g. Thomas, Simcox & Clarke, 2009). Population trends and the rate of global and localised declines is vital to inform and target conservation efforts (e.g. Paleczny *et al.*, 2015; Laidre *et al.*, 2015; Steege *et al.*, 2015). Additionally, distribution data and identification of suitable habitat can be used to locate all present populations and areas suitable for future population expansion (e.g. Olsson & Rogers, 2009; Embling *et al.*, 2009). To target conservation action to key areas, identification of crucial or high-density habitat is often conducted through physical surveys or theoretical models (Goetz *et al.*, 2012; Esteban *et al.*, 2018; Moore, 2018). Some interventions also consider local populations and stakeholders to improve understanding and support for mitigation efforts (Rust, 2017; Sterling *et al.*, 2017). A combination of these data types is likely to improve the result of conservation efforts, but often much or all of these data are not available for understudied species. Detailed below are two data types or approaches to understanding conservation of threatened taxa that are relevant to this thesis: understanding population decline and improving understanding of data-poor species.

1.2.1 Understanding and quantifying decline in a population

As mentioned, Caughley's model of species recovery (Caughley, 1994) requires identification and removal of threats. This process requires that the threats to any small population are well understood and quantified so that recovery efforts can be targeted to those causes of decline. Quantification and prioritisation of threats has received insufficient attention in many species recovery plans (Clark *et al.*, 2002), and poor understanding of the relative importance of threats can lead to failure of such plans (Lawler *et al.*, 2010). For example, division of habitat due to political changes and hunting for horn were identified as two key drivers of decline in the saiga antelope in Kazakhstan and Russia (*Saiga tatarica,* Bekenov *et al.* 1998). This knowledge allowed interventions to be appropriately targeted to those main threats (Howe, Medzhidov & Milner-Gulland, 2011; Howe, Obgenova & Milner-Gulland, 2012).

The method of intervention depends on the species, for example, targeting introduced predators as a cause of decline was successful in mitigating decline in the Echo parakeet (*Psittacula echo,* MWF 1994-2002), and interventions aimed at improving the depleted bamboo-based habitat for the giant panda (*Ailuropoda melanoleuca,* Taylor & Zisheng 1993) has led to successful conservation recovery. For many species, however, conservation is complicated by the presence of multiple threats that may vary on complex spatial and temporal scales (e.g. Isaac & Cowlishaw, 2004; Maxwell *et al.*, 2013). Quantifying the effect of multiple threats is therefore vital to create interventions targeted to those threats causing the most mortality whilst also accounting for variation in those threats on temporal or spatial scales (Bolten *et al.*, 2011; Lacy *et al.*, 2017).

If available information is insufficient to identify the cause or causes of population decline, mitigation may be ineffective, causing delays and risking further population decline and extinction. For example, establishment of extensive protected areas failed to mitigate decline in the large blue butterfly (*Maculinea arion*) until it was discovered this lepidopteran species relies on a specific species of ant for its complex parasitic life cycle (Thomas, Simcox & Clarke, 2009). This highlights the importance of having reliable ecological information to inform mitigation, and the failures that can occur if this information is not available or directly applied to conservation design.

1.2.2 Improved data collection and analysis of poorly studied species

A growing body of research techniques is allowing researchers to better understand poorly-studied threatened populations, whether by direct observation or using theoretical or modelling techniques. For example, local ecological knowledge (LEK) is an undervalued source of information that can be utilised for species where data are otherwise unavailable (e.g. Bender *et al.* 2014; Turvey *et al.* 2015; Nash *et al.* 2016; Gray *et al.* 2017). LEK based studies have successfully been used to confirm presence of cryptic species (Cullen-Unsworth *et al.*, 2017; Turvey *et al.*, 2014), assess and detail threats (Nash, Wong & Turvey, 2016; Turvey *et al.*, 2014), detect population status and trends (Gray *et al.*, 2017; Nash, Wong & Turvey, 2016), and provide information relating to social dimensions of species conservation (Miard, Nekaris & Ramlee, 2017).

Given sufficient data, modelling techniques can aid conservation by predicting suitable habitats for translocations (Olsson & Rogers, 2009; Laws & Kesler, 2012), predicting where unknown populations of rare species may remain (Fois *et al.*, 2015), or where to target conservation measures (Guisan *et al.*, 2013). These types of analyses can improve understanding of the dynamics of population decline and can inform effective conservation practices. In scenarios where data to inform conservation are limited and incomplete, a range of different investigative and analytical approaches may therefore be required to take full advantage of rapid collection of conservation-relevant data and to maximise the analytical power and application of available data.

1.3 The plight of freshwater cetaceans

1.3.1 Freshwater cetaceans under threat

Freshwater ecosystems are amongst the most threatened ecosystems in the world (Revenga *et al.*, 2005). The Living Planet Index (LPI) report of 2016 documented the greatest biodiversity losses in freshwater environments, noting fragmentation and abstraction as common threats (WWF, 2016). The six exclusively freshwater cetacean species (plus others that sometimes range into freshwater or vice-versa) that inhabit these highly modified environments are therefore subject to a spectrum of human disturbance depending on the river in which they are located (e.g. Amazon basin, Ganges and Yangtze, Smith & Reeves, 2012, Table 1.1). Many of these species are subject to high levels of bycatch from fishing activity, are at risk from vessel strikes, are targeted for subsistence hunting, are at risk from high levels of pollution from industry and agriculture, and are subjected to damaging levels of acoustic disturbance, amongst other potential threats (Smith & Jefferson, 2002; Mansur *et al.*, 2008; Raby *et al.*, 2011; Khanal *et al.*, 2016). These pressures can force freshwater cetaceans into marginal habitat that is less suitable to their ecological requirements, a phenomenon observed with the Endangered Indus River dolphin (*Platanista gangetica minor,* Braulik *et al.*, 2015)*.* In addition to the direct detrimental effects of threats, species forced into marginal habitats tend to have reduced ecological fitness (Shreeve, Dennis & Pullin, 1996).

The consequence of these pressures has been decline in many freshwater cetacean taxa; some species of Amazonian river dolphin (e.g. Amazon river dolphin, *Inia geoffrensis*), for example, are likely to be in a state of decline and are under threat from numerous present and potential damming projects, amongst other threats (Williams *et al.*, 2016a). This relatively strong correlation between riverine ecosystem health and cetacean abundance means that river dolphins can be indicators of ecosystem degradation (Gomez-Salazar *et al.,* 2012; Turvey *et al.*, 2012).

Biodiversity in Asian freshwater habitats is under particular pressure due to very high human population densities and rapid, poorly regulated industrial expansion (Dudgeon, 2000; Reeves, Smith & Kasuya, 2000; Braulik *et al.*, 2014; FAO, 2016). As a result of these multiple threats, Asian freshwater cetaceans are now amongst the most threatened large mammal taxa (Reeves 2000). This includes the Endangered Ganges river dolphin (*Platanista gangetica,* Braulik & Smith 2017) and its sub species the Indus River dolphin (*Platanista gangetica minor,* Braulik & Smith 2017), and the Endangered freshwater populations of the Irrawaddy dolphin (*Orcaella brevirostris,* Minton *et al.* 2017) across parts of Southeast Asia.

These species face a multitude of extinction pressures due to their occurrence in areas of high human population density, habitat modification, and industrialisation. Relatively long-lived life strategies and an inability to adapt to rapid environmental change exacerbates the effect of these threats and means any recovery from population decline is usually very slow (Lotze *et al.*, 2011). The effect of this multitude of pressures has already been observed in the functional extinction of the Yangtze River dolphin, the first loss of a large mammal species in over 50 years (Turvey *et al.*, 2007). This loss emphasises the urgency of understanding decline dynamics and identifying effective conservation strategies for remaining Asian freshwater cetaceans.

Table 1.1: Global status of and threats to freshwater cetaceans. Information from the IUCN RedList website. All information correct as of May 2019.

Species	River	IUCN RedList Status	Noted threats	Interventions applied
Inia geoffrensis (including sub-species *Inia geoffrensis boliviensis, Inia geoffrensis geoffrensis, Inia geoffrensis humboldtiana*)	Amazon	Endangered	› Development (housing and urban areas) › Energy production and mining (oil and gas, mining, quarries) › Resource use (fishing and harvesting) › Human intrusions and disturbance (war, civil unrest and military) › Natural system modifications (dams and water modifications) › Pollution (industrial, military, agricultural and forestry effluent)	› Action recovery plan › Identification of conservation sites › Protected areas › Protected in local legislation › Protected by international trade controls
Lipotes vexillifer, Baiji	Yangtze	Critically Endangered (functionally extinct)	› Development (housing, commercial and industrial) › Agriculture and aquaculture (timber crops) › Transportation and service corridors (shipping lanes) › Biological resource use (fishing and harvesting) › Natural systems modifications dams and water management, other modifications) › Pollution (domestic, urban, industrial, military, agricultural effluents, garbage and solid wastes, excess energy) › Climate change and severe weather (droughts)	› Action recovery plan › Conservation sites identified › Protected in local legislation › Protected by international trade controls
Platanista gangetica, South Asian River Dolphin (sub-species *Platanista gangetica minor,* Indus river dolphin, and *Platanista gangetica gangetica,* Ganges river dolphin)	Ganges	Endangered	› Biological resource use (fishing and harvesting) › Natural system modifications (dams and water management) › Invasive and other problematic species, genes and diseases › Pollution (domestic, urban, industrial, military, agricultural waste water and effluent)	› Conservation sites identified › Some protected sites › Covered by international legislation and trade controls
Orcaella brevirostris, Irrawady	Euryhaline (predominantly marine) found in the Mekong, Irrawaddy and Ganges Rivers.	Endangered	› Agriculture and aquaculture (timber crops, wood pulp plantations) › Energy production and mining (mining and quarrying) › Transportation and service corridors (shipping lanes) › Biological resource use (fishing and harvesting aquatic resources) › Natural system modifications (dams and water management) › Pollution (domestic, urban, agricultural effluent)	› Action recovery plan › Conservation sites identified › Protected areas › Covered by international legislation and trade controls
Sotalia fluviatilis, Tucuxi	Amazon River	Data deficient	› Residential and commercial development › Biological resource use (fishing) › Natural system modifications (dams and water management) › Pollution (industrial, military and agricultural effluents)	› Action recovery plan › Conservation sites identified › Protected areas › Covered by international legislation and trade controls

1.3.2 Conservation of freshwater cetaceans

For coastal cetaceans, it was noted by Thompson *et al.* (2000) that (1) there is a high level of uncertainty about population size, (2) consequently they are likely to be under-protected and (3) the risk is increased as there are typically multiple threats, all of which have a low risk individually and therefore low power to detect harm. The burden of proof to support intervention is therefore not met and a cetacean species is likely to be inadequately protected. The same three factors also apply to freshwater cetaceans, and it is likely these factors are even more pronounced as these species occur in rapidly developing countries with very little baseline data or population status and trends data (Reeves, Smith & Kasuya, 2000). As a result of these three issues, it has been recommended that the precautionary principle should be applied to cetacean conservation management (Thompson *et al.*, 2000).

For bottlenose dolphins (*Tursiops truncatus*) in the Moray Firth, Scotland, for example, it has been demonstrated that a precautionary approach should be applied to their management given predicted detrimental consequences of evidence-based approaches (Thompson *et al.*, 2000). This is exemplified by the worrying state of the remaining population of vaquita (*Phocoena sinus*), which is now likely the most threatened mammal in the world (Thomas *et al.*, 2017). Failure to mitigate the predominant cause of decline, bycatch, is attributed to too much focus on data acquisition and a lack of direct on-the-ground action (Jaramillo-Legorreta *et al.*, 2007).

There has been considerable research into several aspects of the biology, ecology and conservation of freshwater cetaceans (e.g. Smith & Jefferson 2002; Braulik *et al.* 2015; Loch *et al.* 2009; Shiang-Lin Huang *et al.* 2012; Reeves *et al.* 2000b), and also some attention from conservation organisations (Reeves, Smith & Kasuya, 2000; Trujillo *et al.*, 2010). However, there are still vast knowledge gaps and conservation attention and action is inadequate (Strayer & Dudgeon, 2010). Parsons *et al.* (2015) identified 15 key research gaps of global importance for cetacean conservation. Key gaps include prioritising conservation projects; integrating multidisciplinary research and non-conventional data; increasing understanding of conservation interventions; furthering understanding of sublethal and nonlethal stressors; and managing data deficiency (Parsons *et al.*, 2015). Due to the severe data deficiency surrounding many cetacean taxa, there has been a call for all “Data Deficient” cetacean species to be precautionarily listed as “Assume Threatened” (Parsons, 2016). Urgent research is therefore required to assess the status of many cetacean species, and conservation-relevant data are severely insufficient to conserve those that have been identified as requiring protection.

1.4 Yangtze River cetaceans

1.4.1 The Yangtze River – a heavily modified ecosystem

The People’s Republic of China is a “mega-diverse” country, home to 33,000 high plants and more than 6350 vertebrate species, many of which are endemic (He, 2009). China is also the most populous country in the world (1.415 billion people, United Nations Department of Economic and Social Affairs, 2017) and has very rapidly gone from a developing country to the third largest global economic body (He, 2009). The environmental cost has been significant; severe impacts on water resources, air quality (including dust storms), and human health have been noted (He, 2009). High traffic on trade routes have also facilitated invasive species transfer (Lin *et al.*, 2007). Both terrestrial and marine biodiversity in the region is now under severe threat from losses of natural habitat (Schipper *et al.*, 2008; Sodhi *et al.*, 2010).

To counter these losses, the number and area of protected reserves in China has been rapidly increasing since around 1980 to a current estimate of 2740 (Ma *et al.*, 2017) and an area of around 1.5million km^2 by 2009 (He, 2009). The effectiveness of these reserves is difficult to determine as there is little to no available data relating to flora and fauna contained within them (He, 2009). Conservation based research is an increasing area of interest in China, but there are notable gaps in (1) knowledge relating to threatened species including baseline data and threat mechanisms, (2) long-term observational and experimental studies, (3) studies with broader spatial and temporal scales, (4) more application based studies, and (5) trans-boundary research (Ma *et al.*, 2017).

The approximately 6,300-km long Yangtze River is the longest in China and the third-longest river in the world (Gupta, 2007). It begins in the Qinghai-Tibetan Plateau and weaves through central China where it meets the East China Sea at Shanghai (**Error! Reference source not found.**). The Yangtze River has eight major tributaries and a catchment area of 1.8 million km^2, which is equivalent to one-fifth of Chinas total land area (Kram *et al.*, 2012).

Modern industrialisation has also taken a significant environmental toll on the Yangtze River; shipping vessels are estimated at more than one per 100m of river (Turvey *et al.*, 2007); the river is heavily polluted (Yi, Yang & Zhang, 2011; Sun *et al.*, 2013a; Dong *et al.*, 2014a; Xu *et al.*, 2014); heavily extracted from by overfishing and sand mining (de Leeuw *et al.*, 2010; Huang, Wu & Li, 2013; Lai *et al.*, 2014); and the hydrodynamic, sediment and nutrient regime of the whole river has been altered by large hydroelectric damming projects (Li *et al.*, 2011; Gao, Yang & Yang, 2013; Feng *et al.*, 2014). These activities have caused severe biodiversity loss in the river (Zhao *et al.*, 2005; Turvey *et al.*, 2007; Huang, Wu & Li, 2013; Zhang *et al.*, 2017a).

1.4.2 The precautionary tale of the Yangtze River dolphin (baiji)

Prior to its functional extinction by 2006 (Turvey *et al.*, 2007), an estimated 95% of known Yangtze river dolphin (*Lipotes vexillifer*, otherwise known and hereafter referred to as the baiji) mortality was associated with a range of harmful human activities including boat propeller collision, fishing gear bycatch, and explosions for clearing river channels (Chen *et al.*, 1997). Of 12 baiji mortalities in the 1990s, 40% were directly attributable to illegal electrofishing, and other identified causes of death during this period were poison and trapping in fishing nets (Zhang *et al.*, 2003). There are no indications that the population decline was due to loss of genetic diversity (Xu *et al.*, 2012b), and there have been conflicting conclusions on spatial population fragmentation (Zhang *et al.* 2003; Turvey *et al.* 2010). To date, there is no conclusive quantification of the predominant causes of baiji extinction beyond small scale studies such as these, and this knowledge gap likely contributed to the failure in conservation of this species. Successful intervention was fraught with delays and compounded by a fundamental lack of understanding of how to best conserve the species; this is thought to have been a key factor responsible for conservation failure for the species and ultimately its extinction (Turvey, 2008).

1.4.3 The Yangtze finless porpoise – a taxon under severe threat

The Yangtze finless porpoise (*Neophocaena asiaeorientalis,* hereafter referred to as YFP) is a unique freshwater porpoise endemic to the middle-lower reaches of the Yangtze River, eastern China, including significant populations in the appended lakes of Dongting and Poyang (Figure 1.1**Error! Reference source not found.**). Up until 2018, this species was thought to be one of two sub-species of *Neophocaena asiaeorientalis,* and was therefore previously referred to as *Neophocaena asiaeorientalis asiaeorientalis* (Figure 1.2). Recent genetic profiling in Zhou *et al.* (2018) has determined that the Yangtze finless porpoise is an incipient species separate from the marine narrow-ridged finless porpoise present in the nearby Yellow Sea and East China Sea (*Neophocaena sunameri,* previously known as *Neophocaena asiaeorientalis sunameri,* Figure 1.2).

The range of the YFP is sympatric with the extinct baiji and, as such, they have been subject to similar extinction pressures. Their restriction to the freshwater reaches of the heavily industrialised Yangtze River means their entire habitat is impacted by a high level of anthropogenic habitat modification and direct and indirect environmental threats. Sand mining, intense fishing practices, pollution, high vessel traffic and other threats are prevalent throughout the river system, which may cause both direct and/or indirect mortality and may be reducing the carrying capacity of the system (Zhao *et al.*, 2008; Wang, 2009; Mei *et al.*, 2012). Each of these threats is detailed in later sections.

As a result, severe YFP population decline has occurred in recent decades and this taxon is now thought to be in an accelerated level of population decline; estimates of abundance in the main Yangtze channel have fallen from an estimated 2702 in the early-mid 1990s (Zhang *et al.*, 1993) to 1100-1200 in 2006 (Zhao *et al.*, 2008) and subsequently down to c.500 in 2012 (Mei et al., 2014, Table 1.2). Older estimates are considered less accurate and reliable, however, as the census methodology did not follow standard distance sampling techniques and standard correction factors were not applied to the population calculation (Buckland *et al.*, 2007; Thomas *et al.*, 2010). These earliest YFP population estimates were taken around a time when severe environmental issues had been noted in China (Boxer, 1989) and the Baiji was already known to be severely declining in number (Zhou, 1986; Zhou & Wang, 1994). Therefore, these YFP estimates represent the best published minimum estimate of carrying capacity available for an industrialised modern Yangtze River, despite the likelihood that YFP were probably already in a state of population decline.

Table 1.2: Published YFP population estimates to date

Author	Survey year(s)	Location			Total
		Mainstem	Dongting Lake	Poyang Lake	
Zhang *et al.* (1993)	1984 – 1991	2546	104	52	2702
Xiao & Zhang (2000)	1999	-	-	388	-
Xiao & Zhang (2002)	1997 – 1998	-	-	100 – 400	-
Zhao *et al.* (2008)	2006	1225	100 – 150	400	1800
Mei *et al.* (2014)	2012	505	90	450	1040

Genetic studies have indicated the genetic diversity of the YFP population has been reduced to ~2% of its maximum historical size, signifying a population collapse similar to other species declines (Chen *et al.*, 2017). The taxon was upgraded to Critically Endangered on the IUCN Red List of species in 2013 (Wang *et al.* 2013) and is listed under CITES Appendix I. It is now one of the most threatened cetacean taxa on a global scale.

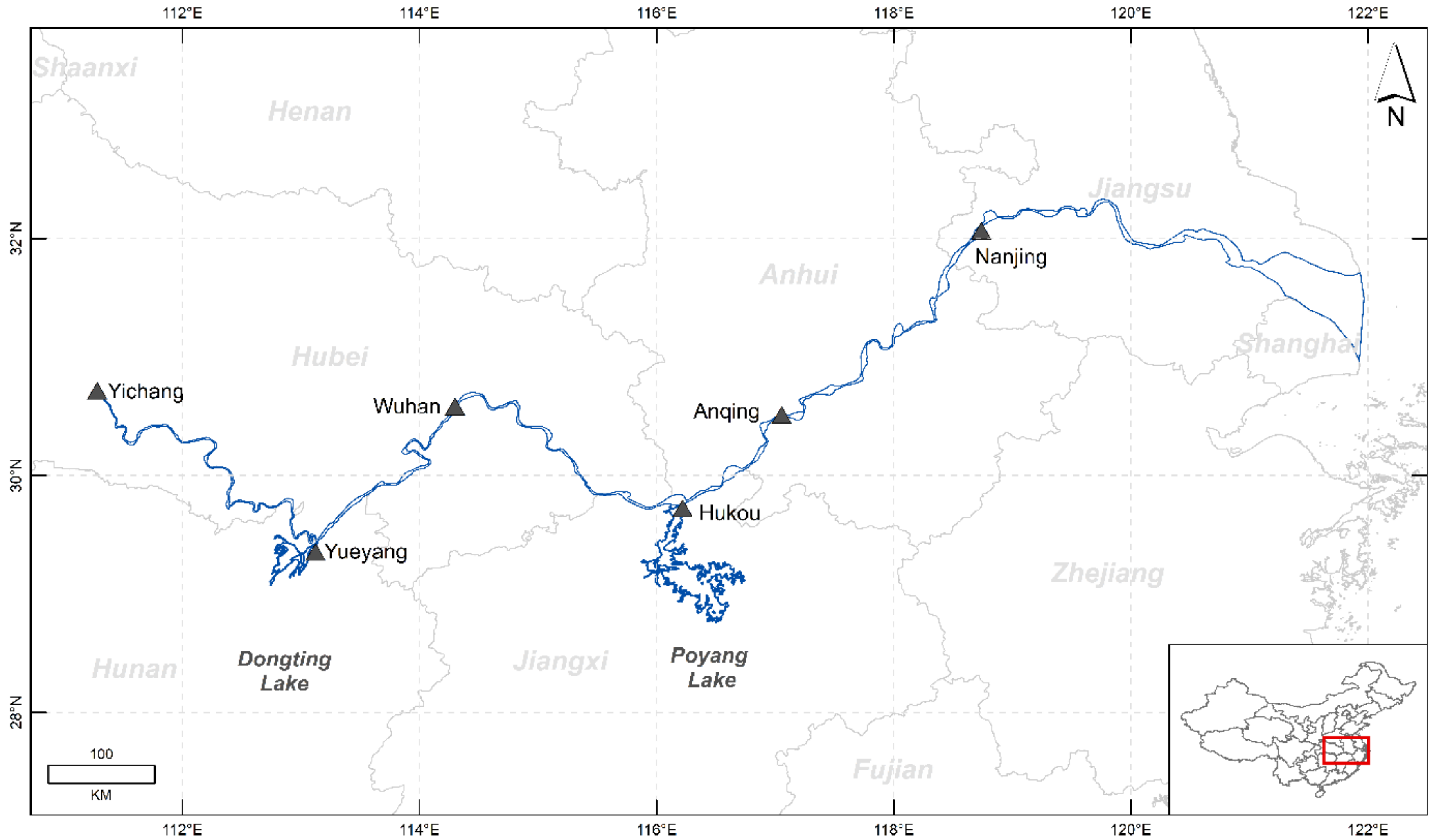


Figure 1.1: Range of the YFP within the Yangtze River and two appended lakes of Poyang and Dongting. Map made in ArcMap (ESRI, 2014).

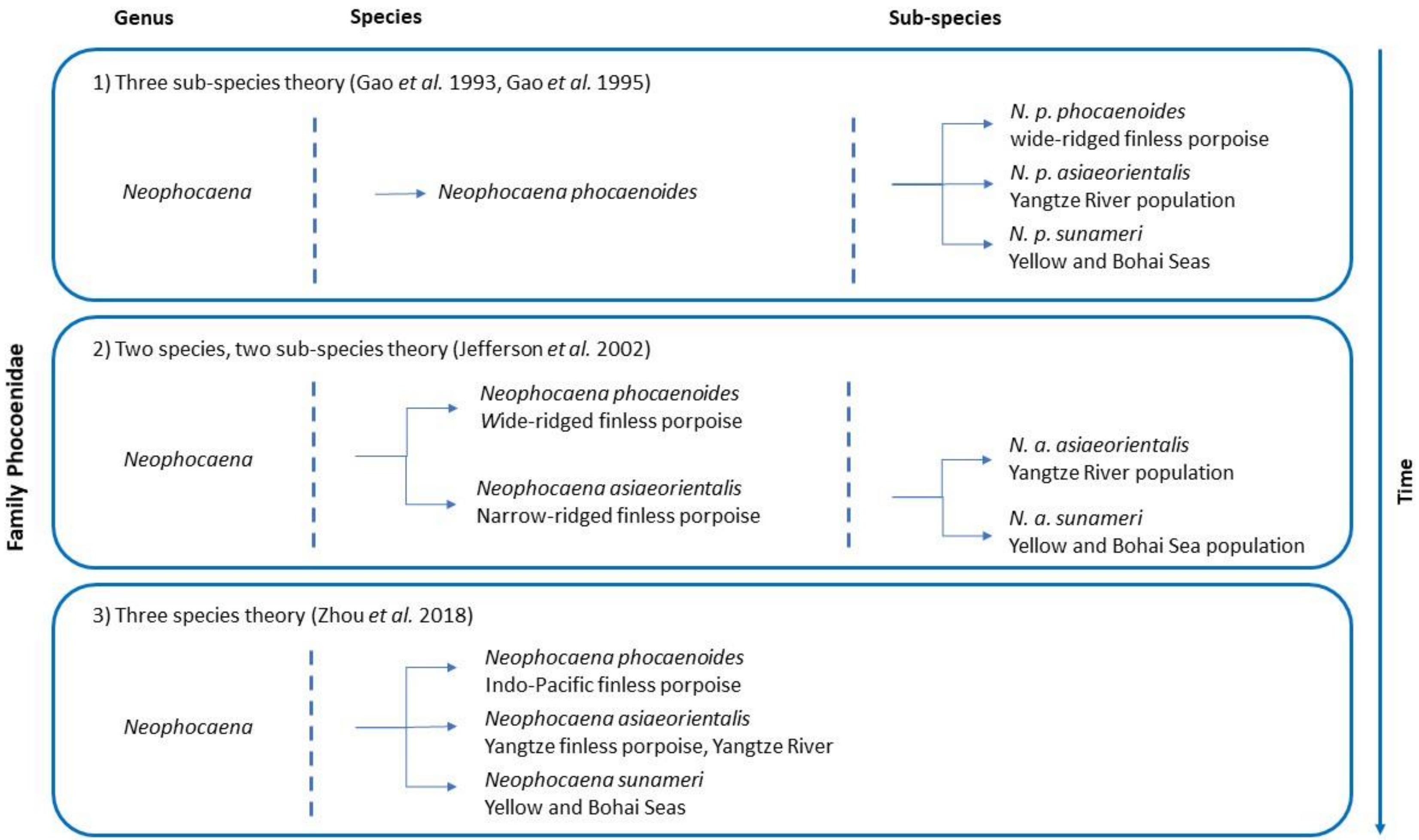


Figure 1.2: Diagrammatic representation of the progress made in taxonomically grouping the family Phocoenidae over time (top to bottom)

1.4.4 Biology and ecology of the Yangtze finless porpoise

As a dominant local predator, the YFP relies heavily on its primary food source of fish and additionally requires a functionally stable habitat (Wang, 2009). YFP have highly developed echolocation abilities and use sonar as their primary sense in the poor visibility of the Yangtze. Sonar click trains are used every ~5.2 seconds to inspect up to 77m ahead before entering an area (Akamatsu *et al.*, 2005), and frequent short range sonar sounds with very short (<10ms) inter-click intervals are used to accurately pursue and catch prey (Wang *et al.*, 2014). The average swim speed of the YFP is ~4.3 km/hour and dive duration can be up to 3 minutes (Akamatsu, 2002). Two particular diving types have been noted, deep dive (≥2.7m) and shallow dive (Akamatsu, 2002), whilst exhibiting breathing intervals of 34.4.seconds ± s.d. 4.39 (Zhuo *et al.*, 2002b). The feeding grounds of the YFP are usually close to sandy areas with reedy swamps, and they tend to prefer habitat around large, bending water courses (Yu *et al.*, 2005). The YFP favours sand bars, soil and rock banks, lake confluences, river bends, eddies, and mixing currents, and prefers a water depth of >3m (Wei *et al.*, 2003). Similar to the Baiji and other river dolphin species (Bashir *et al.*, 2010; Vidal *et al.*, 1997), they are commonly found at the confluence of rivers (Zhang *et al.*, 2015). YFP may have smaller ranges and travel less extensively compared to the Baiji (Turvey *et al.*, 2010a) but distribution throughout the Yangtze does change on a seasonal basis (Kimura *et al.*, 2011), which is likely to follow fish abundance (Kimura *et al.*, 2012). Temporal and spatial variation in food abundance and habitat preference is therefore likely to affect spatio-temporal interaction of YFP with fishing gear and vessel. Seasonality and spatial range must therefore be considered when investigating causes of decline, and understanding the dynamics of this overlap may indicate which of the numerous threats are likely to be causing mortality.

Cetaceans have relatively long lifespans and low intrinsic rate of population increase, which typically means that population change under environmental modification is relatively slow as population numbers take time to respond and adapt. YFP females reach maturity at about 137-150 cm and 5-6 years, and males at 138-154 cm and 4-5 years (Jefferson *et al.* 2002). The YFP is unique in its ability to osmoregulate in freshwater meaning it cannot extend its habitat into marine waters (Guo *et al.*, 2014). The restricted range and slow reproduction rate of this species limit their ability to move away from threats and to recover from, meaning they are vulnerable to population decline. Understanding population level responses to anthropogenic threats is therefore key to quantifying sustainable limits of mortality and the potential for this species to recover from the observed declines.

1.4.5 Overview of potential threats to the YFP

When trying to conserve a population in a state of decline often the first step is to understand the threats and causes of that decline. Firstly, it should be established how and why a population has declined to the present state. Secondly, it should be established whether the threats that have previously driven that decline are still present and operating and subsequently those threats should be managed to stop and hopefully reverse population decline.

As the YFP is restricted solely to the Yangtze River, its entire habitat is sympatric with a high level of anthropogenic habitat modification and environmental threats. Each has the potential to cause direct or indirect mortality, a reduction in fecundity or juvenile survival, or reduce the carrying capacity of this system. Each threat is listed in Table 1.3, detailing the potential observable and indirect effects of each threat and whether there are any available published studies detailing the effect of each threat on YFP. It is likely there are multiple causes of YFP mortality, with one or more key causes of population decline. Also listed is the possibility of synergistic or cumulative effects, which has not been studied in YFP but has been noted as a problem in other cetacean species (Weilgart, 2007; Williams *et al.*, 2016b; Lacy *et al.*, 2017; Avila, Kaschner & Dormann, 2018).

The following sections provide further detail about each of the potential threats to the YFP population that have been proposed by previous authors, and the knowledge gaps identified for each potential threat.

Table 1.3: Details of all potential threats, the observable and indirect effects of each, and any publications directly relating to each threat.

Threat (thesis section)	*Direct, observable signs of threat*	*Indirect signs or implications of threat*	*Published evidence implicating as a cause of decline or threat?*
Fishing (1.4.5.1)	› Direct mortality with distinct wounds from hooks or nets. › Death by drowning.	› Possible avoidance behaviour from fishing intensive areas.	Some data available.
Vessel collision (1.4.5.2)	› Direct mortality with distinct cut-like wounds.	› Avoidance behaviour from vessel-dense areas. › Physiological signs of stress from noise and disturbance. › Indirect effect of noise – separation of mother calf pairs.	Some data available.
Sand mining (1.4.5.3)	› Possibility of direct mortality, but no evidence that this has ever happened.	› Avoidance behaviour from mining intensive areas. › Physiological signs of stress from noise and disturbance. › Indirect effect of noise – separation of mother calf pairs.	No data available relating specifically to YFP.
Pollution (1.4.5.4)	› Acute pollution events could cause direct mass mortality events.	› Reduced fecundity and calf survival rate. › Impaired immune health and an increase in susceptibility to disease. › Possible behavioural problems or alterations.	Some data available.
Loss of prey resources (1.4.5.5)	› Direct mortality with signs of malnutrition (only detectable though post-mortem).	› Reduction in carrying capacity of system. › Reduced fecundity and calf survival rate.	No data available relating specifically to YFP.
Habitat alteration, degradation and loss (1.4.5.6)	› No directly observable effects.	› Reduced carrying capacity of system. › Reduced fecundity and calf survival rate.	No data available relating specifically to YFP.
Genetic bottleneck (1.4.5.7)	› No directly observable effects.	› Population fragmentation and gaps (as a cause). › Reduced fecundity and calf survival. › Genetically distinct markers of reduced genetic fitness.	Some data available.
Cumulative or synergistic effects	› No directly observable effects.	› Not well understood or studied.	No data available relating specifically to YFP.

1.4.5.1 Fishing Gear Bycatch

Freshwater yields comprise 11% of total global fisheries catch (Raby *et al.*, 2011). However, there is still relatively very little literature relating to spatial patterns, levels and sustainability of cetacean bycatch in freshwater systems, despite it being documented as a key potential threat (e.g. Kelkar *et al.* 2010; Iriarte & Marmontel 2013).

Legal fishing gears in the Yangtze can be broadly divided into two categories; fixed gear that is typically left in place for a period of time (e.g. fyke nets, fixed maze nets, and traps) and free-floating gear that is usually actively attended whilst in the water (e.g. rolling hook lines, gill nets) (Zhou & Wang, 1994; Wang, 2009; Turvey *et al.*, 2013). Illegal methods include poison fishing and electric fishing gear (Turvey *et al.*, 2013). Gill nets, electro fishing, and rolling hook methods kill indiscriminately and as such can cause significant bycatch to cetacean species (IWC 1994). Gillnets are known to kill all six marine species of porpoise (Jefferson & Curry, 1994).

Baiji and YFP mortalities have been reported as a result of all of these high-risk gears (Zhou & Wang, 1994; Wang, 2009; Turvey *et al.*, 2013) and accidental bycatch is the leading cause of mortality in other populations of finless porpoise outside the Yangtze region (Jefferson, Curry & Kinoshita, 2002). Accidental bycatch has been determined as a probable major extinction driver of the baiji and is likely to play a similar role with the YFP (Reeves *et al.*, 2003), but this has not been adequately quantified. Some fishing methods such as electric fishing and hook based fishing have now been banned in some parts of the Yangtze (Turvey *et al.*, 2013) but this action was more an effort to preserve fish stocks and prevent baiji mortality than to protect YFP (Zhou *et al.*, 1998). Despite this, these potentially lethal fishing methods are still widely used due to a lack of awareness and enforcement difficulties (Zhou *et al.*, 1998), even in reserve areas (Turvey *et al.*, 2007).

1.4.5.2 Vessel Collision

Cargo and shipping vessel density was estimated at around one large vessel every 100 metres in the Yangtze mainstem over a decade ago (Turvey *et al.*, 2007), and has likely increased since. Vessel traffic is a potential threat to porpoises in two ways, by direct injury due to propeller strike, or by disruption to behaviour, feeding and navigation through vessel noise and use of sonar based vessel navigation equipment (Kastelein *et al.*, 2015; Dyndo *et al.*, 2015; Wisniewska *et al.*, 2016; Moore *et al.*, 2010). In the closely related harbour porpoise species *Phocoena phocoena*, vessel noise reduces the number of prey capture attempts, resulting in negative long-term fitness consequences (Wisniewska *et al.*, 2018).

In the Yangtze system there is little detailed, reliable information relating to both of these impacts; there is only sporadic data on vessel strike fatalities (Turvey *et al.*, 2013) and there are mixed reports on the level of impact (if any) of vessel presence on behaviour and movements (Kimura *et al.* 2012; LI *et al.* 2008; Wang *et al.* 2015). However, by analysing available mortality records, the results of Turvey *et al.* (2013) suggest that vessel collisions are more likely to be driving population decline than fishing bycatch.

In the winter, low water season (approx. late Oct.-Mar.), the key YFP habitats of both Dongting and Poyang lakes contract drastically; there is some evidence that the resulting higher vessel density in the smaller remaining area results in a higher incidence of YFP vessel collisions (Dong *et al.*, 2011). A recent paper by Turvey *et al.* (2013), suggested vessel collisions are more likely associated with the YFP population decline based on mortality records. Vessel collisions have recently been suggested as a key cause of decline based on YFP mortality records However, a lack of high-resolution landscape level data currently prevents assessment of the potential impacts of vessel traffic through understanding the spatio-temporal patterns in vessel and porpoise distribution overlap.

1.4.5.3 Sand mining

Satellite imagery analysis has determined Poyang Lake to be the biggest sand mining operation in the world (de Leeuw *et al.*, 2010). Despite being widespread and intensive in the Yangtze, most especially within the two lake systems, very little research has been conducted on the impacts of sand mining to wildlife. In other comparable systems sand mining results in direct habitat loss, causes surrounding habitat degradation, increases water turbidity, and likely re-suspends heavy metals and persistent organic pollutants (POPs) otherwise trapped in the benthic sediment (Desprez, 2000; Boyd *et al.*, 2005). In the only representative study in the Yangtze River, localised short-term effects of sand mining activity in Dongting Lake were a reduction in macroinvertebrate taxa richness, abundance and biomass, likely due to increased turbidity and reduced oxygen concentration (Meng *et al.*, 2018). However, long-term trends (1-year post-sand mining) indicate an increase in abundance, biomass and biodiversity of macroinvertebrates in regions adjacent to sand mining areas. These increases may be due to a reduction in predatory pressure by the expulsion of top predators by noise and vibration, and possibly as a result of dispersal out of the mining areas to adjacent regions (Meng *et al.*, 2018).

Sand mining is not thought to alter the distribution of YFP (Kimura *et al.*, 2012), but is likely to have an impact through increased water turbidity, heavy ship traffic (Wu et al. 2007), and direct habitat loss and degradation (Kreb *et al.*, 2010). Noise from sand mining is also a consideration (de Leeuw *et al.*, 2010), as it can cause disturbance to echolocation abilities and possibly hunting behaviour (Wisniewska *et al.*, 2018). Noise can also reduce ecological fitness by pushing individuals into less optimal marginal habitat (Shreeve, Dennis & Pullin, 1996). Whether there is direct mortality from sand mining is not known, and the lack of information on this potential threat means there is little to no information as to how to regulate the industry with respect to YFP protection.

1.4.5.4 Pollution

Rapid intensification of agriculture and industry along the course of the Yangtze River has supported China's economic growth in recent decades, but the environmental implications are widespread. The associated pollution now means that the Yangtze River has the highest density of microplastics entering the sea of any river in the world (Schmidt, Krauth & Wagner, 2017), and toxic compounds are at worryingly high concentrations (Floehr *et al.*, 2013).

Artificial compounds such as PCBs, PBDEs and PCDD/Fs have been found in the blubber, liver, kidney, stomach, small intestine and brains of stranded YFP (Yang *et al.*, 2008). Stranded YFP from Dongting Lake have been found to have very high mercury concentrations in the liver, and one juvenile had very high concentrations in the liver and kidney (Dong et al. 2006). Chlorinated compounds, aromatic hydrocarbons, phenols, PAHs, mercury and herbicides have also been detected in the Yangtze itself at 'considerable' concentrations (Müller *et al.*, 2008).

As similar compounds (HBCDs and PBDEs) are found in fish samples from the Yangtze River (Xian *et al.*, 2008; Zhu *et al.*, 2013), it is likely these compounds are entering YFPs through the food chain. HBCD concentrations in finless porpoise populations in the South China Sea have increased from 9.5 ng/g/lipid in 1990 to 35 ng/g lipid in 2000 (Isobe *et al.*, 2011), and DDT and PCBs have been found at increasing concentrations in marine finless porpoises in the Pearl River and Dongshan regions of the South China Sea (Ramu *et al.*, 2006). These compounds are of concern due their lipophilicity, stability in the environment, bioaccumulatory properties in cetaceans (e.g. marine finless porpoises in the South China Sea, Ramu *et al.* 2006), and potential for toxicity; these compounds can cause immunosuppression and susceptibility to parasites (Beineke *et al.*, 2005; Isobe *et al.*, 2011), and fecundity issues in cetacean species (Schwacke *et al.*, 2002; Hall *et al.*, 2018).

Although these pollutants have been identified in tissues from dead YFP samples, the geographic scope of these studies is limited to Dongting Lake (Dong *et al.*, 2006; Yang *et al.*, 2008), and an in-depth analysis of the potential effects at the observed concentrations has never been completed. This makes it very difficult to assess the likely impact of pollutants in YFP decline.

1.4.5.5 Loss of Prey Resources

Diet composition of YFP has not been fully detailed, but YFP are thought to be morphologically most adept at feeding on fish near the surface of the water (Yu *et al.*, 2005; Zhang *et al.*, 2015). Finless porpoises living in marine environments from Japan to Hong Kong consume small fish (e.g. Gobiidae, Atherinidae, Apogonidae) and other small prey such as cephalopods, crustaceans and bivalves (Barros, Jefferson & Parsons, 2002; Shirakihara *et al.*, 2008; Lu *et al.*, 2016), representing a similar generalist hunter type diet to most porpoise species. Similar species such as the harbour porpoise (*Phocaena phocaenoides*) forage almost continuously and have high prey demands due to high energetic costs (Wisniewska *et al.*, 2016). Harbour porpoises are therefore thought to be susceptible to human disturbance (Wisniewska *et al.*, 2016) and starvation (Read, *et al.* 1997; Lockyer *et al.*, 2003).

Intensive fishing practices are widespread in the Yangtze River and both lake systems, which has resulted in significant, long term losses in fish biomass and species diversity (Fu *et al.*, 2003; Ye *et al.*, 2013). Spawning of fish has also been restricted and altered by modification of water flow due to large hydropower projects, which further inhibits recovery of fish stocks in the Yangtze River (Duan *et al.*, 2009; Gao *et al.*, 2009; Zhang *et al.*, 2011; Chen & Wu, 2011).

Despite aquaculture production tripling between 1995 and 2014 to counter the loss of fish stocks in the Yangtze, fisheries capture from inland waters still increased until 2013, when it began to fall (FAO, 2016). Unfortunately, there are relatively very little data available relating to species-specific stock decline in the Yangtze, as data are not typically shared with the public and FAO reports are not specific enough to interpret for this purpose. Anecdotally, there are reports of strandings of YFP with empty stomachs, thought to have died of starvation (IHB, Wuhan, China, pers. comm.) although this has not been confirmed by full necropsy. Lack of prey resources has been identified as a key factor limiting recovery in other cetaceans (Lacy *et al.*, 2017), and as a primary driver of decline in other cetacean populations (Bearzi *et al.*, 2006, 2008). The effect of observed fish stock declines in the Yangtze River on YFP populations is not well understood.

Since 2003, spatial intensity of fishing has varied throughout the year due to the advent of a seasonal fishing ban from April 1st to the end of June in the Yangtze mainstem (Wang, 2009), and between the dates 20th March – 20th June in the two lake systems (exact date varies year to year). However, whether this has been effective at slowing or reversing fish stock decline has not been specifically studied.

1.4.5.6 Habitat Degradation, Alteration and Loss

In addition to the impacts directly associated with human settlement, the Yangtze River itself has been altered significantly by numerous dams, construction of artificial embankments and sand-mining of sandbars (Li *et al.*, 2011; Yang *et al.*, 2014; Mei *et al.*, 2015). Opened in July 2012, the Three Gorges Dam (TGD) is the largest hydropower facility in the world. By altering the hydrological regime, the presence of the TGD has affected saltwater intrusion into the Yangtze (An *et al.*, 2008), altered nutrient characteristics (Chai *et al.*, 2009), altered suspended organic matter concentrations (Bao *et al.*, 2014), reduced and altered sediment load and discharge (Chen *et al.*, 2008; Dai & Lu, 2013; Feng *et al.*, 2014; Gao *et al.*, 2014), altered flow and channel dynamics (Chen *et al.*, 2010b; Guo *et al.*, 2012; Gao, Yang & Yang, 2013; Jiang *et al.*, 2014), caused low water levels in the middle-lower Yangtze river (Lai *et al.*, 2014), and altered organic carbon cycling in sediments (Li *et al.*, 2014a). The dam has also reduced phosphorus and inorganic nitrogen levels in the middle-lower Yangtze and therefore probably reduced primary productivity (Zhou *et al.* 2013; Sun *et al.* 2013; Sun *et al.* 2013). Patterns of floods have also changed (Li *et al.*, 2014b), altering fish communities and triggering a loss of

YFP hunting grounds (Gao *et al.*, 2014; Fang *et al.*, 2006). Completed in 1981, construction of the Gezhouba dam has had similar consequences, but not on quite the same scale (Li *et al.*, 2011; Zhang *et al.*, 2017a).

In addition to the threats that cover the Yangtze River, there are plans to construct a large dam across the mouth of Poyang Lake to regulate the water level (WWF-China, 2017). The proposed dam would alter the hydrological, sediment and nutrient regime of the lake, and prevent movement of the YFP between the Yangtze mainstem and Poyang Lake.

1.4.5.7 Genetic Bottleneck

As a result of the severe YFP population decline, genetic bottlenecking is likely occurring due to low levels of diversity in the remaining population (Zheng *et al.*, 2005; Chen *et al.*, 2014b). Low genetic diversity is associated with lower reproductive success and adaptability to environmental change, resulting in further vulnerability to extinction (Mei *et al.* 2012). In addition, gaps in the spatial distribution of YFP have been noted in the Yangtze mainstem (Chen *et al.* 2014); a 250km gap between Shishou and Yueyang was identified in 2006 (Zhao *et al.*, 2008), and two gaps were observed by Mei *et al.* (2014); one between Yichang and Shashi, and another 150km gap around Wuhan. Genetic isolation of populations is therefore occurring, which is likely to be exacerbated if population decline continues (Chen *et al.*, 2014b).

Changes in water levels in the Yangtze have caused YFP to stop migrating between Poyang Lake and the Yangtze mainstem, reducing migratory mixing between populations and exacerbating distribution gaps (Zhuo *et al.*, 2002a). Further distribution gaps caused by population decline would additionally restrict gene flow through fragmentation of the population. Genetic issues are not an extrinsic threat associated with human activity but are a result of YFP population decline and should be considered here as these issues are likely to become more pronounced as the population declines further.

1.4.6 YFP research; past, present, and future

1.4.6.1 Past and current

In 1978, the Chinese Academy of Sciences (CAS) created the Baiji Research Collaboration Group, which comprised the Institute of Hydrobiology (IHB), Nanjing Normal University, the Institute of Acoustics, and the Institute of Biophysics. Although this group’s primary focus was baiji conservation, population surveys were conducted across the geographic range of the YFP. The surveys contributed to the first estimate of YFP population numbers by Zhang *et al.* (1993) and have led to ongoing YFP census and survey work that have documented its progressive population decline (Zhang & Wang, 1999; Zhao *et al.*, 2008; Wang, 2009; Mei *et al.*, 2012; Zhao *et al.*, 2013; Zhang *et al.*, 2014).

Workshops and conventions have been a key part of bringing together relevant researchers internationally, with YFP (and baiji) conservation workshops held in 1997 at Ocean Park, Hong

Kong (Reeves, Smith & Kasuya, 2000) and in 2004 by the Institute of Hydrobiology (Braulik *et al.*, 2004).

Periodic boat-based YFP population monitoring has been conducted by the IHB including prominent range-wide surveys in 2006 and 2012 (Zhao *et al.*, 2008; Mei *et al.*, 2014) and more regular landscape-level monitoring at Dongting and Poyang Lakes (e.g. Zhang *et al.* 2013). This has led to some understanding of the magnitude of both local and range-wide population declines (Mei *et al.*, 2012). However, the International Union Conservation of Nature Cetacean Specialist Group (IUCN CSG) has noted that more effort is needed to run monitoring networks, and more financial support is needed to instigate a more regular assessment of population status (Kreb *et al.*, 2010).

Other than census surveys, an array of biological and behavioural studies of the captive YFP population in Wuhan are ongoing (Xiao, Wang & Wang, 2005; Zheng *et al.*, 2007; Lin, Hao & Din, 2008; Li *et al.*, 2009; Wu *et al.*, 2010b; Wang & Wang, 2011; McLaughlin *et al.*, 2012) but very little, if any, of this research is specifically related to optimising conservation. Several interview surveys have been conducted in Yangtze fishing communities between 2008 and 2012 (Turvey *et al.* 2010; 2013) demonstrating the effectiveness of this approach for collecting cetacean mortality data and associated socio-economic activity data for local fisheries, and establishing effective and culturally sensitive data-collection protocols.

The likely impact of different potential threats in driving observed YFP decline has been the subject of almost no research so far in China, beyond opportunistic, anecdotal reporting of occasional YFP mortalities associated with specific anthropogenic factors (e.g. Dong *et al.*, 2006; Wang, Li and Waerebeek, 2015). There have been observed fatalities as a result of fishing gear entanglement, propeller damage and pollution spills, amongst other causes (Zhao *et al.*, 2008; Wang, 2009; Mei *et al.*, 2012; Wang *et al.* 2015). Despite strong recommendations (Turvey, Hao & Ding, 2012; Turvey *et al.*, 2013), no systematic post mortem system has been set up for the YFP in China. This is severely hampering efforts to successfully understand and therefore mitigate population decline.

1.4.6.2 Conservation interventions

Several interventions have occurred from the 1990's onwards. The Honghu Xin-Luo baiji National Nature reserve was established in 1992 as an in-situ reserve in the Yangtze mainstem. Since the functional extinction of the baiji, this reserve has been used for protection of the YFP. To date, there are now eight in-situ reserves that aim to protect the YFP and its habitat (Figure 1.3, Table 1.4). In addition to in-situ reserves, several semi-natural YFP reserves have now been established (Figure 1.3, Table 1.4). Each reserve is an oxbow lake that is separate to the Yangtze mainstem, and they are therefore not subject to the same anthropogenic pressures and threats to the YFP. The first of these semi-natural reserves, Tian'e-Zhou, was established in 1992 as a protected area specifically for baiji conservation but is now used for YFP protection and breeding. To date, four of these semi-natural YFP reserves have been established (Figure 1.3, Table 1.4). YFPs have been captured from the main stem and transferred to the semi-natural lake systems to establish protected breeding populations (Zhang *et al.* 1995; Wang *et al.* 2013). The information shown in Table 1.4 is a summary of all publicly available information at the time of writing; further information such as the quality of habitat or water quality monitoring is not available.

Given the precipitous decline in number in the wild, these reserve populations are undoubtedly vital for conservation of the species. However, they are not without their difficulties and drawbacks. The population in Tian’e-Zhou reserve has increased from the 13 individuals introduced in 1997 (Zhuo *et al.*, 2002b) to ~40 in 2014 (Guo *et al.*, 2014) but the YFP population in the reserve is suffering from genetic inbreeding already (Chen *et al.*, 2014a). The reserve populations have relied on re-population by transfers from wild populations and movements between reserves to maintain genetic diversity (WWF-China, 2017). Transfers and additions are hazardous, resulting in 8 individuals dying during previous transfer attempts between 1990 and 2008 (Wang, 2009; WWF-China, 2017). That the numbers in the reserves have increased means this intervention is somewhat successful, but sole reliance on this method of conservation is unwise given the inbreeding difficulties. These small populations are also subject to rare environmental or anthropogenic events such as pollution spills or environmental disaster (WWF-China, 2017). There has been arguably little to no successful conservation effort in natural, Yangtze mainstem habitat as shown by continuing population decline (Zhao *et al.*, 2008; Mei *et al.*, 2014).

Since 1996, a captive breeding programme focussed on a small group of YFPs has been ongoing at the Institute of Hydrobiology, Wuhan. A calf was born for the first time in July 2005, making it the first freshwater cetacean born in captivity (Wang *et al.*, 2005). Three further calves were born in 2007, 2008 and 2016, all but one of which has died. Intensification of this captive breeding programme has been recommended (Wang & Zhao 2010), but refinement of the programme is needed as evidenced by the loss of calves and no net growth in numbers due to loss of individuals from old age (Dr Yujiang Hao, Institute of Hydrobiology, pers. comm.).

Table 1.4: Details of the four current semi-natural YFP reserves

Reserve	*Tian-e-zhou National Baiji Natural Reserve*	*Hewangmiao (/Jicheng) Reserve*	*Tongling Freshwater Porpoise Reserve*	*Xijiang Reserve*
Location	Shishou, Hubei	Hubei and Hunan	Tongling, Anhui	Anqing, Anhui
Legal level	National	Provincial	Provincial	Local
Size	20km^2	44km^2	1.6km long, 80-220m wide	Unknown
Established	1990	2015	1994	2016
Initial YFP added	› 5 added in 1990 (Wang, 2009; WWF-China, 2017)	› Initial addition of 4 males, 4 females (WWF-China, 2017) › 4 (2M, 2F) were added from Poyang Lake › 4 (2M, 2F) were added from Tian-e-zhou	› 5 added in 2001 (Wang, 2009)	› 5 added in 2014 (WWF-China, 2017)
Calves born	Conflicting reports of birth rate: › calves/year (Wang *et al.,* 2005), › 2-4 calves/year (Zhao *et al.,* 2008), › 5-10 calves/year (WWF-China, 2017), › 31 YFP born 1990 – 2008 (Wang, 2009)	› One calf born in 2016 (WWF-China, 2017)	› 1 calf/year 2003, 2005, 2006, 2007, 2008 (Wang *et al.,* 2005)	› 1 calf born 2014 (WWF-China, 2017)
Deaths	› 25 have died or been killed in the reserve by accidental causes (Wang, 2009)	› One adult died in 2016 (WWF-China, 2017)	› Unknown	› Unknown
YFP additions	› 4 individuals added from Poyang Lake 2017 (WWF-China, 2017) › Total added: 30 individuals (WWF-China, 2017)	› 4 YFP translocated from Poyang Lake in 2017 (WWF-China, 2017)	› None	› 9 YFP added 2016 (WWF-China, 2017) › 7 from mainstem › from Tian-e-zhou
Current population	› Estimated at 27 in 2005 (Wang *et al.,* 2005) › Estimated at ~30 in 2008 (Zhao *et al.,* 2008) › ~60 individuals by 2015 (WWF-China, 2017)	› Unknown	› Still 5 YFP in 2004 (Li *et al.,* 2006)	› Currently 15 individuals (WWF-China, 2017)
Carrying capacity	› 80-100 (WWF-China, 2017)	› 20-50 (WWF-China, 2017)	› Unknown	› 20-50 (WWF-China, 2017)
Other	› YFP population supported by fish stock fry addition to the lake (WWF-China, 2017)	› Seasonally connected to the Yangtze mainstem at summer highwater › Buffer zone 5km^2, Experimental zone 22km^2, Core zone 16.6km^2 (WWF-China, 2017)	› Supplemental feeding every day (personal observation)	› Some pollution concerns about this habitat (WWF-China, 2017)
Further plans for future reserve populations				
› Four potential reserves planned: Lao-jiang-he (Hubei province), Lao-wan (Hubei province), Xi-hai (Jiangxi province), Liao-jia-gou (Jiangsu province) (WWF-China, 2017) › Goal of a total ~200 individuals within these reserves (WWF-China, 2017)				

1.4.7 YFP conservation research requirements

YFP are currently protected under China's Wildlife Protection Act 1989, and in 2014 the species was upgraded to the strictest wildlife classification category: National First Grade Key Protected Wild Animals, AKA a Priority I species (WWF-China, 2017). Under Chinese National Law, this classification required that threats to the species are monitored and managed within all of the YFP reserves. Additionally, fishing should now be regulated (with severe penalties for illegal activities) in the central and lower Yangtze and there should be more funding to species conservation from the Ministry of Agriculture (WWF-China, 2017). Additionally, the MoA released a new action plan – 'Action Plan for Saving Yangtze Finless Porpoise (2016-2025)' – in 2016. However, it has been noted that despite this change in law and a new action plan, no budget has been attached to implementing or enforcing any of the new changes. Enforcing the law is a key priority to reduce mortality in Asian freshwater cetacean populations (Kreb *et al.*, 2010), however, it is very difficult given the social, political and logistical constraints surrounding its protection across the vast area of the Yangtze basin.

Rapid conservation action is needed to avoid a second freshwater cetacean extinction in the Yangtze, and the urgency of the rate of documented YFP decline means that any intervention must be targeted and effective. There has therefore been a call for increased quantification of threats in many YFP related studies from the last decade (e.g. Huang *et al.,* 2012; Mei *et al.*, 2012; Wang, *et al*. 2015), yet few studies have focussed on achieving this aim.

Improved understanding of the degree to which different potential threats are contributing to YFP decline is essential for effective mitigation and conservation of this taxon. There is also little to no information on spatio-temporal interactions between YFP and threat factors in key YFP habitats. Each of the potential threats to YFP survival require differing conservation mitigation and management strategies; quantifying the relative significance of each anthropogenic threat is therefore an urgent conservation priority (Wang & Zhao, 2010). There have also been no studies monitoring the effectiveness of past and current mitigation methods, meaning there is firstly no way of knowing to what degree they are effective, and secondly that there is no way to improve upon them for the future.

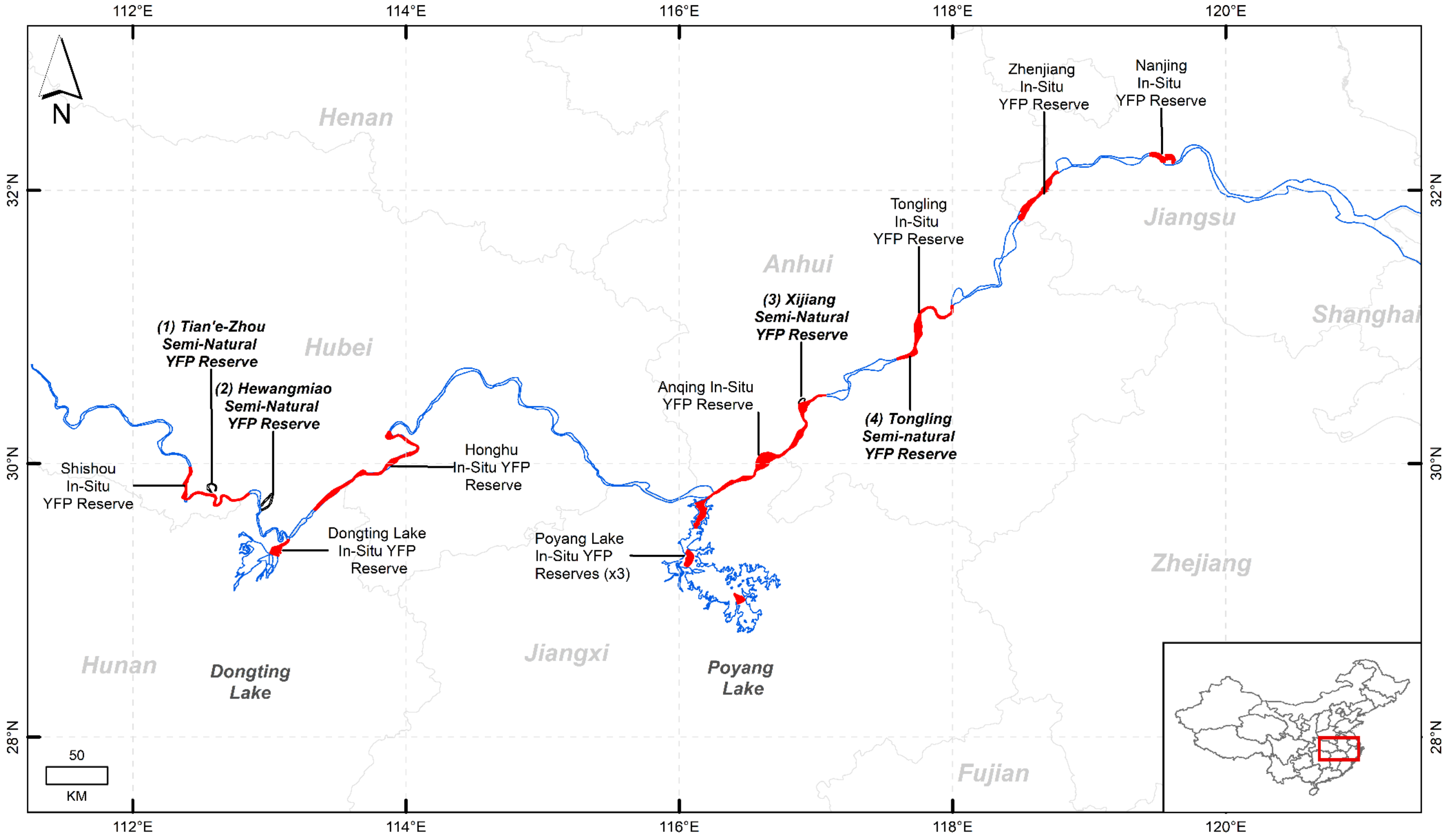


Figure 1.3: Location of eight in-situ and four semi-natural (numbered 1-4, bold text) cetacean reserves in the Yangtze River basin
Adapted information from in-country GPS readings on site, published maps observed in-country, and from paper sources; Mei *et al.* (2012).

1.5 Objectives

The aim of this project is to better understand and quantify the dynamics surrounding YFP decline. Firstly, a comprehensive assessment of the current evidence base surrounding causes of YFP mortality will evaluate whether existing data are sufficient to identify or further understand drivers of decline. Subsequently, a range of survey methods and analytical techniques will be used to further quantify spatial and temporal dynamics of YFP distribution and movement in relation to different potential threats, and to identify which, if any, potential threats can be associated with observed mortalities or population-level effect. Lastly, the degree to which evidence-based conservation has been applied to YFP protection is assessed, which is used to identify key gaps and areas for improvement in the mitigation process.

1.5.1 Overarching Research Questions

- What information can be derived from existing data to establish primary causes of mortality and population decline in the remaining YFP population, and what data gaps and questions remain? (Chapter 2)
- Given all current knowledge surrounding biology, threats and observed decline, should conservation of the YFP adopt a more precautionary or evidence-based approach? (Chapter 2)
- What is the current distribution and overlap of potential threats and YFP occurrence in key YFP habitats on a landscape scale, and how does it vary spatially and temporally? How does this affect conservation? (Chapter 3)
- How does fishing gear type, intensity and distribution vary seasonally and spatially in key habitats, and how might this relate to YFP mortality? (Chapter 3, Chapter 4)
- How have fishing practices changed over time in key YFP habitats, and how does this relate to social, economic and biological factors? (Chapter 4)
- Are current research priorities improving the knowledge base surrounding YFP conservation? If not, what are they key remaining research gaps? (Chapter 5)
- To what extent are existing YFP conservation methods based on evidence, and, if they are not, what factors are influencing YFP mitigation choices? (Chapter 5)
- Are current mitigation and intervention methods currently sufficient to maintain a wild YFP population? If not, how can they be improved? (Chapter 5)

2 Chapter 2: Evidence-based conservation versus the precautionary principle: determining the current evidence base from existing data to inform Yangtze finless porpoise conservation

Two deceased YFP observed during (left) Poyang Lake winter 2016 boat survey and (right) Poyang Lake summer 2017 boat survey

2.1 Abstract

Understanding key threats causing population decline is essential to successfully mitigate causes of mortality in at-risk species. Many threatened species are data-poor as they are difficult to study and have not yet received sufficient conservation attention. Threatened species typically require rapid intervention to reverse population decline, hence using valuable time collecting robust long-term data to inform conservation is often not the best option. In these cases, it is vital to critically evaluate the information content of available data sets, even if they were not originally collected for conservation purposes. In this chapter I present the results of four lines of analysis aimed at furthering our understanding of primary causes of mortality and population level decline in the Critically Endangered Yangtze finless porpoise. By combining multiple already-existing data sets and conducting novel analyses, the information content of these data sets has provided valuable insight into the possible causes of population level decline of this unique species. These analyses have demonstrated that anthropogenically caused Yangtze finless porpoise mortality far exceeds the estimated sustainable loss estimations, and further results shown here empirically demonstrate for the first time that vessel traffic is a probable key cause of Yangtze finless porpoise mortality. In addition, two of the analyses indicate that fishing activity is less likely to be driving the decline, with limited spatial overlap demonstrated between fishing gear and either Yangtze finless porpoise occurrence or observed porpoise mortalities in the river. The final analysis presented here demonstrates that there has also been a significant decline in the proportion of YFP calves observed between 2006 and 2012. The new analyses presented here demonstrate that critical re-analysis of existing and combined data sets can provide important new insights into drivers and dynamics of decline in threatened species, supporting the possibility of an evidence-based approach to conservation management even for poorly understood species.

2.2 Introduction

2.2.1 Conservation of data poor species: precautionary or evidence-based approach?

An evidence-based approach to conservation is reliant on the existence of robust, long-term data sets to understand causes of decline and inform best practice for conservation management (Sutherland *et al.*, 2004; Bower *et al.*, 2017). In the case of many threatened species however, existing data are limited in terms of quantity and quality, and any usable data are often restricted in spatial (e.g. Rondinini, Stuart & Boitani, 2005; Boakes *et al.*, 2010; Boitani *et al.*, 2011) and temporal range (e.g. Boakes *et al.*, 2010; D'Souza *et al.*, 2013; Laidre *et al.*, 2015). This absence of robust data can limit the ability of decision makers to make informed, effective choices with regards to reserve placement, mitigation, and management practices (Catullo *et al.*, 2008; McDonald-Madden, Baxter & Possingham, 2008; Lindenmayer, Piggott & Wintle, 2013).

An alternative is to take a precautionary approach to species conservation, which would take a more pro-intervention route even in data-poor environments. However, this approach can involve more risk and the likelihood of failure or sub-optimal outcomes is higher as interventions will be poorly informed. This means interventions are more likely to waste time and resources as they are less likely to be effectively designed to target key causes of mortality (e.g. VanderWerf *et al.*, 2006).

One solution to overcome data limitation is to conduct further research, which typically requires a large investment in time and resources that could otherwise have been allocated to more practical interventions. Delays in implementing conservation measures can lead to little guarantee of improved conservation prospects when actions are eventually carried out (e.g. as in the case of the vaquita, *Phocoena sinus*, Jaramillo-Legorreta *et al.*, 2007) and further data gathering can exhibit a diminishing return on investment (Grantham *et al.*, 2008). An alternative solution is that conservation relevant conclusions for data poor species can often be provided from more rigorous analysis of existing data sets, potentially through multiple types of novel analyses (e.g. McDonald-Madden, Baxter & Possingham, 2008; Zhang & Vincent, 2017). It is therefore important to fully analyse potentially valuable existing data and extract any possible conservation-relevant inferences before moving forward. This process may involve multiple methods of analysis and inference on sometimes limited data to extract the most useful information to inform conservation (e.g. MacMillan & Marshall, 2006; Thieme *et al.*, 2007; Rodrigues, 2011). Ensuring this process is completed can help avoid replication of work that could determine the same conclusions, and this potentially saves valuable time in the race against extinction. After thorough analysis of existing data is completed, key remaining data gaps can be identified allowing more informed assessment of whether a precautionary or evidence-based approach is most appropriate.

2.2.2 The YFP: precautionary or evidence-based approach?

For coastal cetaceans, it was noted by Thompson *et al.* (2000) that (1) there is a high level of uncertainty about population size, (2) consequently they are likely to be under-protected and

(3) the risk is increased as there are typically multiple threats, all of which have a low risk individually and therefore low power to detect harm. The burden of proof to support intervention is therefore often not met and a species is likely to be inadequately protected. It is likely these three factors are even more pronounced in freshwater species as they occur in rapidly developing countries and have very few baseline data on population status and trends (Reeves, Smith & Kasuya, 2000). As a result, it has been recommended that the precautionary principle should be generally applied to cetacean conservation management (Thompson *et al.*, 2000).

Before moving forward with further research surrounding threats to YFP, it is important to assess the current evidence base. Firstly, it is possible that available data may be able to inform conservation if analysed in a novel way. Secondly, this process will allow identification of remaining data gaps for further work. Lastly, this process will inform whether an evidence-based approach to conservation of YFP is viable, or whether a precautionary approach should be adopted.

2.2.3 Current evidence base around threats to YFP

As discussed in chapter 1, spatial and temporal dynamics of potential threats to YFP have been poorly studied and are not well quantified. Strandings data are often a key source of information about causes of mortality in cetaceans, and can also indicate temporal and spatial trends (e.g. Leeney *et al.*, 2008; Pikesley *et al.*, 2012); however, these data are not available for the YFP. The limited information currently available on YFP mortality is provided by sporadic reports of stranded carcasses and limited post-mortem data (Zhou & Wang, 1994; Wang *et al.*, 2000; Dong *et al.*, 2006; Yang *et al.*, 2008; Wang & Zhao, 2010; Wang, Li & Waerebeek, 2015). This is hindering the mitigation process as key causes of decline cannot be targeted. As detailed in chapter 1, previous YFP conservation research has predominantly been restricted to boat based surveys documenting population decline (Zhao *et al.*, 2008; Mei *et al.*, 2014) and some investigations into ecology and biology of the species, rather than detailed investigations to identify probable drivers of population decline.

In the absence of sufficient strandings data, other data sources such as proxy metrics or indirect information can be used to investigate potential drivers of population decline. This may include grey literature (e.g. Sáenz-Arroyo *et al.*, 2005; Pinnegar & Engelhard, 2008), information derived from environmental NGOs, or demographic data. For example, local ecological knowledge (LEK) can be used as an alternative source of mortality data or for information relating to potential threats (e.g. Turvey *et al.*, 2015; Nash, Wong & Turvey, 2016; Miard, Nekaris & Ramlee, 2017), including for cetacean and other aquatic mammal species (Turvey *et al.*, 2013; Frans & Augé, 2016; Liu *et al.*, 2017). LEK surveys have previously been used (2008 and 2011-2012, hereafter referred to as the “2008 survey” and the “2011/2012 survey”, respectively) to reveal the potential importance of vessel strikes as a possible driver of population decline as well as some spatial patterns in YFP mortality, and to gather a range of conservation-relevant socio-economic data associated with potentially harmful fishing activities (Turvey *et al.,* 2010; Turvey *et al.,* 2013). In addition to these two existing data sets, other types of data are available that have not yet been analysed in full. For example, calf abundance data from the 2006 and 2012 Yangtze Freshwater Dolphin Expedition (YFDE) surveys have not been analysed. There is also a wealth of grey literature (e.g. reports in the media, databases kept by NGOs) relating to YFP mortality that is as-yet unused.

Before conducting further novel field-based research, it is important to comprehensively analyse what can be concluded about threats to YFP from all currently available information, and then establish remaining data gaps. This chapter presents results from four lines of enquiry:

(1) An analysis of potential sustainable levels of YFP mortality using two standard methods. Firstly, this will estimate the current sustainable and likely actual level of anthropogenic loss from the YFP population. Secondly, these estimates can be used to investigate whether reported YFP mortality associated with different threats (from interview data and other sources) is likely to be sustainable.

(2) An analysis aimed at investigating landscape-scale correlations between varying levels of potentially harmful fishing gear use and shipping vessel presence with reported YFP mortalities from interview data gathered in 2008 and 2011/2012. This also includes YFP sighting data from the 2006 YFDE.

(3) An analysis investigating finer-scale overlap of functional categories of fishing equipment and YFP presence across the near-bank to mid-channel profile of the Yangtze River.

(4) An analysis of the proportion of YFP calves to adults observed in 2006 and 2012 from YFDE census survey data and whether this changed over time on a range-wide spatial scale.

The results of these four analyses are presented in this order, after which conclusions are discussed, and remaining data gaps identified. An introduction to some of the concepts and theory behind these four analyses is provided below.

2.2.4 How is sustainable removal from a population quantified?

Sustainability is generally understood to be the maintenance of a resource without causing long-term damage or depletion, preserving it for future generations. It was fully detailed as an essential conservation construct by the IUCN in 1980 as a key part of their World Conservation Strategy (IUCN, 1980), and it is now a core concept within wildlife management. It has evolved over recent decades and is now considered to encompass social, economic and biological dimensions (OECD, 2008). Within biodiversity conservation, sustainable removal from a population is the level of removal that is allowable to maintain long-term viability. Here, sustainability with respect to YFP is discussed in terms of predominantly incidental anthropogenically caused mortality and, as such, will be referred to as “sustainable loss” or “loss” of YFP instead of “offtake” or other commonly used terms to describe managed removal of individuals from a population. When discussing the topic more broadly, offtake or removal will still be used in the context of sustainable management practices in other systems or theory, where appropriate.

Quantifying sustainable removal is typically achieved by statistical techniques that model a given population based on current and projected scenarios. Several different modelling techniques have been developed to investigate sustainability in a biological conservation context (e.g. population viability analysis, PVA, Boyce 1992). For sustainable management of bushmeat as a resource for example, sustainability indices tend to be used (Milner-Gulland & Akçakaya, 2001), but for aquatic mammals, a number of other sustainability assessment techniques can be applied, which are typically used to inform sustainable rules for managing populations. These include Potential Biological Removal (PBR), the IWC Revised Management Procedure (RMP; mainly for larger cetaceans) and the Helsinki Commission (HELCOM) approaches (Lonergan, 2011). PBR is generally thought to be a conservative method that considers uncertainty in a number of population parameters. PBR also has flexible subjective components such as the recovery factor, which can be set to reflect desired conservativeness of the estimate (Lonergan, 2011). IWC RMP and HELCOM techniques are more applicable for informing policy and management of licenses for intentional rather than incidental removals.

Quantifying sustainable offtake is not a simple undertaking, as many systems are subject to unpredictable fluctuations and poorly-understood biological and anthropogenic influences that may interact to effect sustainable removal over a range of spatial and temporal scales (Mockrin *et al.*, 2011; Levi *et al.*, 2011; Weinbaum *et al.*, 2013). These uncertainties are compounded by uncertainty in the models created to represent these systems, which often has to be explicitly taken into account (Cortés, 2002). There are therefore three forms of uncertainty when trying to model sustainable offtake; firstly, uncertainty about our observations of a system (data uncertainty); secondly, uncertainty relating to variability in the system (system uncertainty); and lastly, uncertainty within the models which are created (model uncertainty). A precautionary approach to management of at-risk populations would mean defining, using and interpreting these uncertainties with preference to the resource being studied, i.e. any use or interpretations of these models should favour protection of the species where appropriate.

Statistical modelling of cetacean population and mortality data is a useful tool in predicting population trends and demographic scenarios. It has been used to predict possible future decline scenarios in populations of Hectors dolphin (*Cephalorhynchus hectori*) (Martien *et al.*, 1999), understand decline in the North Atlantic right whale (*Eubalaena glacialis*) (Fujiwara & Caswell, 2001) and even reconstruct the population level effects of past whaling efforts (Baker & Clapham, 2004). As mentioned, interpretation of such models is highly dependent on how uncertainty in the data is accounted for (Taylor *et al.*, 2000), which is important when considering data-poor taxa that are already at small numbers. Below, two commonly used methods to estimate sustainable offtake (or, in this case, loss), PBR and logistic growth models, are detailed and discussed.

2.2.4.1 Method 1: The Potential Biological Removal (PBR) approach

Growth of a population cannot be infinite; as numbers increase, finite resources will be limiting to further growth and the population will eventually reach a carrying capacity. At this point, births are equal to deaths and the population will theoretically remain stable. Any given population will therefore have slower growth at very low (nearing zero) and very high levels of abundance due to low growth rate and limited resources, respectively, and will have peak recruitment at an intermediate abundance (Maximum Net Productivity Level, MNPL). In populations with very low carrying capacity and very high growth rates, it is difficult to predict population change as it can fluctuate over and beyond carrying capacity, causing what is known as ‘deterministic chaos’ (May, 1976). However, when applied to slow growing species with more predictable reproductive rates such as mammals, this method can be used to understand past, current and possible future stock fluctuation scenarios, which is especially important when considering highly at-risk small populations.

The Potential Biological Removal approach (PBR, Wade, 1998) attempts to quantify to what level individuals can be removed from a population without leading to long-term population depletion. It is based on a logistic model of population growth, using the lower estimation of Maximum Net Productivity Level (peak recruitment at an intermediate abundance, MNPL) as 0.5 the value of the carrying capacity, *K*. *K* can be estimated in a number of ways, for example by using home-range of individuals (Ryan & Jamieson, 1998; Gregr *et al.*, 2008) or biomass of prey species (Hayward, O’Brien & Kerley, 2007), or spacing distances between (Braithwaite, Meeuwig & Jenner, 2012) but these methods require robust ecological and biological data to be accurate. Growth is assumed to be greatest at small population sizes, and is 0 at *K.* MNPL is therefore the population size that results in the maximum number of individuals being added to the population per year. For marine cetaceans this is thought to be between 0.5K and 0.85K (Taylor & de Master, 1993). Maximum Mortality Rate (MMR) can then be calculated, defined as the maximum proportion of the population that may be killed annually through anthropogenic causes, while still maintaining a steady population number through intrinsic population growth. If human caused mortalities are less than the MMR, then a depleted population will be able to recover so that, given sufficient time, it has a 95% probability of being over half the carrying capacity.

The PBR technique has previously been used to estimate sustainable mortality for other cetacean taxa, such as Hector’s dolphin (*Cephalorhynchus hectori hectori*, Slooten and Dawson, 2008), Maui’s dolphin (*Cephalorhynchus hectori maui*, Hamner *et al.*, 2014), dusky dolphin (*Lagenorhynchus obscurus*, Dans *et al.*, 2003), narrow-ridged finless porpoise (*Neophocaena asiaeorientalis sunameri*, Shirakihara and Shirakihara, 2013), Indo-Pacific bottlenose dolphin (*Tursiops aduncus,* Shirakihara and Shirakihara, 2012), and other species (Williams, Hall & Winship, 2008). For the narrow-ridged finless porpoise in Japanese waters, PBR was estimated at 27 individuals annually (Shirakihara and Shirakihara, 2013). This value was compared to estimated annual bycatch by scaling up individual interview data from fishers to the entire fishing fleet. The difference between the two values was almost by an order of 10 (estimated actual removal was 238 for 2007 and 270 for 2008), implicating fishing bycatch as a key cause of population decline. As demonstrated by this study, the use and comparison of PBR with likely actual anthropogenic mortality can be applied to quantify sustainable anthropogenic removal from a population and can also provide insights into the likely causes of population decline.

2.2.4.2 Method 2: Population modelling using the logistic growth equation

As noted earlier, population growth is finite. Growth will tail off at the carrying capacity, at which point births and deaths will theoretically remain stable. This is commonly represented by the Ricker equation [1], first put forward to assess salmon stocks (Ricker, 1954) but now commonly applied to any population for which certain demographic parameters are known.

[1] $$N_{t+1=}\ N_t\, e^{R_{\max}\left(1-\frac{N_t}{K}\right)}$$, where

N is the population estimate in t year, $R_{\max}$ is the maximum annual population growth rate, and K is the population size at carrying capacity.

Sustainable harvesting of any population requires that removals are not ever any higher than the rate of population growth. The maximum rate of sustainable yield is therefore theoretically equal to a population’s intrinsic rate of increase, but only under optimal growth conditions i.e. sufficient resources are available to sustain the population. Any harvesting beyond this threshold level will eventually lead to decline and possibly extinction. This method of assigning a removal quota can be interpreted as the Maximum Sustainable Yield (MSY), which is calculated as per formula [1] above, but with a fixed level of offtake, C_t, and an added parameter to account for environmental stochasticity, ε.

[2] $$N_{t+1=}\ N_t\, e^{r_{\max}\left(1-\frac{N_t}{K}\right)+\varepsilon} - C_t$$

2.2.4.3 Choosing appropriate sustainability estimation techniques

Choosing an appropriate method of estimating sustainable anthropogenic removal is dependent on the reasons for conducting the analysis. The chosen method should be relevant to the species being studied and should be specific to the targeted cause of anthropogenic removals, if possible. For instance, PBR was designed by the United States Marine Mammal Protection Act (MMPA) for marine mammal bycatch stocks specifically (Wade, 1998a; Williams *et al.*, 2016b). For species that are specifically killed for other purposes such as subsistence hunting (e.g. the Pacific walrus, *Odobenus rosmarus divergens* Maccracken *et al.*, 2014), PBR is not recommended by the MMPA as bycatch is not the predominant cause of mortality. PBR is also designed to be conservative, with the current population set intentionally to a very low threshold to account for uncertainty within the estimation. This method has been applied to many populations of marine mammals (e.g. Slooten & Dawson, 2008; Maccracken *et al.*, 2014;

Williams *et al.*, 2016b) but the predominant intention of using this method is to set a guideline for continued management of marine mammal stocks, not for analysis of removals from past population estimates.

Logistic population models are designed to be an accurate (so far as is possible) representation of population growth given a current population estimate, rather than conservative estimate of sustainable anthropogenic removal. They are flexible and can be modified to match the requirements of the intended analysis. The accuracy of logistic population models is reliant on two broad aspects: firstly, the accuracy of the population estimate is, and secondly the accuracy of estimated life-history parameters within the formula itself. Species specific R_{max} and population specific K values should be used, if available (e.g. Hectors dolphin, Slooten & Dawson, 2008), and if they are not then using generic genus or family estimates may be less accurate. Using logistic population modelling is therefore more flexible than simply calculating PBR, but both have their applications and should be chosen based on the intention of the study. As logistic models account for more sources of possible variation and are constructed to contain extra life history variables, they are more likely to be reflective of reality.

For example, Laake *et al.* (2018) adapted a generalised population model to estimate past populations of California sea lions (*Zalophus californianus*) under changing sea surface temperatures. Similarly, Monnahan, Branch & Punt, (2015) used a logistic model to investigate the effect of ship strikes on a population of eastern North Pacific blue whales (*Balaenoptera musculus*).

2.2.4.4 Reported versus actual YFP mortality rates

Previous studies have noted that there is a large disparity between YFP mortality numbers in official stranding records and the rapid population decline (Wang *et al.* 2015), with official records from local authorities only totalling 24 for the period of 2000-2006 (Wang, Li & Waerebeek, 2015) despite an estimated population decline of likely hundreds of individuals over recent decades (Zhang *et al.*, 1993; Zhao *et al.*, 2008; Mei *et al.*, 2012). This is largely due to the lack of a systematic reporting system across China, and because fishers may be apprehensive to report mortalities to government bodies (Wang et al. 2015). In contrast, there are many times more reported mortalities within the 2008 and 2011/2012 interview data, which is more likely to reflect reality given the known population decline. Here, we use population modelling techniques to establish the degree to which observed mortalities (interview data) match known population decline (census survey data).

2.2.5 Understanding landscape scale and finer scale interactions of YFP with potential threats and reported YFP mortalities

Without long-term standardised post-mortem data (years or likely decades worth), it is difficult to quantify the role each potential threat has had on the decline of the YFP population. The accelerating rate of YFP population decline (Mei *et al.*, 2012) means that more urgent interventions are required and waiting for such data is not a viable option. An alternative approach for trying to understand or quantify causes of mortality is to investigate spatial overlap of potential threats and key habitat. The dynamics of threatening processes vary spatially on global (Halpern *et al.*, 2008) and local (e.g. Grelle *et al.*, 1999; Carpenter *et al.*, 2008; Orozco *et al.*, 2014) scales. The patterns in species and threat overlap are therefore likely to vary at the overall ecosystem scale and at localised, finer spatial scales. Understanding the interaction of at-risk species with potential threats over different spatial scales can inform causes of mortality (Redfern *et al.*, 2013) and is key to understanding how to target causes of decline through interventions (e.g. Evans *et al.*, 2011; Tulloch *et al.*, 2015).

Quantifying threats on a range of spatial scales has been a key component of recent cetacean and other marine mammal based conservation research, through investigation of the spatial variation in the overlap of threats and target species (e.g. Leeney *et al.*, 2008; Brown, Reid & Rogan, 2015; Avila, Kaschner & Dormann, 2018). In particular, effective conservation of highly mobile species such as marine mammals is reliant on incorporating species distribution patterns into conservation measures (Singh & Milner-Gulland, 2011; Runge, 2014) whilst also understanding overlap with potential threats across spatial scales. By improving the understanding of the spatial dynamics of threats as well as spatial overlap with YFP, these kinds of analyses can provide conservation-relevant data that can help inform and improve mitigation efforts.

2.2.5.1 Current understanding of the spatial overlap of threats and YFP

During the 2006 YFDE, 19,380 shipping vessels were observed during the survey, equating to ~1 vessel per 100m of river surveyed (Turvey *et al.*, 2007), and 1175 fishing vessels were also observed. Detection of large vessels varied along the river with respect to port locations and other focal areas for transport. The number of registered fishers varies between legislative areas (Turvey, Hao & Ding, 2012) and so fishing practices in the Yangtze basin varies spatially. The density of these potential threats therefore varies on an along-river basis. How this spatial variation in threats overlaps with YFP distribution is not known. Investigating the overlap of these two data sets could provide insight into causes of mortality.

Fishing practices in the Yangtze include of a range of gear types utilised across the full bathymetric profile of the river from shallow, near bank habitat to deeper, mid-channel sections (Turvey, Hao & Ding, 2012; Turvey *et al.*, 2013). Different types of fishing gear are likely to be used in specific depths and sections of the bathymetric profile of the river depending on their functionality, dimensions, and target species; however, this probable variation in gear use has so far not been investigated through qualitative analysis. In addition, YFP are known to preferentially use certain parts of the onshore-offshore river profile (Mei *et al.*, 2017), preferring mid water depths from 7-12m and a relatively flat benthic slope.

Bycatch from certain fishing gears is known to cause YFP mortality (Zhou & Wang, 1994; Zhao *et al.*, 2008; Turvey *et al.*, 2013). However, investigating the potential importance of fishing gear interactions in driving YFP declines by quantifying how distribution and habitat use of YFP overlaps with spatial use of fishing gears has not been conducted, either on broad or small spatial scales and no information is available on where specific fishing gears are used within the YFPs range. This is also the case for potential overlap of shipping lanes and vessel density hotspots with key YFP habitat. As a result, potential mitigation for the effects of bycatch and vessel strikes are poorly informed and cannot be spatially targeted to key areas of overlap or high threat density.

2.2.6 Investigating YFP reproductive success

Quantifying reproductive success of a species can provide insights into causes of decline (Alava, Barragán & Denkinger, 2012; Gero & Whitehead, 2016; Hall *et al.*, 2018). Proportion of young within a population can indicate overall health and fecundity; mammals are known to produce more viable healthy offspring when resources are plentiful, habitat is appropriate and sufficient in extent, and other biological and ecological characteristics are suitable for the species in question (Ford *et al.*, 2009; Ashe *et al.*, 2010; Lacy *et al.*, 2017). Factors such as stress, pollution, restricted genetic diversity, reduced prey resources and poor habitat quality can reduce viability of a population (Hamner *et al.*, 2014; Lacy *et al.*, 2017; Hall *et al.*, 2018; Nabi *et al.*, 2018). If reproduction is stable within a population, relatively similar calf proportions would be expected in any survey year, if the method of survey is uniform.

There is little to no information relating to YFP reproductive rates within the wild Yangtze River mainstem. From the semi-captive YFP group in Tian-e-zhou, Huang *et al.* (2015) estimated annual population increase to be 5%. This estimate is for a protected, semi-natural and maintained population in which there is supplementation of the fish stocks and removal of all potential threatening activity (Table 1.4). Reproductive success in a wild YFP population has not been studied and there are no published data available. As there were no surveys conducted in pre-industrial China, there are no estimates of the proportion of calves expected in a “healthy” YFP population. Even in the absence of baseline calf proportion data, relative trends in YFP reproduction could still provide information on relative trends in YFP reproduction between survey years. As a proxy for reproductive success, calf-based data could potentially provide insights into pollution, prey restriction, and genetic factors as potential threats that are currently very poorly understood.

2.2.7 Research Questions

- Do we currently have sufficient data to identify primary causes of human-induced mortality in the Yangtze finless porpoise?
- Is current Yangtze finless porpoise mortality due to fishing sustainable?
- What conclusions about the relative importance of different potential threats can be extracted from already existing data sets?
- If current data are not sufficient, what data are needed to better understand threats, and therefore mitigate them effectively?

2.3 Methods

In this chapter, previously gathered data sets have been utilised detailed in Table 2.1. These data sets are of two main types: the first type is YFP census data from boat-based surveys conducted by the IHB, and the second type is interview data from surveys conducted to gather LEK from fishers within the Yangtze system. These data sets have been provided with permission by their respective researchers or are openly available in published works.

Table 2.1: Previously gathered data sets relating to the YFP used in Chapter 2

Year	*Survey Format*	*Location(s)*	*Data Available*	*Source of data*
YFP census survey data				
2006	YFDE - boat-based range-wide survey	Yangtze River: Yichang-Shanghai	Counts of calves and adults observed during the survey.	Institute of Hydrobiology (IHB), Chinese Academy of Sciences (CAS), Wuhan, China, with permission.
> Overall survey data published in Zhao et al. (2008), calf data not published				
2012	YFDE - boat-based range-wide survey	Yangtze River: Yichang-Shanghai	Counts of calves and adults observed during the survey.	Institute of Hydrobiology (IHB), Chinese Academy of Sciences (CAS), Wuhan, China, with permission.
> Overall survey data published in Mei et al. (2014), calf data not published				
Fisher interview survey data				
2008	Fisher Interview	Yangtze River, Yichang – Chongming	Extensive interview data relating to fishing habits, porpoise mortality and socio-economic data (n= 499).	Dr. Samuel Turvey, with permission.
> Some interview survey data published in Turvey et al. (2013)				
2011/ 2012	Fisher Interview	Poyang Lake, Dongting Lake, Yangtze River from Ezhou to Anqing	Extensive interview data relating to fishing habits, porpoise mortality and socio-economic data (n= 417).	Dr. Samuel Turvey, with permission.
> Some interview survey data published in Turvey, Hao & Ding (2012)				

2.3.1 Estimating sustainable loss in YFP: does available mortality data explain population decline?

Before investigating causes of YFP mortality, it would be useful to quantify rates of mortality beyond simply understanding that the population is declining (Zhao *et al.*, 2008; Mei *et al.*, 2014). Two previous PVAs have been conducted to predict future decline and Time to Extinction (TE) (Zhang & Wang, 1999; Huang *et al.*, 2017), but neither the sustainable rate nor likely actual current rate of anthropogenic YFP mortality have been quantified. This information is important firstly to quantify the current mortality rate of YFP individuals, and to allow comparison between available mortality data from observation-based sources (e.g. media, fisher interviews) and the likely actual level of mortality and therefore to quantify the similarity or difference between these estimates.

To estimate sustainable loss or MMR of YFP, we used two commonly applied mathematical models. The first is a standard PBR analysis typically used to quantify a conservative estimate of sustainable loss for management purposes, and the second is a logistic model of population growth to more realistically estimate maximum annual sustainable loss. The results will quantify sustainable loss of the YFP population for the first time and can be compared to each other as a comparative analysis of these two methods, and the results of both sustainable l methods will also be compared to actual rates of observed YFP decline. Both analyses will also provide a benchmark against which levels of interview reported YFP mortality can be compared. These analyses can also be used to assess the level to which known reported causes of mortality may or may not have driven YFP population decline.

2.3.1.1 PBR from 2006 and 2012 population estimates

PBR values were calculated for the 2006 and 2012 YFP population estimates using the following standard formula by Wade (1998):

[3] $$PBR = N_{min}\ 0.5\, R_{max}\ F_r \text{ , where}$$

N_{min} is a lower estimate of the population size (the 20th percentile of the population size estimate, see formula [4] below), R_{max} is the maximum annual population growth rate and F_r is a recovery factor set between 0.1 and 0.5. The default recovery factor for threatened species is typically set to 0.1 (Wade & Angliss, 1997). A generic R_{max} for cetaceans is typically 0.04 (Wade 1998), and has been estimated at 0.04 for the Indo-Pacific finless porpoise (*Neophocaena phocaenoides*, Taylor *et al.* 2007). Based on observations of the captive Tian-e-zhou YFP reserve population, R_{max} has recently been estimated to be 0.0353 for the YFP (Huang *et al.*, 2017). However, as this is an estimate using a singular maintained reserve population and not observations based on truly “wild” populations, separate calculations have been completed using both values for comparison.

For formula [3], N_{min} is calculated as follows:

[4] $$N_{min} = O_{abs}\ \exp\Big[Z\sqrt{\log\left(1 + CV_{abs}^2\right)}\ \Big] \text{ , where}$$

O_{abs} is a survey estimate of absolute abundance, Z is a standard normal deviate (this is a fixed expression within mathematics, which at the 20th percentile is 0.842 as per Wade, 1998), and CV_{abs} is the coefficient of variation from the population estimate (this is the standardised way of expressing relative standard deviation in the population estimate). In this case, the mean CV value for the 2006 survey population estimate was used, estimated as 0.1326 from the 2006 survey (value taken directly from Zhao *et al.*, 2008) and 0.1586 for the 2012 survey (value taken directly from Mei *et al.*, 2014).

PBR was therefore calculated for a range of given populations and parameters: firstly for the 2006 and 2012 population estimates, secondly using both the generic and YPF-specific R_{max}, and thirdly based solely on the mainstem population or the total range-wide populations. For each calculation, the N_{min} value was calculated for the respective population estimate.

2.3.1.2 Estimating sustainable loss using a density dependant population model

Density dependent population growth is typically estimated using the generalised logistic equation (Pella & Tomlinson, 1969; Gilpin & Case, 1976), a method commonly applied to predict changes in cetacean populations over time (e.g. Williams, Hall and Winship, 2008). This is a modified version of the Ricker equation discussed in section 2.2.2.1.

The size of a population in any given year is estimated by taking the population estimate in the previous year, N_t, and multiplying by a factor relating to the natural intrinsic rate of population increase under standard conditions. This factor considers the limitations imposed by the carrying capacity, K, and uses the same R_{max} value as in the PBR analysis (see formula [3]). The population of the subsequent year N_{t+1}, and subsequent years is calculated as follows:

[5] $$N_{t+1} = N_t \left[1 + R_{max}\left(1 - \frac{N_t}{K}\right)\right] - C_t$$, where

N is the population estimate in any given year, t is the year, R_{max} is the maximum annual population growth rate (default 0.04 for cetaceans, or 0.0353 for YFP), K is the population size at carrying capacity, and C_t is loss in year t.

Annual additions (A) to the population (without loss) can therefore be expressed as:

[6] $$A = \frac{R_{max}\ N}{K}\ (K - N)$$

As with the PBR calculation, as the YFP R_{max} is an estimate using a singular maintained reserve population and not observations based on truly “wild” populations, separate models have been constructed here using both the generic and YFP-specific R_{max} values for comparison.

Carrying capacity of YFP in the modern Yangtze ecosystem has never been calculated. The first systematic survey regime began in the late 1980s, when decline had likely already started due to industrialisation and habitat loss. The methods covered in section 2.2.4.1 (spacing distances, prey density, home range) cannot be calculated accurately for YFP due to insufficient data. Instead, here the largest known population of YFP has been used in place of estimated *K* values. The earliest population estimate was 2702 individuals over the full range of the YFP, with 2546 in the mainstem, 104 in Dongting Lake, and 52 in Poyang Lake (Zhang *et al.*, 1993). However, the estimates of the two lake systems are thought to be too low due to poor sampling in these habitats (Mei *et al.*, 2014). To counter this likely bias, the highest ever recorded populations for the lake systems have been used as a minimum estimate of carrying capacity; this equates to 450 in Poyang Lake (Mei *et al.*, 2014) and 150 in Dongting Lake (Zhao *et al.*, 2008). Totalled, the maximum populations recorded in each of the three systems equates to 3146 as a minimum number for carrying capacity for the Yangtze River. With the minimal data available, this is the best option for estimating *K* for YFP.

By using these values, the YFP population was modelled using formula [5] within an Ordinary Differential Equation (ODE) framework within R v3.4.3 (R Core Team, 2017) using the package DeSolve (Soetaert, Petzoldt & Setzer, 2010) for the years 2006 to 2012. The YFP population estimate for the full YFP range in 2006 was 1800 individuals (Zhao *et al.*, 2008), which reduced to 1040 individuals by 2012 (Mei *et al.*, 2014). The model was re-run with different starting and carrying capacity parameters as below:

1) YFP range - Yangtze River including Poyang Lake and Dongting Lake using
    a. population, *N,* in 2006 = 1800 as per Zhao et al. (2008), and
    b. carrying capacity, *K* = 3146.
2) Yangtze mainstem only (not including lake systems) using
    a. population, *N,* in 2006 = 1225, and
    b. carrying capacity, *K* = 2546 as per Zhang *et al.* (1993).
3) Models (1) and (2) run to estimate maximum sustainable loss rate, C_t, to maintain 2006 and 2012 population estimates.
4) Models (1) and (2) run to estimate likely actual loss rates, C_t, to explain observed decline between 2006 and 2012 population estimates (1800 individuals reducing to 1040 individuals by 2012).

The mainstem-only model (model 2 above) was also run to make the loss estimations comparable to the mainstem-only interview data from 2008. As we are not intending to predict sensitive future population scenarios, sensitivity analysis for parameters used in the logistic population model was not conducted here. The values calculated in these analyses are estimates and guidelines of likely sustainable and actual loss based on best estimates of the parameters of this logistic equation for YFP.

2.3.1.3 Estimating observed minimum YFP mortality rates

Theoretical loss limits from the two methods calculated here (PBR and logistic growth model) were compared to reported mortalities from fisher interviews conducted in 2008. This has allowed comparison between estimated loss and observed loss from some known causes of mortality, and some inferences to be made relating to disparity between the two estimates. The interview survey was conducted in the Yangtze mainstem only, and so did not include the two lake systems of Dongting and Poyang. Only data on reported mortalities recalled for the year immediately prior to the interviews (2007) was used to minimise recall bias and maximise quality of the data, representing the best estimate of minimum annual loss rate.

2.3.2 Can we associate key threats with increased YFP mortality?

Data are available from two interview surveys conducted in 2008 and 2011/2012 across certain parts of the YFP range. These data contain information relating to YFP deaths in the form of observed mortalities from fishers. In addition, these data contain spatially explicit information on the types of fishing gear used across the surveys target areas. Other data are also available that are relevant; in addition to noting all observations of YFP, the 2006 YFDE survey recorded the number of fishing vessels and the number of large cargo vessels along the survey route. The fishing gear data from the interview surveys and the vessel observations from the 2006 YFDE survey represent indices of two potential threats to the YFP, and observations of dead YFP by fishers collected in the interview surveys represent an index of mortality.

We therefore conducted two analyses aimed at investigating whether it is possible to detect correlations between the distribution of YFP deaths and variation in these two potential threats for which data are available.

2.3.2.1 Correlating threats and mortality: Yangtze wide 2008 data

An extensive interview survey conducted in 2008 quantified fishing practices in 24 locations (ranging from city level to much smaller fishing villages and communities) across the middle-lower Yangtze from Yichang to Shanghai, comprising 499 interviews with current (i.e. not retired) fishers (Turvey *et al.*, 2013). To ensure the data were representative of the wider Yangtze fishing communities in the 2008 survey, a sample of 30 fisher interviews was conducted per locality. Within each community, fishers were targeted using either key locations such as known fishing villages and ports, or through identification of a local informants to assist targeting interviews to known fisher communities. Unpublished data from this survey has been provided by Dr Samuel Turvey, for the purposes of further analysis presented here. This data set includes questions relating to both YFP mortality and the presence of threats, which have been investigated here in a predictive GLM framework.

To investigate possible links between the spatial distribution of different potential threats and reported levels of porpoise mortality on a relatively coarse Yangtze-wide scale, data from this survey were assigned to 17 river sections (Table 2.2). This 17-bin data grouping design matches the analysis presented in Turvey *et al.* (2010a) and Turvey *et al.* (2013), where other data from the same interview survey were similarly grouped to ensure each section contained sufficient interviews to be statistically viable and an even coverage based on an uneven underlying distribution of communities. Interview data gathered in any location were assigned to these 17 sections using 100km distance bins starting at Yichang, with each section containing from between one to three towns/cities where interviews were conducted in 2008 (Figure 2.1). The mean number of interviews per section was 29.9± 10.6 with a range of 9 (section 6, Jinkou) to 54 (section 9, Wuxue and Hukou Table 2.2).

The furthest downstream section, section 17 (Chongming), was not included in the final analysis, as the interviews here included reports likely also relating to the marine finless porpoise (*Neophocaena asiaeorientalis sunameri*) and marine-type fishing gear, which is not relevant to the YFP. Hukou is at the entrance of Poyang Lake, but is within section 9 so was included in that bin. For each of the 16 100km units, two parameters can be calculated; firstly, the proportion of each main type of fishing gear used, and secondly a count of observed YFP mortalities reported by fishers. Due to reasons mentioned previously, this represents a minimum estimate of porpoise mortality.

Table 2.2: Interview locations and sample sizes from 2008 interview survey by Dr Samuel Turvey *et al*.

Section Number	*Towns included in section*	*KM from Yichang*	*Number of Interviews Conducted*
1	Yichang	0 - 99	31
2	Longzhou and Jianglin	100 – 199	32
3	Xinchang and Shishou	200 – 299	31
4	Jianli	300 – 399	18
5	Honghu and jiayu	400 – 499	47
6	Jinkou	500 – 599	9
7	Wuhan	600 - 699	30
8	Ezhou, Huangshi and Qizhou	700 – 799	31
9	Wuxue and Hukou	800 – 899	50
10	Pengze	900 – 999	15
11	Anqing	1000 – 1099	35
12	Tongling	1100 – 1199	34
13	Wuhu	1200 – 1299	21
14	Nanjing	1300 – 1399	37
15	Zhenjiang	1400 – 1499	28
16	Jiangyin and Nantong	1500 – 1599	30
17	Chongming *(not included)*	1600 - 1699	*NA*
		Total	*479*

In addition, data from the 2006 YFDE have also been grouped into each distance bin; the survey recorded (1) the number of live sightings of YFP (2) the number of cargo vessels and (3) the number of fishing vessels as a proxy for the intensity of fishing-based activity. This grouping technique matches the way data were grouped spatially in Turvey *et al.* (2013), and allows direct comparison with the previously mentioned interview data. This provides an index for the two types of vessels as an overall proxy for potential threat. The inclusion of the live sighting data from the YFDE allows further investigation of the relationship between YFP distribution and mortalities; for example, if there is no evidence of a positive association between live YFP and observed YFP mortalities, this could indicate that the observed mortalities are causing a localised population decline.

There are a large number of fishing types within the Yangtze (detailed in Chapter 5) but they can be grouped by functionality. Given that certain types of gear are more (e.g. rolling hook Zhou & Wang, 1994; Turvey *et al.*, 2013) or less likely to cause direct mortality, fishing gear was separated into similar functional categories based on type as follows:

1) All large net-type fishing gear, including gill, drag and free-floating nets
2) Fixed fishing gear, including fyke nets and maze type fixed nets e.g. mihunzhen
3) Electric type fishing gear
4) Hook-type fishing gear (e.g. gungou, tiegou)
5) Traps and pots (not used in this analysis; never been reported to cause mortality)

Very few fishers admitted to using electric fishing gear as it is illegal, and so the interview data are prone to bias by omission. Instead of direct admission of use data, an indirect metric of electric fishing gear use was used. As part of the 2008 interview, fishers were also asked whether they thought electric fishing gear use was an issue in their local area. The proportion of respondents that gave a positive response was used instead as a metric of electric gear use. For all other fishing-based metrics, the proportion of respondents that use a type of each fishing gear was used. In addition to the individual gear types, fishing vessels was included as a separate metric for overall fishing threat. As this was direct observational data from the YFDE survey, it accounts for any possible disparities that may have arisen in the interview data, which can be subject to bias if interviewees do not fully disclose their fishing activities.

After testing for spatial autocorrelation (see section 2.3.2.3), possible relationships between these parameters were investigated using a generalised linear model (GLM) framework within R v3.4.3 (R Core Team, 2017). A GLM is a flexible generalisation of ordinary linear regression that allows for response variables that have error distribution models other than a normal distribution. The GLM fits a linear regression to the data and uses predictor variables to predict an outcome; in this case, it is using the threat data mentioned above (predictor variables) to predict areas of higher or lower observed YFP deaths in any section (response variable).

The basic GLM structure was therefore as follows:

$$[7]\ glm\ (YFPdeaths \sim fixed + hook + net + electric + fishing.vessels + cargo.vessels + live.sightings)$$

In the original survey, fishers were asked if they had seen a dead YFP within the last 12 months. These data were used as the response variable in the form of proportional data, in which observation of a dead porpoise in the 12-month period before the interview survey constitutes a “success” and no observation as a “failure”. These proportional data therefore allowed the data to be analysed within a binomial GLM framework.

The variables of fishing vessels and cargo vessels had relatively much larger values and were larger in range than all other parameters. To account for this issue, these two variables were individually rescaled within R v3.4.3 (R Core Team, 2017) so that they have a mean of 0 and a standard deviation of 1. This is standard practice used to limit the large variation within individual data sets that may mask the underlying pattern when compared to other parameters.

Inspection of the residuals from the binomial GLM indicated over-dispersion of the data (residual variance of 214.982 on 15 degrees of freedom). To control for over-dispersion, the data were subsequently fitted in a beta-binomial framework. Nested averages were used to derive model average coefficients for both models. The resulting models were ranked by AIC and the nesting rule was applied to obtain a final model set.

As this data set is small, the data were also fitted into a logit gaussian model (Cramer, 2003) to check the robustness and directionality of the significant predictor variables observed in the beta-binomial model. Using both a beta-binomial and a logit gaussian framework allowed comparison of results to ensure the model outputs and were robust conclusions accurate. The overall results were largely insensitive to model choice and similar conclusions were derived from both, showing both models are likely to be representative of reality.

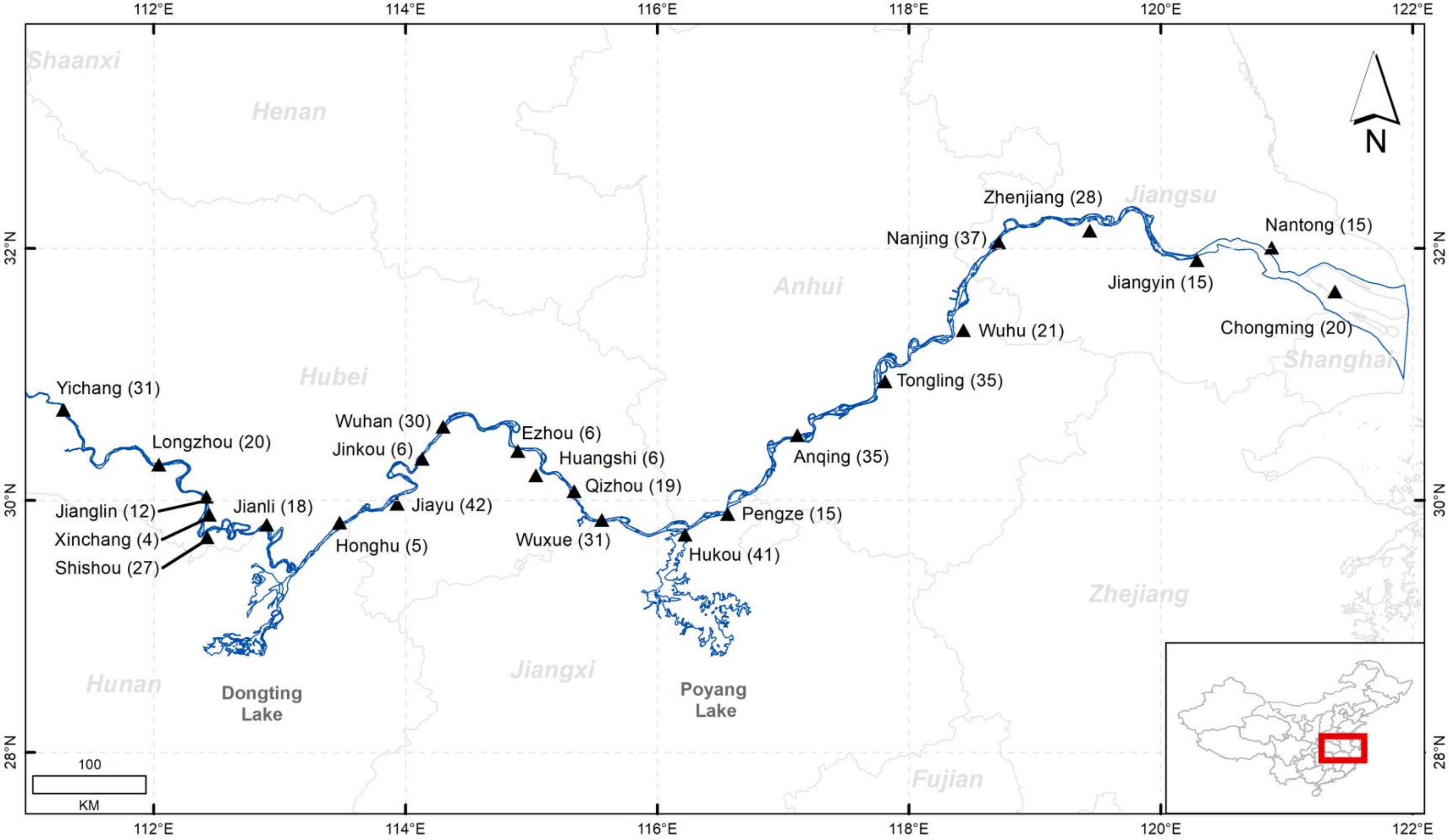


Figure 2.1: Interview locations targeted during the 2008 survey from Yichang (west) to the river mouth at Shanghai (east). Numbers in brackets provide number of interviews conducted in each location in the survey. Map made in ArcMap (ESRI, 2014).

2.3.2.2 Correlating threats and YFP mortality: “hotspot” 2011/2012 data

The 2011/2012 interview survey was conducted on 15-23 November 2011 and 23 March – 20 April 2012 (Table 2.3. Figure 2.2). Only the middle section of the river channel was included in the 2011/2012 survey based on the distribution of apparent YFP hotspots identified by Zhao *et al.* (2013). Interviews were conducted in all Poyang Lake counties within the distribution of the lake’s YFP population and in all riverside counties of the Yangtze mainstem from Huanggang to Dongzhi (Figure 2.2) (a “county” is more synonymous to “municipality” than to the western concept of this administrative term). These data represent a finer scale investigation of the habits and observations of fishers than the 2008 Yangtze-wide interview survey (counties in this region are approximately 15 to 30 km apart). For this reason, a similar investigation to the GLM analysis discussed in the previous section has been conducted for this data set, allowing further investigation into the predictors of YFP mortality in the Yangtze system on a much finer scale resolution than the previous GLM, and also incorporating data from Poyang Lake.

The mean number of interviews completed per section was 21.4 ± 15.3 (range = 6 to 59). To ensure the data were representative of the wider Yangtze fishing communities in this 2011/12 survey, proportional stratified random sampling of interviewees per county was used. In order to achieve this sampling strategy, the number of licenced fishing families in each city was obtained by informally interviewing fisheries officials at city and county level prior to starting the survey (Turvey *et al.*, 2013). From these values, the survey aimed to target ~10% of the known fishing community per locality. Localities where <5 interviewees were required based on this proportional sampling strategy were excluded due to low data reward for the logistical and resource input required to get to the location. Within each community, fishers were targeted using either key locations such as known fishing villages and ports, or through identification of a local informant to assist targeting interviews to known fisher communities. Full information about the interview surveys is detailed in Turvey, Hao & Ding (2012).

As the 2011/12 survey did not cover the same area as the 2008 interview survey, the data cannot be analysed in the same 100km section groupings; data are instead grouped and summarised by county. Data for live YFP sightings, fishing vessels and cargo ships are only available for 100km section bins in the Yangtze mainstem, and are unavailable for Poyang Lake. Available predictor variables used here are therefore only fishing gear related; the interview data were grouped by the same four categories of fishing gear as for 2008 (fixed type gears: “fixed”, hook-based equipment: “hook”, large net-based equipment: “net”, and electric based equipment: “electric”, see section 2.3.2.1).

Table 2.3: Interview locations, quantity and number of reported YFP mortalities from 2011/12 interview survey

County	*Number of Interviews Conducted*
Poyang Lake	
Hukou (PL)	8
Xingzi	21
Yongxiu	32
Duchang	39
Yugan	42
Poyang	59
Yangtze Mainstem	
Huangshi	6
Yangxin	26
Huanggang	8
Xishui	19
Qichun	19
Huangmei	9
Jiujiang	6
Lushan	7
Hukou (MS)	24
Susong	9
Wangjiang	12
Anqing	43
Dongzhi	17
Total 19	*406*

Note: Hukou interviews were divided into interviewees that fished in Poyang Lake (PL) or the Yangtze mainstem (MS) and were analysed separately.

Hukou county is located at the mouth of Poyang Lake where it is met by the Yangtze River flowing eastward. The fishers in Hukou tend to either fish in the Yangtze mainstem or in Poyang Lake. For this reason, two Hukou categories were used; the first for those fishers that reported fishing in Poyang Lake, and the second for those that reported fishing around Hukou and on the Yangtze River (fishers reported that they fish exclusively in only one of these two areas).

As direct reported counts for electric fishing were again too low to use, levels of electrofishing were estimated using data from the question “What proportion of this village practices electrofishing?”. A series of standard rules were applied to convert responses into usable data. If the answer was “above 50%”, the Excel “randbetween” function was used to randomly select a number between 50 and 100. The same method was applied to responses such as 1-3%, between 10 and 30%, etc. Responses such as “almost none” were interpreted as 0%, as no number can be reliably deduced from this response. Other responses that were not interpretable as a reliable number (“Don’t know, but many”) were not included. If the answer was “Don’t know”, the interviewees response was not included. The percentages were summarised as an average percentage for each county and included in the final GLM analysis as a predictor variable.

Patterns of YFP mortality and fishing gear type were again investigated using a GLM framework in R. The GLM structure was therefore as follows:

[8] $$glm(deaths \sim fixed + hook + net + electric)$$

As with the 2008 analysis, the data were analysed within a binomial GLM framework, with one representing a “success” in having seen a dead YFP within the 12 months period immediately before the survey, and a zero representing a “failure” of not having seen a dead YFP in that period. Within a standard binomial framework, the model was over-dispersed (residuals 52.875 on 18 degrees of freedom), which was not successfully corrected for by using a quasibinomial model. To account for this, a logit gaussian model was instead fitted, which successfully fitted the data. This model uses a logit transformation on the proportion of interviewees that had seen a dead YFP in the last 12 months as a response variable. The most parsimonious model was selected from the models included within **Δ**6 set from **Δ**AICc.

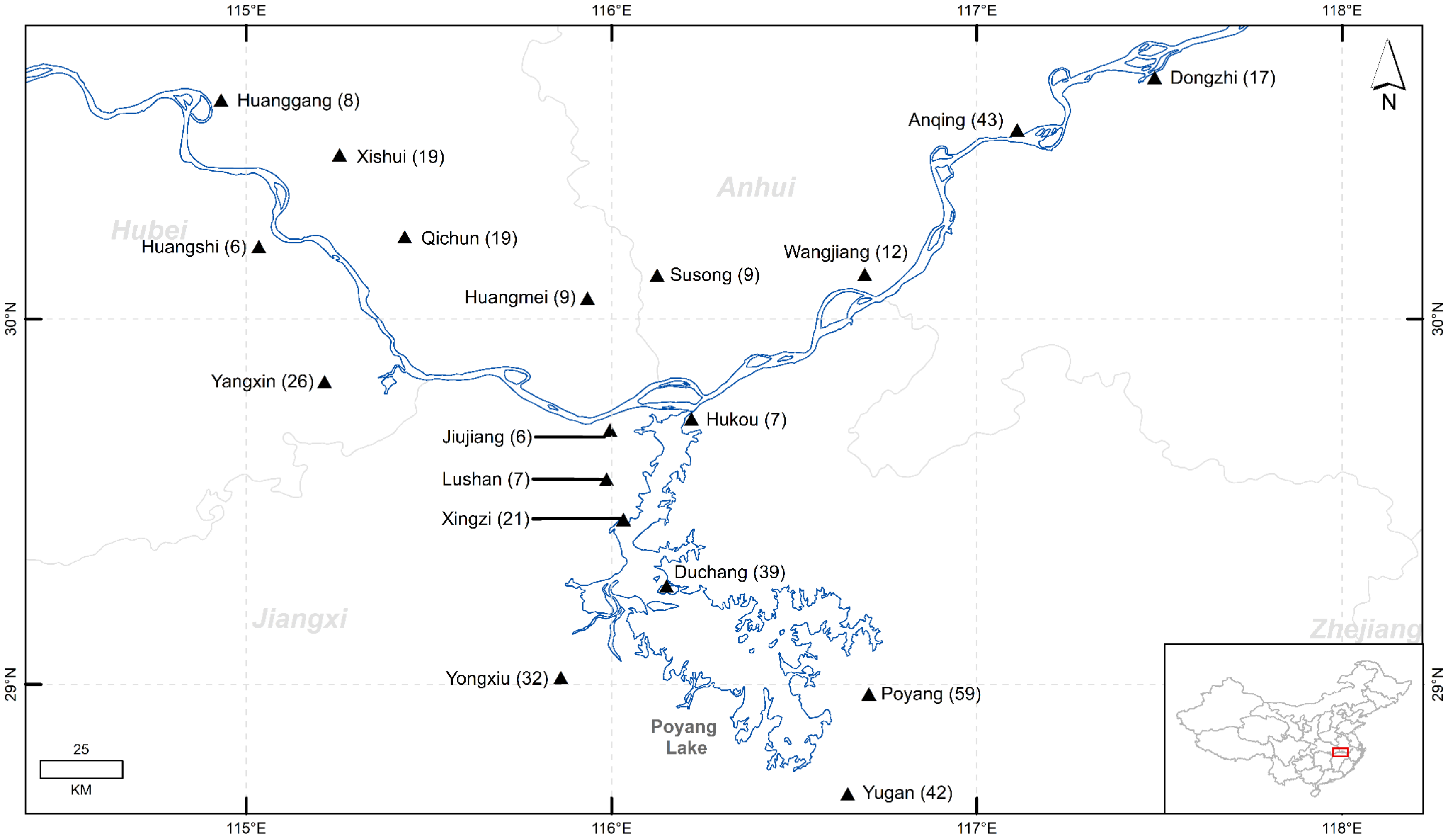


Figure 2.2: Number of fisher interviews in counties around Poyang Lake and the central Yangtze River region interview in 2011/12 survey. Map made in ArcMap (ESRI, 2014).

2.3.2.3 Testing for spatial autocorrelation (2008 and 2011/2012 data)

Before fitting any of the models, both the 2008 and the 2011/12 data had to be tested for spatial autocorrelation. To test for spatial autocorrelation in the 2008 interview data, the data were first tested using a Moran's I test within the "Ape" package (Paradis *et al.,* 2004) in R. To test the data on a spatially explicit basis, coordinates were taken for the mid-point of each of the 16 100km sections of river that were used in the analysis. The results indicated that some spatial autocorrelation may be present in two of the 2008 data parameters: number of cargo vessels (p=0.0008) and live YFP sightings (p=0.0006). To further investigate the presence of spatial autocorrelation and to test if the autocorrelation detected would affect the GLM analysis outcome, a generalised least squares (GLS) correction was applied to three of the predictors used in the final GLM: live YFP sightings, number of cargo vessels, and number of fishing vessels (this predictor was statistically significant, and so was also included for verification that no spatial autocorrelation was present). Three methods of controlling for spatial autocorrelation were used: gaussian, exponential and spherical. The best fit from AIC was spherical structure but there was very little difference between the three methods. The GLS results indicated very little influence of spatial autocorrelation on the outcome of a naïve gaussian model, and so the influence of spatial autocorrelation on the final models was discounted. Bubble plots for the residuals before and after spatial autocorrelation can be found in Appendix A.

To test for spatial autocorrelation in these 2011/2012 data, coordinates were taken at a central point in the Yangtze River or Poyang Lake adjacent to the corresponding interview location in a similar manner to the 2008 data (Figure 2.2). Using these coordinates, each parameter was then tested for spatial autocorrelation using Moran's I test within the Ape package in R v3.4.3 (R Core Team, 2017) as with the 2008 data. Spatial autocorrelation was not detected in any of the parameters included in the 2011/2012 analysis.

2.3.3 Investigating patterns in the overlap of fishing activity and YFP presence across the river

We complemented the two along-river analyses described above by additionally investigating the spatial patterns of threat and YFP distribution and overlap over an across-river transect. This analysis used survey data from the 2006 YFDE and fishing information from the 2011/12 interview survey conducted by Turvey *et al.* (2013) (full survey details provided in 2.3.2.2). Individual observations of YFP from the 2006 YFDE grouped by distance from river bank are available in Zhao *et al.* (2008), who categorised distance from bank into four distance bins; near-bank: 0-149m, near-bank:150-299m, near-bank: 300-500, and mid-channel: >500m (Figure 2.3). These authors additionally categorised their observational counts into three along-river distance bins by distance downstream from Yichang into upper (Yichang – Ezhou), middle (Ezhou – Huayang), and lower (Huayang – Shanghai) sections (Table 2.4). Our comparative interview data for the 2011/12 interview survey only covered the latter two categories, so YFP observation data from the middle and lower sections only were pooled for this analysis (Table 2.4).

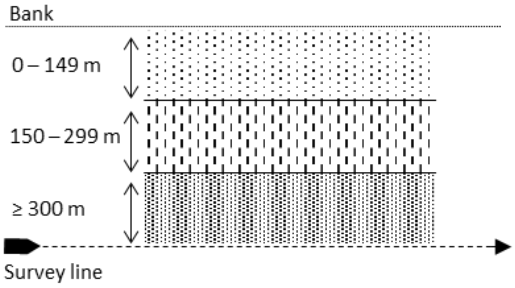


Figure 2.3: Stratification method for categorising distance from the bank,. Image adapated from Zhao *et al.* (2008)

Table 2.4: Number of porpoises observed in the middle and lower section of the Yangtze in the 2006 YFDE after correction with a detection function. Taken from Zhao *et al.* (2008).

Distance from bank **(As** *in* **Figure 2.3)**	*River section*		*Total*
	Middle (Ezhou – Huayang)	*Lower (Huayang – Shanghai)*	
Mid-channel (>500m)	146	631	*777*
Near bank (300-500m)	98	125	*223*
Near bank (150-299m)	46	40	*86*
Near bank (0-149m)	3	2	*5*
Total	*293*	*798*	*1091*

To investigate possible overlap of YFP habitat use and fishing activity across the width of the river, these survey-based YFP observational data were compared to information about the onshore-offshore location of fishing gear use from the 2011/12 fisher interview data collected by Turvey *et al.* (2013). Fishers were asked the distance from the bank that they set the gear types that they reported using. These count data were categorised into the same four distance bins from the river bank as the available YFP observational count data (Table 2.4) to allow direct comparison within a chi-squared goodness of fit framework.

If an interviewee noted that they use a type of fishing gear across the full bathymetric range of the river, it was included in all four distance bins. If distance was specified, e.g. 100-300m, it was included individually for each of the categories that the given range covered. These data were categorised into two key types: net type gear including all gill and free-floating nets; and hook type gear. Reports of other gear types that are known to cause porpoise mortality (electrofishing, fixed nets) were not numerous enough to be included in analysis.

Chi-squared goodness of fit tests were used to test for homogeneity across the four distance bins for the three parameters: hook type gear, free-floating net type gear, and YFP.

2.3.4 Is YFP reproduction stable and uniform across the Yangtze River?

If reproduction is stable within a population, relatively similar calf proportions would be expected in any survey year. In the absence of robust threat-based data (e.g. relating pollution directly to reproductive issues), proportional calf data can be used as a proxy measure of fecundity in a population. The analyses presented here investigate three related parameters: firstly, the current proportion of calves within the YFP population is quantified; secondly, longitudinal variation in the observed proportion of calves over time is investigated; and lastly, variation in the observed proportion of calves spatially across the Yangtze River is investigated.

2.3.4.1 Is YFP reproduction stable over time?

To quantify the proportion of YFP calves in the overall population and to investigate whether reproduction of the remaining YFP population is stable across space and time, we statistically compared previously unpublished high-resolution spatial data for YFP calves (IHB, China, pers. comm.) with available data on the distribution and total number of adult YFPs (published survey data, Zhao *et al.*, 2008; Mei *et al.*, 2014). Numbers of calves and adults observed within groups was recorded during the 2006 YFDE (full methods and some results published in Zhao *et al.*, 2008) and the 2012 YFDE (full methods and some results published in Mei *et al.*, 2014), with exact locations of all YFP observations recorded using a GPS. These data were collected using the same method for both surveys, and the same classification of "calf" compared to an adult YFP. The identification of a calf relative to an adult is clear from the distinct difference in size, which can be assessed even at a distance through binoculars. There was no specific size limit to what constituted a calf or an adult within these two surveys, but the methodology was uniform within and between the two surveys so the data are comparable.

In the 2006 YFDE, 438 YFP individuals in total were sighted by two separate vessels, Kekao and Honghu (Zhao *et al.*, 2008), of which 90 were classed as calves. In the 2012 YFDE, a total of 341 individuals were seen by two separate survey vessels (Mei *et al.*, 2014), of which 23 were classified as calves (IHB, China, pers. comm.). If levels of successful reproduction in the YFP population were similar in both years, we would expect no statistical difference in the ratio of calves to adults observed. Relative numbers of calves to adults between both years were compared using chi-squared goodness-of-fit tests.

2.3.4.2 Is YFP reproduction uniform along the river?

It is possible that threatening processes that affect reproduction (e.g. pollution, prey restriction) or calf survival to adulthood vary spatially along the Yangtze River, which could affect the relative proportion of calves present along the river. To investigate the presence of such patterns, the same calf data were analysed on a Yangtze-wide scale within each census year of 2006 and 2012.

Uniformity of calf distribution along the Yangtze River was assessed within a chi-squared goodness of fit framework for the three river sections previously defined in Zhao *et al.* (2008) (upper, middle, lower). As the three river sections are not even in length, they do not represent equal proportions of the river and we would not expect them to contain equal numbers of calves and adults in each. However, we would still expect the ratios of observed calves to observed adults to be relatively similar in each section were reproduction to be uniform along the river.

We again used unpublished calf data provided from all observations from both survey boats in both survey years of 2006 and 2012, with analysis for 2006 and 2012 conducted separately. The total observed YFP count in each survey was 438 individuals and 341 individuals in 2006 and 2012, respectively (Zhao *et al.*, 2008; Mei *et al.*, 2014). However, the total numbers observed within each of the 3 river sections only constitute optimal observations (those that were within the Effective Strip Width, ESW, within on-effort, optimal weather conditions only) in Table 2 of the respective published papers, equating to 242 and 118 individuals. To allow analysis of comparisons of calves to total YFP counts for each of the three sections, published total counts for each section (total 242 and 118) were scaled up to the original total counts (total 438 and 341) by using the proportion reported in each section (Table 2.5). This assumes that the selected observations were chosen in a manner evenly across the three sections; unfortunately, the original data (to compare point for point) are not available to determine whether or not this is the case.

Table 2.5: Observed numbers of adults and calves in 3 sections of the Yangtze River on the 2006 and 2012 YFDE

Survey Year / *River section*	*2006*			*2012*		
	Section count from Zhao (2008)	*Scaled to total count*	*Calf count*	*Section count from Mei (2014)*	*Scaled to total count*	*Calf count*
Upper	21	38.00	10	11	41.22	3
Middle	121	219.00	47	47	176.12	7
Lower	100	180.99	33	60	123.66	13
TOTAL	***242***	***438***	***90***	***118***	***341***	***23***

Calf counts for each section were tallied by plotting each observation within ArcGIS v10.3.1 (ESRI, 2014) and visually dividing the river into the upper, middle and lower sections using the previously published geographical divisions for river sections.

By calculating an overall ratio of caves to adults in the whole river, this ratio can then be compared between each of the three sections to investigate uniformity of calf distribution relative to adults across the river. Underlying patterns of non-uniformity in calf proportion could indicate that YFP are reproducing more or less in certain areas, or that there is non-uniform survival of calves between different sections of the river. These patterns could indicate underlying variation in the presence or effect of some threat processes that can affecting YFP reproduction, such as reproductive issues caused by pollution.

Expected calf count for each section was calculated as follows:

[9] $$E_{i,J} = \left(\frac{C_J}{T_J}\right) x \ \mathrm{T}_{i,J}$$, where

C denotes total calf count, T denotes total count, *i* denotes river section (upper, middle, lower), *J* denotes year of survey (2006 or 2012), and *E* is expected calf count (i.e. if 10 individuals were observed in the middle section in 2006, *E* calves would be expected to be present under uniformity). Values of *E* for the three sections were compared to counts of observed porpoises from both surveys using a chi-squared goodness of fit framework within R.

The 2006 survey data contains some YFP observational survey data from north Poyang Lake, an area the 2012 survey did not include. These data were included in the “middle” section for the 2006 analysis, as this is the section that the data from this region were included in in Zhao *et al.* (2008).

2.4 Results

2.4.1 Is YFP mortality sustainable, and does current data explain current level of anthropogenic mortality?

2.4.1.1 PBR for the YFP

Using the standard PBR framework, in either census year (2006 and 2012) with any given parameters, maximum sustainable loss from the total population is never higher than 3.35 individuals annually (Table 2.6). As would be expected, as the population declined between 2006 and 2012, the maximum sustainable loss also reduced to almost half of the original 2006 value using either of the R_{max} values. Sustainable levels of loss are always lower when the YFP-specific R_{max} value is used.

Table 2.6: Annual PBR values calculated for 2006 and 2012 YFP population estimates, giving values when using both the cetacean generic and the YFP specific R_{max}. Values are annual loss rates based on formula [3] and [4].

R_{max} value	*2006 population estimate*		*2012 population estimate*	
	Mainstem only (N_{min} = 1138.47)	*Total population (N_{min} = 1672.85)*	*Mainstem only (N_{min} = 462.71)*	*Total population (N_{min} = 952.91)*
Generic: 0.04	2.28	3.35	0.93	1.91
*YFP: 0.0352	2.00	2.94	0.81	1.68

*calculated in Huang *et al.* (2017)

2.4.1.2 Density dependent population model

Using the same parameters, the logistic model estimated much higher sustainable loss values; all quotas are higher by an order of nearly 10 for each of the categories (mainstem or total population, generic R_{max} or YFP-specific R_{max}). For example, PBR predicts sustainable loss to be 3.35 individuals per annum for the total 2006 population (R_{max} = 0.04, Table 2.6), whereas the logistic model predicts sustainable loss to be 30 individuals per annum (Table 2.7). For the YFP population to fall from the 2006 to the 2012 estimate over this six-year period, the model predicts annual loss to be at least 140 in any given scenario (Table 2.7).

Table 2.7: Estimated annual loss from mainstem and total YFP populations to maintain stable 2006 population numbers (max. sustainable loss) or to result in actual 2012 population numbers (predicted actual loss). Calculated using formula [5].

R_{max}	*Estimated annual loss (2006 – 2012)*	*Mainstem only population (2006=1225, 2012=505)*	*Total population (2006=1800, 2012=1040)*
Generic R_{max}	Max. sustainable loss	25	30
	Predicted actual loss	142 - 143	157 - 158
YFP R_{max}	Max. sustainable loss	22	27
	Predicted actual loss	140 - 141	153 - 154

Note: Maximum sustainable loss = maximum individuals removed to maintain 2006 population until 2012. Predicted actual loss = estimated actual loss from the population for 2006 population to decrease to 2012 population. For predicted actual loss, two values are given as the exact 2012 population estimate falls between the products of these two values.

From the 2008 interview survey data conducted by Turvey *et al.*, 30 observed YFP mortalities were reported for the Yangtze mainstem in 2007, six of which were attributed to fishing based trauma and seven of which were attributed to boat collisions. The remaining 17 had no reported visible trauma or obvious external cause of death. If we input this loss rate into the logistic equation for 2006, the model predicts a decline, but this decline is not severe enough to reach the mainstem population estimate of 505 individuals observed in the 2012 survey (Table 2.8). This indicates that the interview data only account for around 21-21.5% of actual annual mortality of the mainstem population.

Table 2.8: Estimated annual loss rate for the mainstem YFP population for 2006 and 2012. Calculated using formula [5].

Rate of loss	*R_{max} value*	*2006 population estimate*	*Annual loss rate (n/year)*	*Projected 2012 population estimate*
No loss	Generic: 0.04	1225	0	1377.6
	*YFP: 0.0352	1225	0	1359.3
Estimated max. sustainable loss	Generic: 0.04	1225	25	1227.6
	*YFP: 0.0352	1225	24	1227.3
Observed loss (30, from 2008 interview data)	Generic: 0.04	1225	30	1197.4
	*YFP: 0.0352	1225	30	1179.0
Predicted actual loss (to reach 505 in 2012)	Generic: 0.04	1225	143/142†	504.7 / 510.9†
	*YFP: 0.0352	1225	141/140†	500.0 / 507.0†

*calculated in Huang *et al.* (2017)

† two values are shown as the final population estimate is reached in between the two loss rates

2.4.2 Can we associate key threats with increased YFP mortality?

2.4.2.1 Predicting YFP mortality reports with threats: 2008 along-river analysis

The 2008 along-river analysis investigating potential threat parameters indicates that cargo vessels and live YFP sightings in the YFDE are positive predictors of having observed a YFP mortality in the previous 12 months based on the best-fit beta-binomial models (Table 2.9). In addition, fishing vessels were included in the Δ6 beta-binomial set, but the model averaged estimates for the comparative logit gaussian model disputes the validity of fishing vessels as a predictor of YFP mortality (Table 2.10). The beta-binomial model average estimates also indicate a positive association of both live YFP sightings and cargo vessels with the probability of having observed a dead YFP (Table 2.10). In addition, fishing vessels were included in the final model set as a negative predictor. In comparison, logit-gaussian model average estimates also show the same two predictors as having a positive effect, but the predictor of fishing vessels was also included as a positive predictor rather than negative. However, the confidence interval (CI) limits for fishing vessels as a predictor crossed 0 (-1.396 – 0.010, Table 2.10) meaning that an effect size of 0 is also possible within this model. These two models therefore offer conflicting support for fishing vessels as both a positive and negative predictor of YFP mortality. As 0 is included in the CI range and there is variation in sign between the two models, the potential influence of fishing vessels as a predictor of YFP mortality is unclear. CI for live YFP sightings also crossed 0 for the logit gaussian model, but only by 0.001 (Table 2.10). This parameter is a positive predictor in both models. The null model was included in the **Δ**6 set of best models for the beta binomial and logit gaussian final models. The **Δ**6 set is shown in Table 2.9 for reference.

Table 2.9: Beta-binomial model selection based on the Akaike Information Criterion corrected for small sample sizes (AICc), showing **Δ**6 set. Response variable is the proportion of interviewed fishers that had seen a dead YFP in the last 12 months. Results shown are Akaike Information Criterion corrected for small sample sizes (AICc), AICc scores (**Δ**AICc) and Akaike's weight (**ωi**) and the number of parameters for each candidate model.

No.	*Model structure*	*AICc*	*ΔAICc*	*ωi*	*Number of parameters*
Beta binomial model					
97	pd ~ cargo + fishvess	107.1	0.00	0.192	2
105	pd ~ cargo + fishvess + livep	107.8	0.68	0.137	3
33	pd ~ cargo	108.4	1.29	0.101	1
9	pd ~ livep	108.9	1.84	0.067	1
41	pd ~ cargo + livep	109.2	2.17	0.065	2
101	pd ~ cargo + fishvess + hook	109.8	2.74	0.049	3
107	pd ~ cargo + fishvess + livep + fixed	110.2	3.11	0.041	4
109	pd ~ cargo + fishvess + livep + hook	110.6	3.54	0.033	4
73	pd ~ fishvess + livep	110.6	3.56	0.032	2
98	pd ~ cargo + fishvess + net	111.1	4.05	0.025	3
1	pd ~ intercept only model	111.3	4.24	0.023	0
25	pd ~ elec + livep	111.3	4.27	0.023	2
113	pd ~ cargo + fishvess +elec	111.4	4.31	0.022	3
99	pd ~ cargo + fishvess + fixed	111.4	4.34	0.022	3
37	pd ~ cargo + hook	111.6	4.52	0.020	2
121	pd ~ cargo + fishvess + elec + livep	111.7	4.64	0.019	4
34	pd ~ cargo + net	111.9	4.85	0.017	2
35	pd ~ cargo + fixed	111.9	4.87	0.017	2
49	pd ~ cargo + elec	112.0	4.91	0.016	2
13	pd ~ livep + hook	112.5	5.40	0.013	2
11	pd ~ livep + fixed	112.5	5.46	0.013	2
10	pd ~ livep + net	112.5	5.47	0.012	2
2	pd ~ net	112.7	5.66	0.011	1
57	pd ~ cargo + elec + livep	112.8	5.72	0.011	3
106	pd ~ cargo + fishvess + livep + net	113.1	5.98	0.010	4

Pd= probability of having observed a dead YFP in the last 12 months, **cargo** = cargo vessels, **fishvess** = fishing vessels, **livep** = live YFP observed in 2006 YFDE survey, **elec** = proportion of fishers who believe electric fishing is a problem in their local area, **hook** = proportion of fishers using hook based gear, **fixed** = proportion of fishers using fixed net gear, **net** = proportion of fishers using net based gear.

Table 2.10: Beta-binomial and logit gaussian model averaged parameter estimates

Parameter	*Model averaged estimate*	*95% CI Lower*	*95% CI upper*
Beta-binomial			
Intercept	-0.477	-1.379	0.425
Live YFP sightings	0.013	0.001	0.024
Cargo vessels	0.982	0.182	1.780
Fishing vessels	-0.618	-1.193	-0.043
Logit gaussian			
Intercept	-0.942	-2.237	0.353
Live YFP sightings	0.014	-0.001	0.030
Cargo vessels	1.036	0.250	1.821
Fishing vessels	0.693	-1.396	0.010

2.4.2.2 Correlating YFP mortality reports with fishing gear use along the Yangtze – 2011/12 “hotspot” analysis

The model output for the beta-binomial and the logit gaussian indicated YFP mortality was not predicted well by any of the four fishing-based predictors in the 2011/12 “hotspot” analysis. The final model selection was the intercept model only, with all other model structures discounted as they were nested. Model averaged coefficients could therefore not be calculated as none of the predictor variables were included in the final model set. The **Δ**6 set for the beta-binomial model is shown in Table 2.11 for reference.

Table 2.11: Beta-binomial model selection based on the Akaike Information Criterion corrected for small sample sizes (AICc), showing **Δ**6 set. Response variable is the proportion of interviewed fishers that had seen a dead YFP in the last 12 months. Shown results are Akaike Information Criterion corrected for small sample sizes (AICc), AICc scores (**Δ**AICc) and Akaike’s weight (**ωi**) and the number of parameters for each candidate model.

No.	*Model structure*	*AICc*	*ΔAICc*	*ωi*	*Number of parameters*
Beta binomial model					
1	Pd ~ intercept only	100.0	0.00	0.417	0
9	Pd ~ net	102.4	2.39	0.126	1
2	Pd ~ elec	102.4	2.41	0.125	1
3	Pd ~ fixed	102.8	2.80	0.103	1
5	Pd ~ hook	102.9	2.85	0.100	1
4	Pd ~ elec + fixed	105.4	5.40	0.028	2
10	Pd ~ elec + net	105.5	5.49	0.027	2
13	Pd ~ hook + net	105.7	5.63	0.025	2
11	Pd ~ fixed + net	105.7	5.64	0.025	2
6	Pd ~ elec + hook	105.7	5.67	0.025	2

2.4.3 Patterns in the overlap of fishing activity and YFP presence across the river

Spatial patterns of where types of fishing gear are used in the onshore-offshore profile are visually clear in the data (Figure 2.4). The distribution of hook-based fishing equipment is not uniform across the river, and is biased towards shallow, near bank habitats (X^2=64.77, *n*=4, df=3, *p* <0.001). Free-floating fishing gear is similarly biased towards shallow, near-bank habitats (X^2 = 107.78, *n*=4, df=3, *p*<0.001). Both fishing types included in the onshore-offshore profile analysis are predominantly used within the 0-149.9m distance bin, where over half of hook-based fishing (62.3%) and just under half of net-based fishing is used (49.7%). For both fishing types, the intermediate distance bins of 150-299.9m and 300-500m are where much less fishing occurs, ranging from 19% to 21.2% of the overall fishing activity. Hook type gear is not used beyond 500m from the bank, whereas net type gear is used at all distances to some degree.

In contrast, the 2006 YFDE data indicated YFP presence is biased towards deeper, mid-channel habitats (X^2=1332, *n*=4, df=3, *p* <0.001) largely dominated by the >500m category (Figure 2.4). Very few YFP were observed from 0-299.9m from shore, and only 20.4% between 300-500m from shore. Most overlap between fishing gear and YFP presence occurs in the 300-500m from bank category.

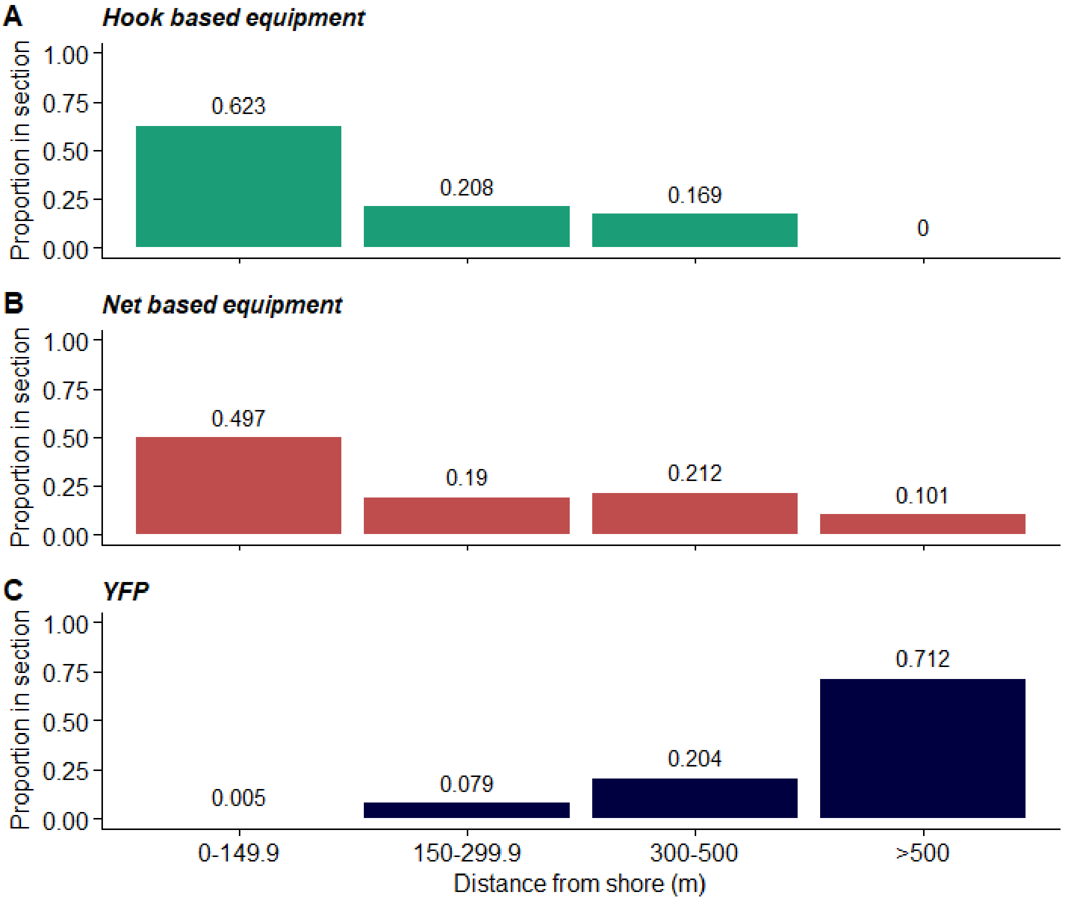


Figure 2.4: Proportion of YFP observations and fishing gear use across the Yangtze river. Distance from bank that YFP were observed in the 2006 survey contrasted with distance from bank that two groups of fishing gear is used in the Yangtze.

2.4.4 Is reproduction observably stable and uniform across the Yangtze River?

Relative to the number of adults observed, calf count was significantly lower in the 2012 YFDE compared to expected ratios from the 2006 YFDE (X^2 = 39.795, df = 1, p= <0.001).

The results of the along-river calf analysis show that the observed number of calves did not significantly deviate from expected counts in each of the three river sections for both the 2006 (X^2 = 1.1751, df = 2, p= 0.5557) and 2012 (X^2 = 4,6242, df = 2, p= 0.09905) YFDE, indicating reproductive rates across the river are relatively uniform.

2.5 Discussion

The new analyses presented here demonstrate that critical re-analysis of existing and combined data sets can provide important new insights into drivers and dynamics of decline in threatened species, supporting the possibility of an evidence-based approach to conservation management even for poorly understood species. These new results have empirically demonstrated that anthropogenically-caused YFP mortality far exceeds the estimated sustainable loss from the YFP population. Vessel collisions have been demonstrated to be a probable key cause of decline, whereas fishing gear is less likely to be driving the decline, with limited spatial overlap demonstrated between fishing gear and YFP occurrence in the river. There has also been a significant decline in the proportion of YFP calves observed between 2006 and 2012. Some of these conclusions are entirely novel, and others either reinforce or counter previous theories about the key causes of YFP decline. These points are discussed below.

2.5.1 Quantifying sustainability of anthropogenic mortality from the YFP population

"Most people would probably agree that an activity could be considered acceptable if it only rarely caused the incidental mortality of a marine mammal" Wade (1998)

Wade's (1998) conclusion should apply to the YFP, and all other freshwater cetacean species. However, both the PBR and logistic population models are consistent with the recent PVA conducted for the PVA (Huang *et al.*, 2017) that suggests the mortality rates of YFP are far too high to maintain a sustainable population. This finding matches the observed YFP population decline in recent decades (Zhao *et al.*, 2008; Mei *et al.*, 2014).

Results of the PBR are similar to studies for comparable species such as the Maui's dolphin (*Cephalorhynchus hectori maui*), which has an overall PBR estimate of 10 individuals per year from a population of 6,452 but less than 1 for most sub-populations (Slooten & Dawson, 2008). Much smaller populations such as the Critically Endangered vaquita have previously been assessed as having a recommended PBR estimate of less than 1 individual for the entire population (D'Agrosa, Lennert-Cody & Vidal, 2000).

Although PBR limits are at a precautionary level, they are inherently a post-depletion tool that is often used to identify where calculated sustainable loss limits have already been exceeded (Robards *et al.*, 2009), as is the case here for the YFP. However, the PBR analysis does tell us that our minimum estimates of observed mortality from fishing (n=6 in 2007) and vessel strikes (n=7 in 2007) are far beyond the PBR sustainable rate of anthropogenic mortality as individual threats. The conclusion is that even if any one individual threat were to be removed entirely, anthropogenic mortality would still be too high to maintain a stable or recovering population.

The difference in sustainable loss rate predicted by the two methods (by an order of ~10) is determined by the underlying model structure and the aims of each method. PBR is a conservative method intentionally designed as a highly precautionary maximum offtake, as it uses the 20th percentile of the lowest available population estimate and halves the estimated recovery rate. This is an attempt to explicitly consider uncertainty in the population estimate and ability of the population to recover, which is not applied within the more complex logistic population model. Both methods should therefore be used as guideline values considered within the assumptions and intentions of each calculation; both these methods are individually applicable given that they have different methods and intended uses. However, given that 30 YFP deaths were observed from an interview of only ~10% of fishers in the Yangtze mainstem (as an absolute minimum mortality rate), the logistic model does seem more realistic as a less conservative model of sustainable offtake. To further understand the differences between the two models, sensitivity analysis on the estimates of K and explicitly accounting for uncertainty in the population estimates would provide more information.

There are a number of possible explanations for the difference between the observed mainstem mortality and predicted actual mortality from the logistic model. As mentioned above, only ~10% of the fishing community was interviewed. The observed mortalities could potentially be multiplied up to represent the likely response levels for the entire fishing community on an 'observed mortality per fisher' basis: however, there would likely be some duplicates that could not be controlled for using this approach, and so it is not attempted here. Another reason for the disparity that fishers are likely to fear reporting YFP deaths due to the protected status of the YFP, leading to an underestimation of mortality reported by fishers. A further reason is that not all mortalities would be observed; a carcass could float downstream without being observed. The last possible reason is that we have assumed all losses would be observable carcasses; as discussed in relation to calf count, pollution and reduced carrying capacity could also be reducing reproductive fitness. This would not be observable as a visible carcass or bycatch as it would only reduce fecundity and therefore reduce new individuals entering the population. This would result in a smaller rate of increase or R_{max} in the logistic equations. In addition, some of the carcasses that do get observed and were included in this count may have been killed by vessel strikes or bycatch but these causes were not identified by the fishers.

Often estimates of sustainable loss cannot entirely take into account uncertainty within the system and model in question, so according to the precautionary principle any estimated losses should therefore be considered at the higher end of sustainable offtake (Milner-Gulland & Akçakaya, 2001). If we were to follow a precautionary approach here, we should take the smaller of the estimates to be the guideline for the highest mortality rate to maintain a sustainable population. In this case, this would be the PBR method, meaning that current maximum recommended mortality rate is less than one individual per year for the mainstem, and less than two individuals for the overall Yangtze. This seems an unrealistic goal given the current rate of decline and observed minimum loss values.

Populations can be subject to random or unpredictable change from factors such as dispersal (Taylor, 1997), which can invalidate the output of such models when it is not taken into account. One unknown factor here is movement of YFP between mainstem and lake-based populations. The population in Poyang Lake is considered stable at around 450 individuals, but the mainstem population has declined severely. It has previously been suggested, although never empirically proven, that there may be movement of YFP from the Yangtze River into the lake systems (Li *et al.*, 2010b; Huang *et al.*, 2017). This would explain why, despite significant observed mortalities in Poyang Lake by fishers (interview data, 2012), a stable population remains in this system. It should be noted here that in the absence of any data to contradict this conclusion, it has been assumed that YFP dying in either Poyang Lake or the Yangtze mainstem are equally likely to be observed by fishers.

The main conclusion we can take from this investigation is that YFP mortality rates reported by fishers are not sufficient to have caused the significant observed depletion in the population. The majority of YFP mortality (~80%) must therefore be missed by casual observations, supporting the call for a systematic post-mortem system for YFP (Turvey, Hao & Ding, 2012). It also brings into question and to some degree supports the possibility of other causes of population decline that are not directly observable, such as reduced carrying capacity, pollution related reproductive and health issues, and other indirect threats such as noise and habitat modification.

For the predicted actual estimated rate of loss (minimum of 140 individuals per annum from 2006 to 2012) to be sustainable, the minimum required YFP population would quite likely be beyond the carrying capacity of the relatively restricted Yangtze River, given the demographics and model constructed here. If the current rate of loss continues, it is therefore impossible for this population to recover. To further understand and quantify the potential effect of current and future YFP mortality it is recommended that demographic population modelling is conducted in which uncertainty in the population estimate is explicitly included.

2.5.2 Can we associate specific threats with YFP mortality based on current information?

Even with the relatively low degrees of freedom, the 2008 along-river analysis of predictors of YFP mortality still contained better models than the null model. This analysis demonstrated the importance of analysing even limited available data sets carefully; by correcting for over-dispersion and standardising parameters that may skew the data, the data can still be effectively modelled. This indicates than even with what may be considered low spatial resolution or ‘weak’ data, we can still gather biologically relevant conclusions.

Both models support the theory that collisions with large vessels are likely to be a significant cause of YFP mortality. Despite the limitations of this data set and the relatively low degrees of freedom present in these analyses, patterns in causes of mortality data are still present. The overall interpretation of this analysis is that even with limited data, the model outputs have still given relevant and logical results. Using fisher interview data to assess relative mortality trends, Turvey *et al.* (2013) concluded that YFP mortality due to vessel strikes has likely increased more than bycatch mortality. The 2008 Yangtze-wide analysis presented here further supports the idea that vessel strikes are likely to be a predominant cause of YFP mortality. This is the first time that vessel strikes have been quantitatively implicated as a key threat to YFP based on direct YFP mortality data. This contradicts a number of studies that focus on or cite bycatch as the main cause of mortality (Zhou & Wang, 1994; Wang, Zhang & Liu, 1998; Wang *et al.*, 2005; Zhao *et al.*, 2008; Zhang *et al.*, 2014). Conversely, none of the fishing-based predictors of YFP mortality were significant within the model constructed using the 2011/12 "hotspot" interview data or in the 2008 Yangtze-wide analyses. This agrees with some previous studies that have indicated that fishing may not be the key driver of YFP mortality (Turvey *et al.*, 2013). It is also possible that the relatively coarse resolution of the data may not be picking up finer scale patterns in bycatch caused mortality.

2.5.3 Localised spatial patterns in fishing gear use across-river

Fisheries bycatch is a key cause of mortality in many other small cetacean species (Reeves, McClellan & Werner, 2013) and numerous cases of YFP bycatch have been documented (Zhou & Wang, 1994; Wang *et al.*, 2000; Wang & Zhao, 2010; Wang, Li & Waerebeek, 2015). However, the minimal overlap of fishing gear and YFP presence demonstrated across the four categories in the onshore-offshore dataset concurs with previous studies that indicate that bycatch may not be as significant a cause of mortality than previously thought (Turvey *et al.*, 2013). Any bycatch in the main river is most likely to occur at mid-distance (i.e. 150-500m) from the bank where overlap of fishing gears and YFP is at its maximum. These results demonstrate that any fishing-based enforcement such as patrols should be focussed here to specifically target resources to areas of higher-risk.

Both the 2008 GLM analysis presented earlier and this across river analysis therefore support the theory that fisheries interactions are unlikely to be driving YFP decline. The across-river analysis provides a likely mechanism as to why; fishing activity and YFPs are not being used in the same parts of the river and so bycatch is likely to be rare. However, YFP presence is known to be influenced by the local hydrology, water quality, substrate type and fish abundance (Wei *et al.*, 2003; Zhao *et al.*, 2013; Zhang *et al.*, 2015, 2018) and, as this cross-river analysis was completed for the river on a landscape scale, there may be finer scale, localised patterns in YFP presence and fishing activity that areas of higher overlap between the two. It is likely that the use of specific fishing gear types varies on an onshore-offshore scale due to differences target fish species and the structure of the fishing gear used. For example, rolling hook fishing is commonly used to target larger fish species, whereas other fishing types of fishing gear are used to target smaller fish (chapter 3, this thesis). There may also be smaller scale variations in the spatial use of the gear types dependant on the target species.

In this analysis, hook type fishing gear overlapped with YFP presence less than net type gear did, but hook type gear has previously been estimated to account for 45.2% of all observed YFP bycatch events by fishers (Turvey *et al.*, 2013). This is similar to what has been observed in marine systems, where hook based gear are a significant cause of cetacean and other marine mammal bycatch (Gilman, Brothers & McPherson, 2006; Read, Drinker & Northridge, 2006). Fewer interviewees reported using rolling hooks in the lake systems than in the main river channel in the 2011/12 interview survey (Turvey *et al.*, 2013), which could partially explain why relatively substantial YFP populations remain there (Mei *et al.*, 2014).

2.5.4 What can we infer about YFP reproduction from past YFP populations?

Proportion of calves in the population reduced significantly from around 20% to 6% between 2006 and 2012 but the spread of calves was uniform across the Yangtze River in both time periods. As the YFP census survey methodology and seasonality was the same for both years, the proportion of calves would be expected to be similar if reproductive success was being maintained between the two survey years. A similar pattern of a reduction in calves and immature individuals was observed (although not tested statistically) in the later stages of decline of the baiji; the proportion of immature individuals was observed to reduce from 31% to 17% from 1985 to 1999 (Zhang *et al.*, 2003). This pattern of decline is therefore of serious concern for survival prospects of the YFP.

Expected proportion of juveniles in a “healthy” YFP population is not known; no baseline exists, and it has not been calculated using life history parameters. Generation length of YFP is estimated to be 16.5 years, similar to marine finless porpoises (Taylor *et al.*, 2007), sexual maturity is thought to be at approximately six years old (Gao & Zhou, 1993). Gestation of one calf at a time lasts approximately one year, with a general pregnancy interval of one calf every two years (Chen et al., 1997; Wei, 2002). Comparable populations of other porpoise taxa show clear seasonality in proportion of calves, with peaks tending to be in late summer months (Table 2.12). No comparable studies are available for the specific survey periods of November or December. Using available information from previous months (July – September), we could expect the proportion of calves to be anywhere from 10 to 27% (Table 2.12). The most relevant study in terms of similar species, location and season was of a narrow-finned finless porpoise population in the Sea of Japan, where between the months of November to March the mean percentage of calves observed was 10% (Kasuya & Kureha, 1979). However, the number of calves that survive into these later months of this period could be lower (due to predation, disease, and other causes of infant mortality) so this may be a slightly lower estimate than would be expected for just November and December. A YFP population containing 6% calves is therefore likely to be a lower percentage than would be expected in a healthy population of YFP.

The 2006 YFP census results showing 20% calves falls within the range of other porpoise species populations, whereas the 6% in 2012 is lower than most of the observations of similar taxa (Table 2.12). The highest percentages of calves observed in populations of other porpoise species (27% and 27.3% for the narrow-ridge finless porpoise and harbour porpoise, respectively, Table 2.12) are higher than for either the 2006 or 2012 YFDE surveys, so it is possible that the calf proportion in the 2006 survey is lower than the maximum possible reproduction rate of YFP under optimal circumstances. However, without baseline data for YFP, it is impossible to state with certainty that this is the case.

Table 2.12: Proportion of calves in comparable species and sub-populations

Publication	*Locality/ sub-population*	*Months survey conducted*	*Estimated proportion of juveniles*
Narrow-finned finless porpoise (Neophocaena phocaenoides)			
Kasuya and Kureha (1979)	Inland Sea of Japan	Year-round	Nov – March: 10% September: up to 27%
Harbour porpoise (Phocoena phocoena)			
Sonntag *et al.* (1999)	North Sea	June & July	5.4 - 14%
Siebert *et al.* (2006)	North Sea Baltic Sea	Year-round	North Sea: 5.3% Baltic Sea: 1.9%
Lockyer and Kinze (2003)	North Atlantic	Year-round	May: 9.1%, June: 6.9% - 10.6%, July: 11.5% - 23.8%, August: 18.2 – 23.5%
Weir, Stockin and Pierce (2007)	Northwest North Sea	Year-round	June: 21.4%
Leopold, Wolf and Van Der Meer (1992)	Southwestern Ireland	Summer	15%
Thomsen, Laczny and Piper (2007)	Helgoland, German Bight	Year-round	May: 3.4 %, July: 27.3%

As noted in Chapter 1, high concentrations of compounds known to affect reproduction and calf survival have been found in carcasses of YFP (Dong *et al.*, 2006; Yang *et al.*, 2008), in Yangtze River fish (Xian *et al.*, 2008; Zhu *et al.*, 2013), and the Yangtze River itself (Müller *et al.*, 2008). These two YFP-specific publications represent the only examples of contamination studies in YFP, and so it is a severely understudied issue. To investigate this potential threat further, below I discuss the negative role that persistent organic pollutants (POPs) such as polychlorinated biphenols (PCBs) and heavy metals such as mercury may be playing in health and reproduction in YFP specifically, as these have both been found in YFP samples.

2.5.4.1 PCB pollution and mammalian reproduction

Bioaccumulation of toxic PCB compounds has been noted as a cause for concern in carnivorous aquatic mammals (Kannan *et al.*, 1989); contamination can cause severe detrimental health and reproductive effects (Safe & Hutzinger, 1984). Noted reproductive implications in aquatic mammals include failure to conceive (Reijnders, 1986), mortality of the first born (Wells *et al.*, 2005), sterility (Helle, Olsson & Jensen, 1976; Bredhult *et al.*, 2008), and sometimes severe reproductive dysfunction, failure, or even hermaphroditism (Beland *et al.*, 1993; De Guise *et al.*, 1994; Martineau *et al.*, 2002). In cetaceans specifically, PCB contamination can “severely impair” reproductive success (Schwacke *et al.*, 2002) and reduce likelihood of calves surviving infancy (Hall *et al.*, 2018). Known effects of PCB/polybrominated diphenyl ether (PBDE) contamination in the harbour porpoise (*Phocoena phocoena*) are immunosuppression (Beineke *et al.*, 2005), increased parasitic load (Isobe *et al.*, 2011), susceptibility to disease (Jepson *et al.*, 2005), and reproductive failure (Murphy *et al.*, 2015).

The only study investigating contamination of these compounds in YFP found PCBs, PBDE's and polychlorobenzodioxin/flurans (PCDD/Fs) in samples from Dongting Lake at considerable concentrations (Yang *et al.*, 2008). PCBs were found in the range of 0.12-1.89 µg/g lipid weight, PBDEs from 5.32-72.76 ng/g lipid weight, and PCDD/Fs at 65-1563 pg/g lipid weight (n=5).

Threshold values are a standard way of assessing the potential impact of a compound on the health of any organism, defined as the concentration that can be tolerated without adverse biological effects (Kannan *et al.*, 2000; Jepson *et al.*, 2005). The accepted threshold value of PCBs in blubber of aquatic mammals is 17 µg/g lipid (Kannan *et al.*, 2000; Jepson *et al.*, 2005). Although it was concluded in this study that PCBs were at relatively low concentrations compared to this threshold, the Hazard Quotient (HQ) was >1 for all individuals, indicating they are still a probable health hazard for YFP (Yang *et al.*, 2008). PCDD/Fs for YFP also had a HQ of >1, and when combining the effects of PCB together with the effect of PCDDD/Fs, HQ was even higher per individual (Yang *et al.*, 2008) and the combined effects are therefore likely to be detrimental to YFP health.

Of particular concern in the study by Yang *et al.* (2008) is that the single YFP calf individual analysed had the highest HQ of PCB in all the samples analysed in this study by an order of around four (37.89) (Yang *et al.*, 2008), which concurs with other studies indicating that these compounds tend to be found in higher concentration in juveniles (Lindström *et al.*, 1999; Norman *et al.*, 2017).

For comparison, in UK based harbour porpoise populations, PCB concentration in blubber ranged from 0.40 – 159.68 mg/kg lipid (N= 706) (Jepson *et al.*, 2015), which has caused reproductive issues (Murphy *et al.*, 2015) and finless porpoises in Japanese waters have been found with PBDEs concentrations ranging from <100 – 7200 pg/g ww (therefore 7.2 ng/g lipid weight) (Ochiai *et al.*, 2017), much lower than in the YFP study described above. It has been suggested that higher levels PBDEs in YFP is a result of the historical use of sodium pentachlorophenol (Na-PCP) to control schistosome abundance in Dongting Lake between the 1960s and 1990s (Yang *et al.*, 2008), resulting in high levels of PBDD/F contamination in fish in the Dongting Lake area (Hu *et al.*, 2018).

The evidence from the study by Yang *et al.* (2008) indicates that concentrations of PCBs in YFP blubber could be causing health and reproductive issues that are a possible explanation for the decrease in YFP calf proportion demonstrated here. However, the investigation by Yang *et al.* (2008) was very localised and small-scale and further contemporary studies are urgently needed. It therefore cannot be explicitly stated that pollutant loads are the cause of decreased reproductive success without a strategic post-mortem system investigating the concentration of PCBs in YFP carcasses and investigating potential reproductive issues.

2.5.4.2 Mercury contamination, health, and reproduction

Mercury is a highly toxic persistent pollutant that is of particular concern to aquatic wildlife (UNEP, 2013). Although it is not as directly linked to reproductive failure like PCBs, it is discussed here as another possible cause of calf decline or barrier to recovery based on the high concentrations of mercury found in YFP by Dong *et al.* (2006).

Mercury bioaccumulates in apex species such as aquatic mammals from dietary sources, leading to a high risk of hepatic damage and compromised immune function (Kannan, Perrotta & Thomas, 2006), as well as behavioural deficits after birth, impaired fertility and foetal death (Wolfe, Schwarzbach & Sulaiman, 1998). High levels of mercury in the brain of aquatic mammals can cause neurotoxic effects (Krey, Ostertag & Chan, 2015), and in porpoise species specifically, mercury contamination can lead to immunosuppression and an increased risk of death from infectious disease (Bennett *et al.*, 2001).

In cetaceans, mercury tends to accumulate with age (e.g. Joiris *et al.* 2001; García-Alvarez *et al.* 2015), and the highest concentrations are often found in the liver (e.g. Joiris *et al.* 1991). Both these patterns have been observed in YFP samples (Dong *et al.*, 2006). In one of the few studies of YFP toxicology, Dong *et al.* (2006) measured total mercury (T-Hg) between 0.17 to 181 µg/g wet weight (“ww”), predominantly in the kidney, liver and small intestine but also in the stomach, blubber and brain (Table 2.13).

Alarmingly, the highest total mercury (T-Hg) concentration in the liver and kidney were found in a two-month old calf, indicating a possibility of high efficiency of mother-calf transfer (Dong *et al.*, 2006). Mother-calf transfer has been observed in other cetacean species (e.g. *Tursiops truncatus,* García-Alvarez *et al.* 2015), but the degree to which this transfer occurs is thought to be species-specific and is not well understood in the YFP aside from observations in the study by Dong *et al.* (2006).

Harbour porpoises in different systems show similar ranges of mercury contamination, but worryingly the highest concentration in YFP of 181 µg/g ww in the liver is almost as high as the highest concentration found so far in any published study (190 µg/g ww, Table 2.13).

Threshold values for mercury in mammals are a contentious issue, as they are dependent on species as well as interactions with other compounds such as selenium. However, two hepatic threshold values have been identified; the first sets a toxic threshold for marine mammals based on bottlenose dolphins (*Tursiops truncatus*) at 61 µg/g ww (Rawson *et al.*, 1993) and the other at a range of 100-400 µg/g ww (Wagemann & Muir, 1984). The former is followed more often in the literature and so is used here as a threshold value for both liver and kidney observations.

Table 2.13: Mercury (T-Hg) concentrations in tissues of YFP samples compared to other porpoise and beluga populations. West Greenland is considered a relatively low contamination area, and the North, Baltic and Irish Seas are considered relatively high contamination areas. All concentrations in µg/g ww.

Species	***YFP***	***Harbour porpoise***			***Beluga whale***	**Threshold value**
Location and source	*Dongting Lake (Dong et al., 2006)*	*West Greenland (Paludan-Miiller et al., 1993)**	*North & Baltic Seas (Siebert et al., 1999)*	*Irish Sea (Law et al., 1992)*	*Canadian Arctic (Krey, Ostertag & Chan, 2015)*	
Sample size	*N = 5*	*N = 26 to 77*[†]	*N = 55 to 57*[†]	*N = 28*	*N = 2*	
Liver	1.40–181	0.475–20.7	0.2 - 130	0.6–*190*[‡]	-	61[a]
Kidney	1 - 43	0.185–2.51	0.1 - 33.5	-	-	61 [a]
Small intestine	2.4 – 66	-	-	-	-	NA
Stomach	0.65 – 5.2	-	-	-	-	NA
Blubber	0.23 – 1.7	-	-	-	-	NA
Brain	0.17 – 5.2	-	-	-	0.04-20.23	>0.1[b]

* *Example of lower concentrations found in literature*
‡ *Highest concentration in any porpoise species found in current literature*
† *N is shown as a range as different numbers of samples were taken for each organ*
[a] *Rawson et al. (1993)*
[b] *Krey et al. (2015), see Table 2.14*

Since the study by Dong *et al.* (2006) was published, threshold values of mercury concentration in the brain of mammals and cetaceans have been studied in more detail. Following a recent comprehensive literature review by Krey *et al.* (2015), the toxic effects of a range of mercury concentrations in the brain of aquatic mammals have been studied and defined (Table 2.14). The highest concentration measured in the brain of YFP samples (Table 2.13) is enough to have likely caused neuropathological effects, which could include behavioural, genetic and immune responses.

Table 2.14: Thresholds for physiological, clinical and neuropathological effects of mercury contamination in the brain (Krey, Ostertag & Chan, 2015).

Concentration in brain (mg T-Hg Kg ww)	*Effect*
>6.75	Clinical signs observed
>4	Neuropathological effects
>2	Clinical signs sometimes detected at this concentration
<0.2	No neuropathological effects
>0.1	Behavioural, genetic or immune response effects.

As with PCB contamination, it is impossible to directly link mercury as a cause of the decrease in YFP calves demonstrated here without conclusive post-mortem studies. However, given the information detailed in the two studies by Dong *et al.* (2006) and Yang *et al.* (2008), health and reproductive issues are likely occurring due to high concentrations of mercury and POPs in the Yangtze River and this could be at the very least a contributor to reproductive difficulties that may be hindering the overall fecundity of the remaining YFP population. Without further detailed information it is difficult to implicate pollution specifically as the only cause of observed calf decline.

2.5.4.3 What other potential threats could be causing YFP calf decline?

Aside from pollution, other factors may be limiting the reproductive ability of YFP or reducing the success of rearing calves to adulthood. Noise induced stress, prey limitation, and genetic restrictions are also possible causes. However, there are very few data available on these three potential causes relating specifically to YFP. The only relevant published studies are discussed here.

Reduced prey availability

Reduced prey availability may be limiting population recovery in YFP by reducing the carrying capacity of the Yangtze system. Predator-prey cycles are well documented for carnivorous terrestrial mammals, whereby the abundance of the predator species is heavily reliant on the abundance of prey. Reduced prey availability as a result of these cycles can reduce the reproductive output of mammals due to nutritional depletion (Sadleir, 1969) and therefore reduce litter size and offspring survival (e.g. lynx, *Lynx canadensis*, Brand & Keith, 1979; coyotes, *Canis latrans*, Todd & Keith, 1983; San Joaquin kit foxes, *Vulpes macrotis mutica,* White & Ralls, 1993). Changes in prey biomass can also affect survival of new-borns for mammal species (Brand & Keith, 1979; Fuller, 1989).

In marine mammals, reduction in reproductive success as a result of decreased prey availability has been observed in Steller sea lion populations (*Eumetopias jubatus,* Trites & Donnelly, 2003), bottlenose dolphins (*Tursiops* sp., Mann, 2000), and Arctic marine mammals (Tynan & DeMaster, 1997; Rode, Amstrup & Regehr, 2010). Population trends in the north-eastern Pacific Ocean population of orcas (*Orcinus* orca) are also significantly correlated with the availability of their primary prey species (Ford *et al.*, 2009). For the same species and population, reducing prey availability by only 10% was predicted to affect the reproductive output to the same degree as PBR estimates of anthropogenically caused loss of individuals (Williams *et al.*, 2016b).

The opposite effect has also been observed in a similar porpoise species; increased prey availability is associated with increased size of juvenile harbour porpoises (and with reduction in the ages of sexual maturity, allowing increased fecundity of the population (Read & Gaskin, 1990). The opposite effect is likely in systems where prey availability is significantly reduced.

There are very few data relating to the decrease of specific fish species in the Yangtze River, although fish stocks have declined overall in recent decades due to extraction, habitat loss and degradation, and the broad reaching effects of hydroelectric projects on the Yangtze ecosystem (Chen *et al.*, 2009; Duan *et al.*, 2009; Ye *et al.*, 2013; Huang, Wu & Li, 2013). In

Chapter 4 of this research, results of an interview survey are presented, where fishers were asked to document changes in catch of nine fish species known to be predated by the YFP (Section 4.4.5). Stocks of all nine species were predominantly reported to be in a state of decline. The effect of this on YFP specifically has not yet been investigated and it is very difficult to empirically measure in a wild population. The effect of starvation on an individual aquatic mammal can only be observed physiologically through a post-mortem. This further emphasises the need for a systematic post-mortem system for YFP across the Yangtze River.

Noise pollution

There are a number of physiological symptoms of noise stress and noise damage in cetaceans. At lower to mid-levels noise can cause temporary threshold shifts (TTS), which do not cause long-term permanent effects on auditory ability (Southall *et al.*, 2009). Permanent threshold shifts (PTS, also called auditory injury) can also occur at high noise levels, and result in irreversible damage to auditory ability (Southall *et al.*, 2009). High noise levels can cause behavioural effects, mask social and hunting signals, result in physiological damage, cause prolonged stress that causes health problems, and ultimately lead to population level detrimental effects (National Research Council, 2005; Erbe, 2011; Williams *et al.*, 2016b; Harris *et al.*, 2018). However, the physiological effect of noise stress on cetaceans is difficult to observe or quantify as the animals themselves are very difficult to observe, meaning there are very few empirical studies relating to how it may affect marine mammal health and reproduction (National Research Council, 2005).

A recent review article implicates noise in reduced reproductive success through a number of possible routes: hormonal effects caused by noise-induced stress; physical injuries; masking of vital communication required for mating displays and for locating young underwater; displacement from feeding grounds; behavioural and energetic alterations; and ecological effects on key prey species and the resulting ability of animals to hunt successfully (Nabi *et al.*, 2018).

Noise levels in the Yangtze River have not been studied or quantified, but the presence of a high number of large vessels and intense sand mining activity means there is likely to be a high level of underwater anthropogenic noise and sonar activity. Noise from vessels and industrial activities has been noted as a possible cause of environmental stress for the YFP (Wang *et al.*, 2005; Wang, 2009; Zhao *et al.*, 2008), but the effect of this noise has never been studied specifically in any wild YFP population.

The only study relating to YFP and noise was conducted by Popov *et al.* (2011). Here, TTS were investigated in the captive YFP individuals housed in the aquarium in Wuhan. This study was not aimed at understanding the effect of noise on YFP populations in the wild, but simply to document occurrence of the physiological response in the species. Given the notable detrimental effects of noise in other species, there is an urgent need for (a) a quantitative assessment of the anthropogenic noise levels in the Yangtze River and (b) a comparative study of whether the measured noise levels may be surpassing physiological thresholds to cause damage or long-term harm to individuals or the remaining wild population.

Reduced genetic diversity

Low genetic diversity within a population can lead to inbreeding depression, which is deleterious to individual and population level fitness (Charlesworth & Charlesworth, 1987). Low genetic diversity is a noted problem in other cetacean species undergoing localised or population level decline, including bottlenose dolphins (*Tursiops truncatus,* Fruet *et al.*, 2014), pygmy blue whales (*Balaenoptera musculus brevicauda,* Attard *et al.*, 2015), and sperm whales (*Physeter macrocephalus,* Alexander *et al.*, 2013). Inbreeding depression in west Australian bottlenose dolphin populations has affected reproductive fitness in females in two ways: firstly it reduces calving success, and secondly it extends the time required for weaning (Frère *et al.*, 2010). Inbreeding depression has also been implicated in reduced resilience to disease in Mediterranean striped dolphin (*Stenella coeruleoalba*, Valsecchi *et al.*, 2004).

A study by Chen *et al.* (2010a) concluded that genetic diversity of YFP was not distinctly lower than that of the two marine taxa of finless porpoise, suggesting inbreeding and genetic bottleneck processes are unlikely to be an important threat at present. However, more recently it has been demonstrated that genetic diversity in the present breeding population of YFP has reduced (Chen *et al.*, 2014b, 2017). Gaps in distribution leading to physical separation that restricts breeding activity may also have some role in the population decline of the YFP (Chen *et al.*, 2014b), and localised sub-population of YFP are becoming more fragmented and therefore genetically isolated from each other (Chen *et al.*, 2017). This pattern is likely to get worse if population decline continues, but the level of effect on breeding success is very difficult to quantify. Also of note here is that the extinction of the baiji was not thought to be due to genetic collapse in the species (Xu *et al.*, 2012b). As with many of the other threats to the YFP, further investigation is needed to quantify the effect the reduced genetic diversity has had on the viability of the remaining YFP population.

2.6 Conclusions

The data presented so far are sufficient to conclude that propeller impacts are likely to be a, if not the, main cause of YFP mortality. Evidence shown here is consistent with the previous study by Turvey *et al.* (2013) that suggested that vessel collisions are a key contributor to YFP population decline. Our analyses also demonstrate the limited level of spatial overlap between YFP and fishing gear and show that fishing activity is not a good predictor of YFP mortality. In addition to these conclusions, our analyses of existing data also provide new evidence that implicates other, less visibly obvious causes of YFP mortality. Interview surveys have previously indicated an increase in the number of observed mortalities classified with an “unknown” cause of death (Turvey *et al.*, 2013) as no visible wound was noted. Pollution, starvation due to lack of available prey and possibly other anthropogenic factors might also be implicated in YFP declines, but these need further investigation. Given comparisons to similar species and the few studies available relating to the effects of POPs on YFP investigations, we can tentatively implicate pollution or some factor causing a reduction in carrying capacity as the probable cause of the decline in calf populations. However, without further data it is not possible to implicate any cause empirically.

In the race against extinction, understanding causes of decline is often restricted by data limitation. The results presented here demonstrate that careful analysis and consideration of even limited data can derive threat-relevant conclusions that can help understand the causes of mortality for a data-poor species. By combining published and unpublished data, spatial and temporal patterns relating to the decline of species can be revealed, if the data are analysed in the appropriate way. This approach is not possible for all species, as for many there are unfortunately few or no relevant data available at all. However, for many species there are numerous researchers or research groups that may not be sharing data or working collaboratively, meaning opportunities to combine data sets are missed (Haddaway, 2015). This means that time and resources may be wasted, and often studies are repeated (Mace, 2000). This study has demonstrated that an evidence-based conservation approach can be possible if data are analysed appropriately, and, in addition, even in the light of somewhat limited data available at this point, a precautionary approach should be taken towards YFP conservation as all evidence points towards significant declines and severe threats to the species. However, key knowledge gaps still remain, and data about other threats are not robust enough (or are simply not available) to inform whether these factors should be made a target for conservation efforts (Table 2.15). There is therefore still relatively high uncertainty surrounding how to make informed conservation decisions for YFP, and an evidence-based approach is not possible concerning these data-poor threats. For example, sand mining operations have never been investigated as a threat, and there remains a severe lack of data on the spatial and temporal interactions or overlap of YFP and various threats. Further data are therefore required before it is possible to make a thorough assessment of the conservation options for the YFP.

Table 2.15: Current evidence base implicating the known or implied causes of mortality to YFP, including remaining data gaps

Potential cause of decline	*Data available and published studies relating to YFP or the Yangtze River*	*Sufficient data to assess threat as a cause decline?*	*Is threat contributing to YFP population decline?*	*Key remaining data gaps*
Fishing bycatch (1.4.5.1)	› Turvey *et al.* (2013): YFP bycatch is decreasing and so it is less likely to be a key driver of decline. › Sporadic YFP mortality reports: ○ **Hook gear:** Zhou & Wang (1994); Wang *et al.* (2000); Wang & Zhao (2010); Turvey *et al.* (2013), ○ **Net gear:** Reeves, Smith & Kasuya (2000); Zhou & Wang (1994); Turvey *et al.* (2013)**,** ○ **Electric gear:** Reeves, Smith & Kasuya (2000); Zhang *et al.* (2003); Turvey *et al.* (2013)**.** › Minimal overlap of fishing on an onshore-offshore transect demonstrated for two gear types here (hook and net-type), predominantly in mid-channel habitat.	Some evidence	Highly likely (specific gear types)	› Spatial overlap of fishing gear and YFP not well quantified on larger scales in key habitats such as the two lake systems. › Temporal patterns in fishing activity not well quantified with respect to YFP distribution or habitat overlap.
Vessel collision (1.4.5.2)	› Turvey *et al.* (2013) strongly implicates vessel collisions as a key cause of mortality. › Strongly implicated as a cause of decline in this chapter (2008 analysis of predictors of YFP mortality).	Some evidence	Highly likely	› Spatial overlap of YFP and large vessels poorly quantified. › Impacts or spatial overlap of YFP with sand mining vessels in Poyang Lake not quantified.
Sand mining (1.4.5.3)	› No YFP-specific relevant studies available.	No	Unknown	› No evidence of sand-mining causing YFP mortality directly, but it has never been thoroughly studied. › No studies into the ecological implications of sand-mining on Yangtze fish species or YFP habitat quality.

Pollution (1.4.5.4)	› Yang *et al.* (2008): high PCB contamination found in YFP samples. › Dong *et al.* (2006): high mercury contamination in YFP samples. › Yi *et al.* (2008): high heavy metal contamination in sediments, especially in the mainstem of the Yangtze. › Proportion of calves decreased between 2006 and 2012, with pollution implicated as a possible contributor.	Some	Likely	› Pollution has been implicated as an issue in the Yangtze system and in YFP, but there are not enough data available to empirically assess the direct effects on YFP mortality or reproduction, or assess this threat as a cause of direct YFP mortality.
Loss of prey resources (1.4.5.5)	› Very few empirical data on status and change in fish stocks over time are publicly available. › Chen *et al.* (2009): status of fish stocks in the Yangtze severely understudied.	No	Unknown	› Data on fish stocks of YFP-specific prey species urgently needed to assess whether their available prey base is depleted.
Habitat alteration, degradation and loss (0)	› No published empirical data or evidence to directly implicate this as a cause of decline.	No	Unknown	› No published empirical data or evidence to directly implicate this as a cause of decline.
Genetic bottleneck (1.4.5.7)	› Chen *et al.* (2017): Extremely low genetic diversity within localised YFP geographic populations. › Zheng *et al.* (2005): Low mitochondrial DNA diversity in YFP. › Du *et al.* (2010): High genetic sequence diversity.	Some	Likely	› Evidence of low genetic diversity that could in any given population cause genetic reproductive difficulties. › No quantification of the reduced capacity to reproduce or the effect of this on decline in the remaining YFP population.
Cumulative or synergistic effects	› Never studied in an empirical way, predominantly due to the lack of quantification of each threat individually.	No	Unknown	› What are the cumulative impacts of habitat loss and fragmentation, reduced prey abundance, noise and disturbance, and pollution?

3 Chapter 3: Spatio-temporal overlap of Yangtze finless porpoise presence and potential threats in Poyang Lake

Boats equipped with electric fishing gear, South Poyang Lake, 2016.

3.1 Abstract

Available resources are not sufficient to protect the world's biodiversity, hence species-specific conservation efforts must be targeted at prioritised areas to maximise the effectiveness of limited resources. Successful conservation is therefore reliant on a robust understanding of the spatial and temporal variations in both species and threat distributions as a means of identifying priority habitat and key areas of species-threat overlap. Understanding these species-threat dynamics is vital to inform effective interventions but can also be used to identify causes of decline and highlight key problem areas. Mapping based studies are an informative way of rapidly gathering spatial data that can be used to fill in these knowledge gaps for at-risk species. Here, the results of boat-based surveys investigating threats and distribution of Critically Endangered Yangtze finless porpoise are shown for the key remaining habitat of Poyang Lake, Jiangxi province, China. These seasonal surveys (winter low-water and summer high-water) have been used to understand spatio-temporal dynamics of porpoise distribution and to infer information relating to fishing activity and sand-mining as potential threats to the species. Using encounter rates and hot-spot analyses, the results demonstrate seasonal movement and changes in distribution of this species that relate to the highly dynamic seasonal environment of Poyang Lake, which have implications for the allocation of the two current protected areas within this habitat. Additionally, seasonal changes in the overlap of porpoises with the two threats investigated has been empirically demonstrated here, with results showing a higher level of overlap with fishing activity than sand-mining activity, indicating that sand-mining is unlikely to directly be a key driver of population decline. Fishing overlap with key porpoise habitat more significantly in the summer, which demonstrates the need for seasonally and spatially targeted enforcement and mitigation to avoid YFP bycatch. This is the first study to investigate spatio-temporal overlap of Yangtze finless porpoise with the presence of potential threats, and the results shown here have successfully demonstrated conservation-relevant seasonal changes in the interaction of this species with two key threats.

3.2 Introduction

3.2.1 Why do we need to understand spatial and temporal patterns of species and threat occurrence?

The geographic range limit of a species is defined by its ecological requirements and tolerance limits (Ferrier & Guisan, 2006; Wisz *et al.*, 2013), geographic occurrence parameters (i.e. where they are physically located on a global scale) (Sax, 2001), as well as interactions with co-occurring species (Wisz *et al.*, 2013). At a smaller, localised scale, habitat use is dependent on species requirements such as distribution of prey and other resources (Bluhm & Gradinger, 2008).

The dynamics of potential threats also vary spatially on global (Halpern *et al.*, 2008) and local (e.g. Grelle *et al.*, 1999; Carpenter *et al.*, 2008; Orozco *et al.*, 2014) scales, and threats are often seasonal or vary in intensity over temporal scales (e.g. Välimäki *et al.*, 2010; Vor *et al.*, 2010; Velez-Rubio *et al.*, 2013). This can alter the range of a species beyond their past distribution, and species ranges are now determined by past and present interactions with humans and human activities rather than ecologically, evolutionarily, or biogeographically dictated distributions (Channell & Lomolino, 2000; Lomolino *et al.*, 2010).

Available resources are not sufficient to protect the world's biodiversity (Vane-Wright, Humphries & Williams, 1991) and so they must be targeted to prioritised areas to maximise effectiveness, known as the 'conservation allocation resource problem' (Wilson *et al.*, 2006). Mapping of multiple species distributions is commonly used to identify biodiversity hotspots or areas of other ecological importance, which can be used to inform and target conservation efforts to priority areas (Myers *et al.*, 2000; Roberts *et al.*, 2002). Similarly, it is often impossible to protect an entire population when carrying out conservation of a specific species. Quantifying species distribution is crucial to inform conservation planning (Guisan *et al.*, 2013), and targeting species-specific conservation efforts often requires a means of identifying priority habitats within that distribution (Peralvo, Cuesta & van Manen, 2005; Olsson & Rogers, 2009; Ross *et al.*, 2011; Moore, 2018). In addition, effective conservation is reliant on understanding the spatial and temporal variations in habitat use and range. For example, by quantifying key areas of seasonal breeding and feeding activity of tagged endangered loggerhead turtles (*Chelonia mydas*), a marine protected area could be designed to target important core habitat (Schofield *et al.*, 2013).

Mapping based studies are commonly used to identify key species conservation areas, whether it be through direct observational surveys or more indirectly through modelling techniques. The resulting maps and data can be used as a useful conservation planning tool to identify previously unknown suitable habitat (e.g. Gogol-Prokurat, 2011); to inform appropriate mitigation and reserve placement (Cañadas *et al.*, 2005; Moore, 2018); or to inform other parameters relevant to conservation (Rodriguez *et al.*, 2007). Species mapping can also improve understanding of species ecology (e.g. Karpouzi, Watson & Pauly, 2007), and be used to predict changes in distribution under the influence of anthropogenic stressors such as climate change or significant habitat alterations (e.g. Kaschner *et al.*, 2011).

In addition to understanding important spatial and temporal habitat use, recent conservation research calls for threats to be specifically assessed and targeted to ensure effective species conservation (Carwardine *et al.*, 2012). This requires that notable threats and causes of population decline are identified and then investigated to quantify the level of interaction of the target species with each threat on a range of spatial and temporal scales (e.g. Barve *et al.*, 2005; Tulloch *et al.*, 2015; Abram *et al.*, 2015; Lacy *et al.*, 2017). Quantifying the overlap of threats and a species can help to identify and understand potential drivers of decline (Abram *et al.*, 2015), and to identify key target areas of higher and lower threat intensity (Barve *et al.*, 2005), both of which are vital for conservation planning. The data from these kinds of studies can be used to inform mitigation choices, reserve selection, and specific targeted actions to reduce the impact of threats on a species.

If information on both key habitat use and potential threats is not available, conservation is likely to be poorly informed and may not be targeted to key habitat and to key causes of decline. Any intervention employed will therefore be less likely to be effective and this increases the risk of wasting resources. For species that are experiencing rapid population decline, wasting invaluable time can increase the risk of extinction.

3.2.2 Identifying key habitat and conservation areas for cetacean species

Accurate identification of priority areas relies on robust ecological and biological data and an accurate understanding of species distribution and movements on both spatial and temporal scales. Most cetacean species have key habitats or areas of higher occupancy, often chosen for important life history stages such as breeding or as key hunting grounds (Weir, Stockin & Pierce, 2007; Hauser *et al.*, 2007; Viddi *et al.*, 2010). Site occupancy therefore varies seasonally with respect to life history phases or seasonality of food availability (Shirakihara *et al.*, 2008; Nuuttila *et al.*, 2018; Esteban *et al.*, 2018). Distribution and movement of aquatic mammals specifically can be further affected by the nature and intensity of anthropogenic disturbances, which can cause both long (Sorensen *et al.*, 1984; Lusseau, 2005) and short-term (Lusseau, 2005; Nowacek, Wells & Solow, 2001) displacements or alterations to residency patterns. Additional to this point, the presence of potential threats or anthropogenic activity can cause avoidance behaviour of aquatic mammals at a local scale, further altering fine-scale distribution of a species (Gilman, Brothers & McPherson, 2006; Bailey *et al.*, 2010; Haskell *et al.*, 2015; Bas *et al.*, 2017).

Although overall biodiversity or distribution maps are a useful tool in conservation planning, Williams *et al.* (2014) argue that density maps are more informative and important for protecting marine (and, by extension, freshwater) cetaceans, as they allow identification of important core habitats. For cetaceans, these habitats may be key breeding (Weir, Stockin & Pierce, 2007) or feeding grounds (Esteban *et al.*, 2018), areas of high density of individuals

(Arcangeli *et al.*, 2014; Wang *et al.*, 2016), or other areas of seasonal importance (Pikesley *et al.*, 2012). Density data for mammal species are often presented in the form of gridded density data (Boitani *et al.*, 2011), as these types of maps can easily be used to identify regions of high ecological importance for highly mobile species (Rondinini *et al.*, 2006; Boitani *et al.*, 2011).

Distance sampling is the predominant method used to observe and study cetaceans. This method has been used to estimate absolute abundances and distribution of freshwater cetaceans such as the Ganges river dolphin (Richman *et al.*, 2014), the Amazon River dolphin (*Inia geoffrensis*) and tucuxi (*Sotalia fluviatilis*) simultaneously (Campbell *et al.*, 2017), and the Yangtze finless porpoise (Kimura *et al.*, 2010; Zhao *et al.*, 2013). Often this approach involves fairly complex field methodology, such as combined visual and underwater acoustic surveys to detect cetacean click trains or song (Akamatsu *et al.*, 2001; Kimura *et al.*, 2009; Richman *et al.*, 2014). This combined method is used to account for availability and detectability biases, which are caused by diving behaviour and observation error, respectively. Rigid methodology and compliance with assumptions must be employed if this method is used to estimate absolute abundance of a target population (Buckland, 2001; Buckland *et al.*, 2015).

If the intention of the survey is not to get absolute population estimates, but instead to attain distribution or habitat use information, rapid sampling using visual observation surveys can be employed (e.g. O’Hern *et al.*, 2014; Marcoux *et al.*, 2016; Ilangakoon & Alling, 2016; Moore & Barlow, 2017). These types of methods are often used to evaluate relative abundance or seasonal distribution changes rather than absolute population counts. For example, Braulik *et al.* (2017) employed rapid visual observation survey techniques to assess the distribution of multiple cetacean species and potential threatening activity without requiring acoustic sampling rigid and time-consuming survey techniques. By ensuring that the survey methods are consistent across areas or seasons, relative counts will be comparable between surveys and observed changes in the distribution of individuals can still be assessed.

3.2.3 Threat mapping as a conservation tool

Mapping of potentially threatening processes (hereafter referred to as “threat maps”) can be a useful tool in trying to understand identify key threats (Jarvis *et al.*, 2010; Sadovy de Mitcheson *et al.*, 2013) and to investigate the spatial and temporal dynamics of multiple threats to a species or system (Evans *et al.*, 2011; Abram *et al.*, 2015; Tulloch *et al.*, 2015). This process can be used to identify hotspots of potential threats (Karpouzi, *et al.* 2007), and to quantify how a population of conservation concern may be overlapping spatially with specific threats (Barve *et al.*, 2005; Gallardo & Aldridge, 2013). As both threats and species distribution can vary temporally, identifying how such patterns of overlap changes over time (e.g. seasonally) may also be critical to inform conservation efforts. Mapping of threats within already established protected areas can also be used to assess the effects of human presence on at-risk species (Barve *et al.*, 2005) or to assess cumulative effects of stressors to enhance current ecosystem restoration efforts (Allan *et al.*, 2013).

Threat mapping is often used to inform conservation decisions (Tulloch *et al.*, 2015), and the resulting maps can be used as a tool to inform allocation of conservation resources and inform spatial planning and management (Halpern *et al.*, 2008). Threat maps can also be used to inform various stages of conservation decision making process (Chapter 5 of this thesis), by informing system status, by indicating where multiple threats and therefore multiple actions may be needed, by informing outcomes of interventions (or if no intervention is taken), and by helping managers prioritize target areas for intervention (Tulloch *et al.*, 2015).

Threat mapping is a commonly used method of investigating population decline and conservation of cetacean species and can be used to identify threats and investigate spatial overlap. For example, Braulik *et al.* (2017) used a rapid survey technique to identify key habitat and threats to cetacean species along the coastline of Tanzania. This included a vessel-based survey, a simultaneous assessment of visible threats, and an interview survey with fishers to understand bycatch. Similarly, Breen *et al.* (2017) used mapping methods to quantify overlap of harbour porpoise (*Phocoena phocoena*) and fishing activity, and Coll *et al.* (2012) mapped the overlap of Mediterranean aquatic mammals and threats by combining and mapping independent sources of species and threat data, highlighting key areas of conservation concern. These are all key data gaps for the YFP, and there is an urgent need to identify and target threats to this species.

Despite their potential, no standardised methodology exists for the production of threat maps, although the International Union for Conservation of Nature Conservations Measures Partnership (IUCN-CMP, 2018) and Salafsky *et al.* (2008) have proposed a method of standardised classification and nomenclature for threat assessments. This method recommends investigating the timing, severity and scope of each threat to assess the potential impact.

Research into underlying threat mechanisms and related conservation measures for threatened species has received relatively little attention in China (Ma *et al.*, 2017), and studies quantifying the broader spatial and temporal scales of threats are also notably lacking within China compared to other conservation topics (Ma *et al.*, 2017). Poor understanding of both species and threat distribution has major implications for effective conservation. Without these sorts of analyses or research, it is impossible to identify and robustly assess threats. Reserve design is also likely to be poorly informed and therefore may not be effective in reducing threats or increasing species survival rates.

3.2.4 Current understanding of spatial and temporal distribution of YFP

On a Yangtze-wide spatial scale, some YFP distribution patterns have already been identified during the YFDE surveys conducted by the IHB, including areas of high and low conservation value and some distribution gaps (Zhao *et al.*, 2008; Mei *et al.*, 2014, note that these data are not currently available from the IHB and so has not been used or presented here), which matches reports that genetic isolation is occurring (Chen *et al.*, 2017). On a smaller spatial scale, boat-based survey data have shown that in the Yangtze mainstem, YFP prefer the confluences of rivers (Zhang *et al.*, 1993; Wei *et al.*, 2003) where abundance and species richness of fish is higher, especially species that inhabit the surface waters (Zhang *et al.*, 2015). Presence of YFP is strongly associated with fish presence (Zhang *et al.*, 2015; Mei *et al.*, 2017). Further quantifying the distribution of YFP in the mainstem is therefore not a priority.

Seasonal movement of YFP so far not been investigated as census surveys have only been conducted in November. It is arguably more important to better understand the interaction of YFP with threats on more local temporal and spatial scales, so that mitigation can better be informed and reserve areas can be appropriately designed, located, and managed.

Mei *et al.* (2017) investigated habitat preference of YFP in the minimally disturbed habitat within Hewangmiao semi-natural reserve, which has had all potential threats controlled or entirely removed. Within this population, preference was shown for moderate water depths between 12 and 17m, a flat benthic slope of lower than 2 degrees, and a moderately-high fish density. Although this is useful to understand habitat preference of YFP, whether these preferences are consistent across wild populations that occur in different freshwater environment across the Yangtze drainage is still unclear, and how these habitat preferences may be modified by the presence of threats is poorly understood. Some anecdotal observations of YFP movement between Poyang Lake and the Yangtze mainstem have also been reported (Mei *et al.*, 2014) but there are no consistently collected data to indicate how frequently this occurs or whether it is a seasonal or more permanent individual range shift.

3.2.5 Present understanding of spatial and temporal distribution of potential threats to YFP

The wide range of potential threats to YFP varies from broad scale (e.g. habitat modification of Yangtze ecosystem from Three Gorges Dam) to smaller, localised scales (e.g. localised patterns in fishing gear presence). Following the information presented and discussed here in Chapters 1 and 2, it is understood that the remaining YFP population is under threat from multiple potentially threatening processes that are causing severe population decline. These threats vary on both spatial and temporal scales (e.g. fishing is seasonal in intensity, and sand mining may be restricted by high or low water seasons) but the spatial and temporal dynamics of these potential threats are not well understood, and so far have only been investigated on a coarse Yangtze-wide spatial scale (chapter 2 of this thesis).

The severe lack of data relating to spatial and temporal distribution and overlap of threats and YFP is restricting the ability of decision makers to make informed choices with regards to conservation interventions. For example, there are very few data to inform where best to place reserves in key remaining habitat, as fine-scale spatial distribution of key YFP habitats and threats is not well understood (Turvey *et al.*, 2013). Despite this, a number of reserves are in place both in the Yangtze main stem and two lake systems (WWF-China, 2017). How these have been allocated, designed and managed is not clear (IHB, pers. comm.). Improving understanding of the spatial overlap of threats and YFP is therefore vital to inform mitigation.

3.2.6 Poyang Lake: a highly seasonal key YFP habitat

Poyang Lake is a highly seasonal environment; in the winter the water level is so low that it becomes comparable to a river-type habitat, whereas in summer the lake extent increases drastically such that large floodplains are inundated (Figure 3.1). Between October 2009 and August 2010, for example, the lake extent varied from a low of 714.1km^2 to a maximum of 3162.9km^2 (Feng *et al.*, 2012). These significant seasonal changes in aquatic habitat extent at Poyang Lake are likely to alter the distribution of prey resources and therefore the distribution of YFP (Zhang *et al.*, 2015). Key threats (shipping lanes, fishing grounds, etc.) are also likely to have a different distribution between seasons, as fishing and sand mining activities move to match their respective resource requirements.

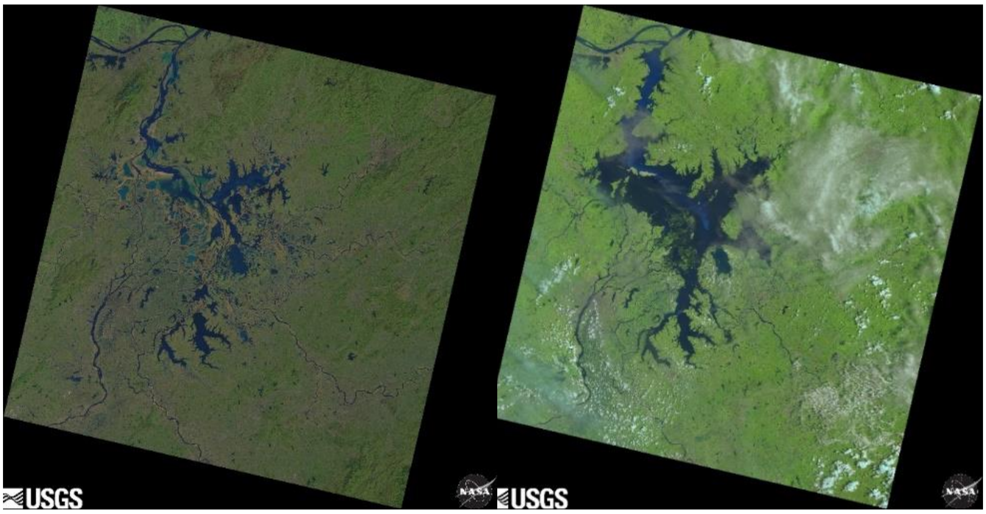


Figure 3.1: USGS satellite imagery showing the change in extent of Poyang Lake between winter (left) and summer (right)

Poyang Lake is a key remaining habitat of the YFP, with around half the remaining population observed there during the 2012 YFDE (Mei *et al.*, 2012). However, localised YFP density patterns within the lake are not well understood, and neither is the effect of the lake's seasonal changes on YFP and threat distribution. In addition, understanding whether YFP are influenced by presence of threats (such as avoidance behaviour) is also vital. Understanding the dynamics of YFP and threat overlap is vital for informing conservation, yet it has never been investigated or quantified. These data gaps have conservation implications; reserve areas are usually fixed in their area coverage and do not shift to account for seasonal variation in the distribution of species or threats. Two YFP reserves currently exist in Poyang Lake, Longkou and Laoyemiao (Figure 1.3). These reserves were officially designated in April 2004, and are controlled by the Duchang and Poyang fisheries bureaus, respectively (IHB, pers. comm.). How and for what reasons these reserves have been assigned to their respective areas is not clear. It is vital that the reserves in this key habitat are well placed to target areas of high YFP density, and to ensure that threats within the reserves are being removed or at least reduced in density. However, whether these reserves cover key YFP habitat has not been clarified in any published literature.

To investigate the significant data gaps noted above, this study quantified the spatial and temporal overlap of YFP and threats in the key habitat of Poyang Lake on a range of spatial scales. Here, YFP and observable threats (sand-mining activity and fishing) are investigated simultaneously through boat-based mapping at both high-water and low-water period, and temporal and spatial patterns and overlap of threats and YFP are investigated in relation to the two existing YFP reserves. Poyang Lake was chosen as a key study area as it contains a relatively large proportion of the remaining YFP population; the last census in 2012 estimated the remaining population at 450 (Mei *et al.*, 2014). High density of individuals in this system means that they can be observed frequently enough to obtain sufficient data for robust statistical analysis. Investigating the distribution of YFP and threats in this system may also provide insights into why there is still a relatively large population remaining in this habitat compared to the Yangtze mainstem.

3.2.7 Research questions

- How does YFP distribution vary seasonally in the key remaining habitat of Poyang Lake?
- What are the key spatial and temporal patterns in threat distribution and density in Poyang Lake?
- How does the presence and intensity of threats overlap with YFP presence?
- Does the presence of threats influence the distribution of YFP?
- How does the variation in YFP and threats relate to current and potential mitigation options?
- Do the current protected areas in Poyang Lake cover seasonally appropriate YFP habitat?
- Have the current protected areas in Poyang Lake been successful at removing potential threats to the YFP?

3.3 Methods

3.3.1 Seasonal YFP distribution and threat mapping surveys

3.3.1.1 Boat survey method

A combined threat-YFP survey was conducted using a visual transect based boat survey in winter 2016 and summer 2017. Each survey lasted six days (Table 3.1). These two surveys represent winter, low-water, low fishing season (hereafter referred to as "winter survey"), and summer, high-water, high fishing season (hereafter referred to as "summer survey"). Further details are listed in Table 3.1. The survey vessels used were relatively small, single engine fishing vessels captained by local fishers familiar with the area in which the survey was conducted. Each observer team consisted of two surveyors, always including the author. To ensure uniformity of survey effort and procedure, each observer was trained in how to use the equipment required for the survey, how to record data, and the specific survey method outlined below.

A standard systematic distance-sampling zig-zag design (Buckland *et al.*, 2007; Thomas, Williams & Sandilands, 2007; Dawson *et al.*, 2008) is not possible within the constraints Poyang Lake; this pattern is unsafe and impractical due to narrow shipping lanes and the high density of shipping traffic (Zhao *et al.*, 2008). The only feasible survey route is along the centre of the channel within the limits of safety, parallel to the banks on either side (as far as is possible). The survey route was chosen based on previous surveys conducted by the IHB, who have been conducting YFP census surveys in Poyang Lake in March for several years (Figure 3.2). This route is the only navigable route that can be taken from Hukou (North Poyang Lake) to Ruihong (South Poyang Lake) when the water level is very low in the winter and can thus be followed in both summer and winter to compare seasonal differences in YFP and threat presence. Previous surveys using this route have gathered sufficient observation data (IHB, pers. comms.), so a pilot survey to investigate detectability was not deemed necessary.

Mean on-effort survey speed was 11.59 km/hr in summer and 10.70 km/hr in winter. Continuous vessel speed data recorded in the GPS show that mean speed was significantly faster in the winter (two sample-t (6079.9) = 6.2077, $p<0.001$) due to stronger currents in winter. However, as all of the mean speeds are well above the mean speed of YFP, which is estimated as 4.5 ± 0.5 km/hr (Akamatsu *et al.*, 2002), the likelihood of double counting is very low for both seasons. The small difference in mean speed (<0.9 km/hr for all) should not notably affect the survey results.

All observations of both YFP and visually detectable threat activity were recorded. The observable threats in this system were fishing activity and sand mining activity. One vessel was used for each survey, with a single observer team at an eyeline of at least 2.5m above water level. Observation teams comprised of two experienced observers using binoculars (Opticron Adventurer Wp 8x42) and a laser range-finder (Hawke LRF 600 Laser Range Finder). Left and right observers searched 90º off the bow of the vessel and 10º beyond the track line. All observations were made in passing mode, meaning the vessel continued on the track line whilst records were made (Dawson *et al.*, 2008).

Tracks and positions were recorded on a GPS device (Garmin GPSMAP64). Weather, visibility and wind conditions were monitored and recorded, and any change in these parameters was noted on record sheets. Data recorded from each YFP sighting included time, distance from the vessel, direction of observation from vessel, distance of group or individual from the nearest bank, number of YFP adults and calves in the group, direction of travel (from observation, hunting behaviour does not tend to be directional but travelling behaviour does; pers. obs.), notable behaviour, and the observer identity. An angle board was used to estimate angle from the boat on a 0-180 degree basis as per Buckland (2001). A group was defined as any gathering of YFP individuals within 100m of each other.

Threat activity was also recorded on the GPS, noting the direction and distance. If the observed threat activity was fishing, the type of fishing was noted if possible, and the number of boats estimated if it was a larger group of fishing vessels. Sand-mining activity was recorded as inactive or active vessels. Distance of any recorded YFP or threat observation from the vessel was estimated using a combination of calibrations from nearby objects using the range-finder and estimation by eye. Each observer was trained in the use of the laser range finder prior to beginning any survey and frequent testing and recalibration in different habitats and light environments were used to improve accuracy of distance estimation during the surveys.

In addition to the main route roughly running north to south in the lake, a ~20km long channel south of Xingzi was also included within the survey area (hereafter referred to as “the channel”). This channel has been surveyed by the IHB seasonally for several years in the winter season and has been observed to contain a relatively high number of YFP (IHB, pers. comms). The survey route was passed only once for the summer and the winter surveys, as a detour from heading north from Duchang to Xingzi (Table 3.1).

Table 3.1: YFP and threat mapping survey details

Section	Route	Summer survey		Winter survey	
		Date	Distance (km)	Date	Distance (km)
Northern PL	Hukou – Xingzi	12.9.2017	40.58	1.3.2016	41.87
Central PL	Xingzi – Duchang	13.9.2017	34.09	2.3.2016	34.1
Southern PL	Duchang – Ruihong	7.9.2017	66.61	3.3.2016	74.22
Southern PL	Ruihong – Duchang	8.9.2017	73.75	4.3.2016	72.82
Central PL	Duchang – Xingzi	9.9.2017	68.42*	6.3.2016	70.83*
Northern PL	Xingzi - Hukou	10.9.2017	40.29	7.3.2016	41.60

* Indicates section where the channel pass was made

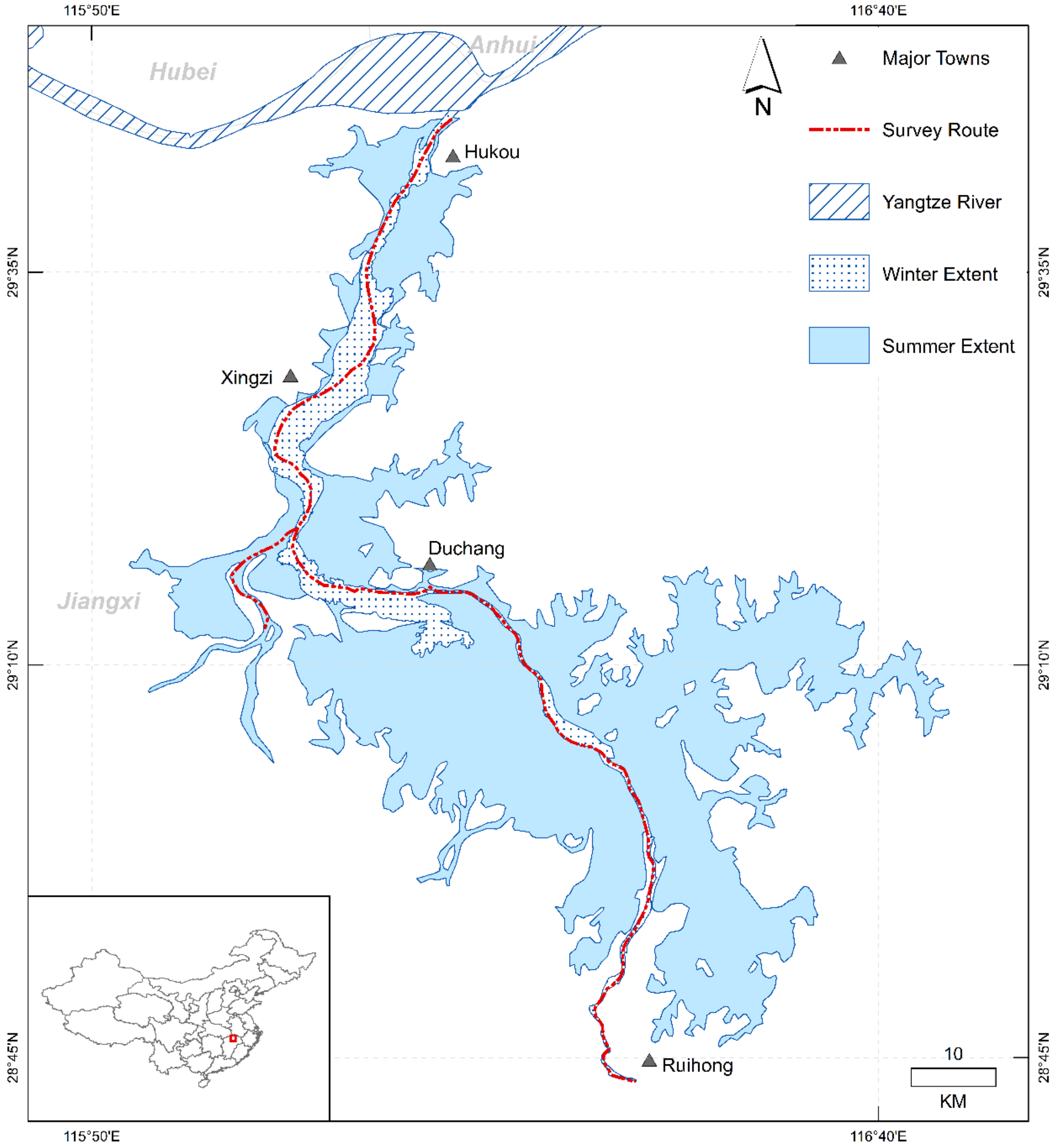


Figure 3.2: Detail of the route of boat based YFP and threat surveys on Poyang Lake in both winter and summer. Winter (low-water) and summer (high-water) lake extent demonstrate the seasonal difference in the lake size. Map made in ArcMap (ESRI, 2014).

Effort is considered uniform between summer and winter surveys as the same route was followed using the same GPS and tracks. Minor deviance from the planned route had to be taken for safety purposes and to take account for where currents and other vessels affected the navigation and effective speed of the boat. For aquatic environments, taking exact repeat lines for multiple transects is considered less important as the system is inherently mobile, meaning repeat transect lines are less likely to show correlation anyway (Buckland *et al.*, 2015, p. 211).

3.3.2 Post-survey processing and mapping methods

Individual survey day GPS tracks were refined and edited within GPS Track Editor (GPS Track Editor © 2010 – 2018) software and converted from GPX to shape files in ArcGIS (ESRI, 2014). Each shape file could then be edited and analysed within ArcGIS in relation to the threat and YFP survey data taken on each survey day.

3.3.3 YFP detection probability

To estimate effective strip width (ESW), numbers of visual YFP detections were plotted by distance from the survey vessel (Figure 3.3). During the summer survey, YFP observations were less frequent closer to the vessel (0-50m distance bin, Figure 3.3) than in winter surveys. This pattern is commonly observed in aquatic mammal distance sampling surveys where vessel avoidance behaviour is occurring (Buckland, 2001; Buckland *et al.*, 2007, 2015). In this instance, the marked difference between the 0-50m distance category between winter and summer may also be influenced by the increase in occupiable area that the YFP inhabit in the summer months in Poyang Lake; with more available space they are (1) more likely to be further away from the vessel as the distribution of YFP is less dense in the summer and (2) there is physically more space to allow YFP to avoid the survey vessel. Despite the minor visual differences in the data, there was no significant difference between winter and summer observations (Kendall's rank correlation test, $\rho = 0.43$, $p = 0.299$) and so they have been treated as comparable for further analysis.

Further analysis of these data under a typical distance sampling framework would require removal of any data beyond the ESW, and subsequent application of correction factors to achieve an estimate of total YFP abundance (Buckland, 2001). Here, we are not aiming to calculate an absolute YFP abundance estimate, but instead are investigating relative abundance across Poyang Lake within and between summer and winter seasons. Calculating absolute abundance from these data is not recommended as there are no acoustic data or second tailing survey vessel to calibrate detection probability (Buckland, 2001; Thomas *et al.*, 2007; Richman *et al.*, 2014). Estimates have therefore not been corrected for the proportion of animals missed on the survey line, a protocol that has also been used in other published studies (e.g. Richman *et al.*, 2014; Rone *et al.*, 2017). Instead, these data have been treated by a protocol aimed at ensuring that, in as much as is possible, the data are relatively comparable within and between seasons.

As is typical of cetacean observation surveys, visual inspection of the survey data indicate distinct declines at distance from the survey vessel in both summer and winter. From field observations, the estimated distance at which estimating group size and calf number in Poyang Lake became difficult (and therefore likely to be less accurate) with or without binoculars was 250m. To ensure group size and distance were as accurate as possible whilst also retaining as much information as possible, a distance of 250m was set as a cut-off for data analysis. This cut-off results in 88.6% (n=148 observations) of winter observations and 80.3% (n = 53 observations) of summer observations being included. Any further analysis presented here only contains YFP observations up to the cut-off of 250m.

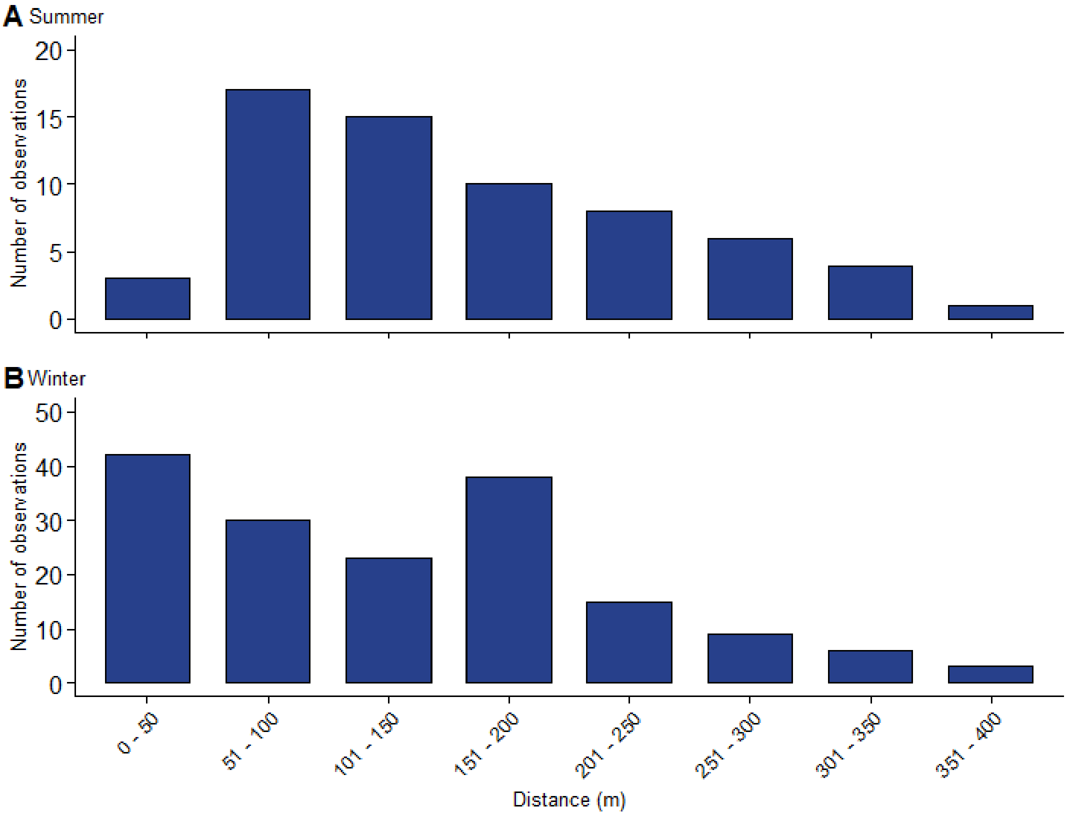


Figure 3.3: Total number of all YFP detections at perpendicular distances from the survey vessel during the summer survey (top, n = 64 groups observed) and winter survey (top, n = 166 groups observed) in Poyang Lake.

3.3.4 Encounter rate

Individual encounter rate (IER) is a commonly used metric used to investigate spatial variation in aquatic mammals (e.g. Di Tullio *et al.*, 2016; Braulik *et al.*, 2017; Rone *et al.*, 2017) and has previously been used as a parameter to analyse patterns in YFP distribution (Zhao *et al.*, 2013). IER is typically calculated as number of individuals per distance on-effort of survey (i.e. individuals/km), and can be used a metric of localised density to fill knowledge gaps and identify target conservation areas (e.g. Braulik *et al.*, 2017). Here, IER has been used to investigate spatial variation in YFP density across Poyang Lake, and temporal changes in YFP density across Poyang Lake between seasons.

To do this analysis, Poyang Lake (PL) was divided into three key sections: (1) northern PL, (2) central PL, and (3) southern PL, which correspond to the individual survey days of Hukou to Xingzi, Xingzi to Duchang, and Duchang to Ruihong, respectively. Encounter rates for each section were calculated here as observed number of YFP individuals per km of active survey. Individual encounter rate was also calculated for within and outside of the three Poyang Lake YFP reserves to investigate the effectiveness of their placement. For the investigation of IER inside and outside of the reserve areas, PL was divided into 6 sections roughly north to south Poyang Lake; Hukou to Longkou Reserve (1), Laoyemiao Reserve (2), Laoyemiao Reserve to Longkou Reserve (3), Longkou Reserve (4), the channel (5) and Longkou Reserve to

Ruihong (6). To investigate differences between sections, the encounter rates per KM in each section were tested using Mann-Whitney U tests in R.

3.3.5 Quantifying overlap of YFP and threats spatially and temporally

To convert the point observation data into an interpretable format, gridded maps have been created in ArcGIS v10.3.1 (ESRI, 2014). Separate maps were created for YFP observation data, and for the observed threat data relating to sand-mining activity and to fishing activity. Separate maps were created for both the summer and the winter data using the survey tracks and GPS data as detailed above.

To create these maps, the data had to be processed in a way to make summer and winter data comparable. To do this, a 300m buffer zone was created around the routes in summer and winter, meaning it was 600m wide. The buffer was not 250m (as with the distance that observation data were cut-off at) as the routes were slightly different due to practical restrictions in following the exact route in both seasons. A 300m buffer covered both summer and winter survey tracks and all data points within a 250m distance band.

A 1 x 1km grid was created that covered Poyang Lake. To restrict the grid to the vessel path, grid cells that do not cover any parts of the 300m buffer were removed, and the remaining overlapping grid cells were used to represent YFP observation and threat data. Within the remaining grid, the observational point data were converted to gridded data that represent the density of observed points within each grid cell. This method allowed both the identification of high- and low-density areas and identification of areas of higher and lower overlap of YFP and threats.

As the vessel route was nonlinear and the grid cells are in a linear north/south pattern, some grid cells will naturally overlap more with and therefore contain larger parts of the 300m buffer than others. This means there is not perfectly even coverage of the area within each grid cell. However, the grid cell pattern used is the same for winter and summer and for both threats and YFP, meaning coverage is equal between seasons, and comparisons of relative patterns of YFP and threat distribution and abundance between seasons can be made. As we are not investigating absolute abundance or absolute density, but rather we are looking at relative distribution, relative patterns within seasons are also still interpretable.

3.3.5.1 Investigating statistical hotpots of YFP and threat distribution

To statistically identify areas where YFP and fishing observations were most dense, the boat-based survey data were analysed using the Optimised Hot Spot Analysis tool in the Spatial Statistics toolbox in ArcGIS 10.3.1. This tool uses the Getis-Ord* statistic to identify statistically significant clusters of high or low values within a data set (Getis & Ord, 1992). Only data within 250m of the survey vessel were included. To allow the tool to work effectively, a 1x1km grid was overlaid over the 300m survey route buffer zone with ArcGIS. Each of the grid cells do not have equal survey coverage, as overlap with the survey route was not uniform. However, no assumption of uniform coverage is required for the optimised Hot Spot analysis, and the overlap of each cell with the survey route is equal between seasons. This means effort and coverage within each cell is comparable between seasons. This allows identification of “relative hot-spot areas” both within and between seasons. The resulting hot-spot maps were plotted using ArcGIS. The two YFP reserve within Poyang Lake were also plotted to assess patterns of seasonal overlap with fishing activity and YFP presence.

3.3.5.2 Nearest threat analysis

To quantify the spatial overlap of observed threats and YFP observations, the distances between these two types of observation data were analysed. For each individual YFP observation, the distances to the nearest fishing activity and nearest sand-mining activity was measured using the “RANN” package (Arya *et al.*, 2015) in R v3.4.3 (R Core Team, 2017) separately for both seasons. As with the grid analysis described earlier, only data within the 250m of the survey route were used, contained within the same 300m buffer zone shape file as described before.

To understand whether YFP observations were closer to or further from threats than would be expected if they were distributed at random, these mean values were then compared to mean values for the same number of random points, which were generated within the same 300m buffer shape file using the “sp” package in R (Pebesma & Bivand, 2005). The distance between the random points and the observed threat data was then measured in the same way as with the observed YFP data. Using a loop function in R, this process was repeated using 10,000 randomly generated sets of points to create a distribution against which the observed YFP data could be compared with. The mean distance of each of the 10,000 iterations was combined to create a null distribution to which the observed data could be compared. By comparing the distances between observed data and simulated data, it could be determined whether the observed YFP data were closer to or further away from each threat than would be expected using a 95% significance threshold.

3.4 Results

3.4.1 How does YFP distribution vary spatially and seasonally?

Far fewer YFP were observed in the summer survey, as would be expected due to the large increase in the size of Poyang Lake in summer (Table 3.2). Mean group size was not significantly different between winter and summer surveys (Figure 3.4, two-sample t(177) = 0.84, p = 0.4). The number of calves observed per group did not significantly vary between winter and summer (two-sample t (94.46) = 0.54, p = 0.591); fewer calves overall were observed in winter (Table 3.2), which is expected as YFP predominantly give birth in spring.

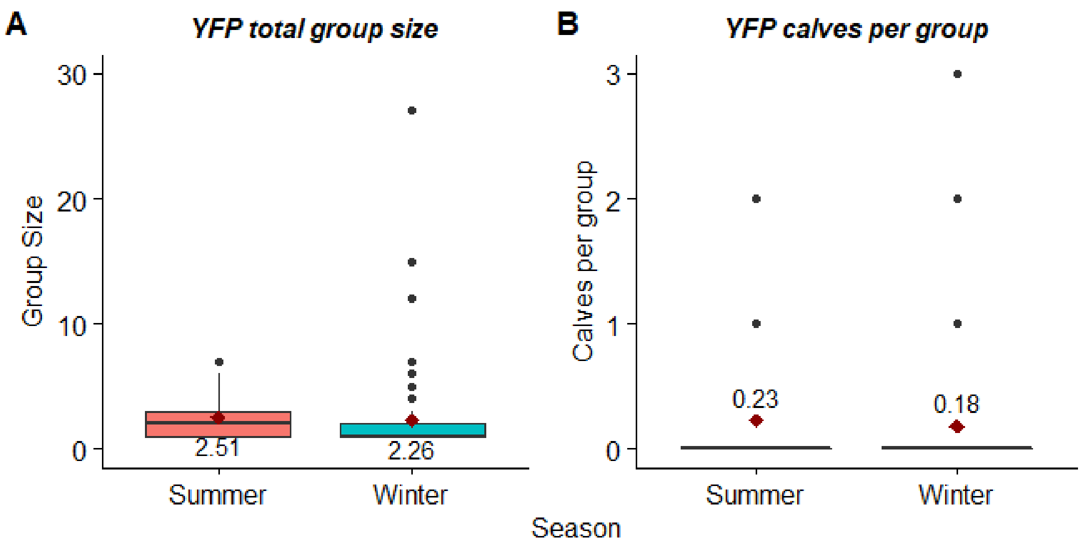


Figure 3.4: Group size of observed YFP in both summer and winter surveys (summer survey n = 133, winter survey n = 334) and calves observed per group (summer survey n = 12, winter survey n = 27)

Table 3.2: Details of summer and winter YFP boat survey data

Parameter	Winter survey	Summer survey
Number of observations (groups)	148	53
Total YFP observed	334	133
Number of calves observed	27	12
Calves (as proportion)	8.08%	9.02%
Mean number of calves per group	0.19	0.23
Mean group size	2.24	2.51
Max/min group size	27 / 1	7 / 1

There are clear seasonal differences in YFP distribution between winter and summer (Figure 3.5). In winter, YFP were observed throughout the lake at relatively high density, with statistically significant demarcated hotspots in central and south Poyang Lake (Figure 3.6). In contrast, there were large gaps in distribution in the summer survey; no YFP were observed south of Longkou reserve in summer, and very few were observed north of Xingzi in north Poyang Lake (Figure 3.5). Significant hotspots were only present in central Poyang Lake in the summer (Figure 3.6).

Calf observations showed a similar pattern, being distributed throughout Poyang Lake in winter but predominantly restricted to central Poyang Lake in summer, and with no clear areas of high calf density to indicate calving grounds. There were too few calf observations to analyse using the Getis-Ord* statistic, which required at least 30 data points, so these data have been mapped in the 1x1km matrix (Figure 3.7).

3.4.2 YFP Encounter Rates

The encounter rate of YFP varied between seasons; IER was significantly higher in northern Poyang Lake (w = 2995, p <0.01) and southern Poyang Lake sections (w = 8245.5, p<0.01) in winter than summer (Table 3.3). The IER did not differ between seasons for the central Poyang Lake section (w = 4812, p = 0.096).

In both winter and summer, there was a lower IER in northern Poyang Lake compared to southern Poyang Lake (w = 8104, p <0.001; w = 6791, p<0.01, respectively). In addition, IER was significantly higher in southern Poyang Lake than central Poyang Lake in winter (w = 9512, p < 0.001). IER was lowest in northern Poyang lake in summer (w = 3824, p<0.05). There were too few calf data to statistically analyse differences between the sections of Poyang Lake, so the data have not been shown.

Table 3.3: Individual encounter rate (IER, individuals/km) during summer and winter Poyang Lake surveys for each section from north (Hukou) to south (Ruihong) Poyang Lake

Section	Route	Winter	Summer
		YFP encounter rate (individuals/km)	YFP encounter rate (individuals/km)
Northern PL	Hukou – Xingzi	0.333 **	0.037 * **
Central PL	Xingzi – Duchang	* 0.451	0.339
Southern PL	Duchang – Ruihong	1.560	0.642
Mean		*0.781*	*0.030*

* indicates significant difference at the 5% level, ** at the 1% level

When comparing patterns of YFP density within and outside of the two protected areas, encounter rate significantly varied between many of the sections in winter and summer (Section 3, Table 3.4). Key results of the Mann-Whitney U tests are shown here, but full results of the analyses between all sections are shown in Appendix B.

In winter, the observed IER was significantly higher in Laoyemiao YFP reserve than in section one (w=1446.5, p=0.0246) and the channel (w=456, p<0.01, Table 3.4). Longkou YFP reserve had a high IER than the channel also (w=263, p<0.05), but IER was not higher in either of the reserve areas than for any other section (Table 3.4).

In summer, IER was higher in Laoyemiao YFP reserve than section one (w=1451.5, p<0.01) and section six (w = 1291.5, p <0.001). IER was not higher in Longkou reserve than any other section in summer (Table 3.4). Section six could not be tested using this analysis for the summer survey, as there were no observations of YFP in section six, this invalidates the statistical test.

Table 3.4: Individual encounter rate (IER, individuals/km) during summer and winter Poyang Lake surveys within Longkou and Laoyemiao Reserves, and in the four sections outside of the reserves. The order of sections is roughly North – South.

* indicates significant difference at the 5% level, ** at the 1% level

Lake section		Winter	Summer
1	Hukou – Laoyemiao Res.	0.4667 * ** **	0.0734 ** **
2	***Laoyemiao YFP Res.***	0.8235 **	0.6364
3	Laoyemiao Res. – Longkou Res.	1.644 **	1.086 *
4	***Longkou YFP Res.***	0.421 *	0.1667
5	Channel	0.2368 **	0.1765
6	Longkou Res. – Ruihong	1.46	0

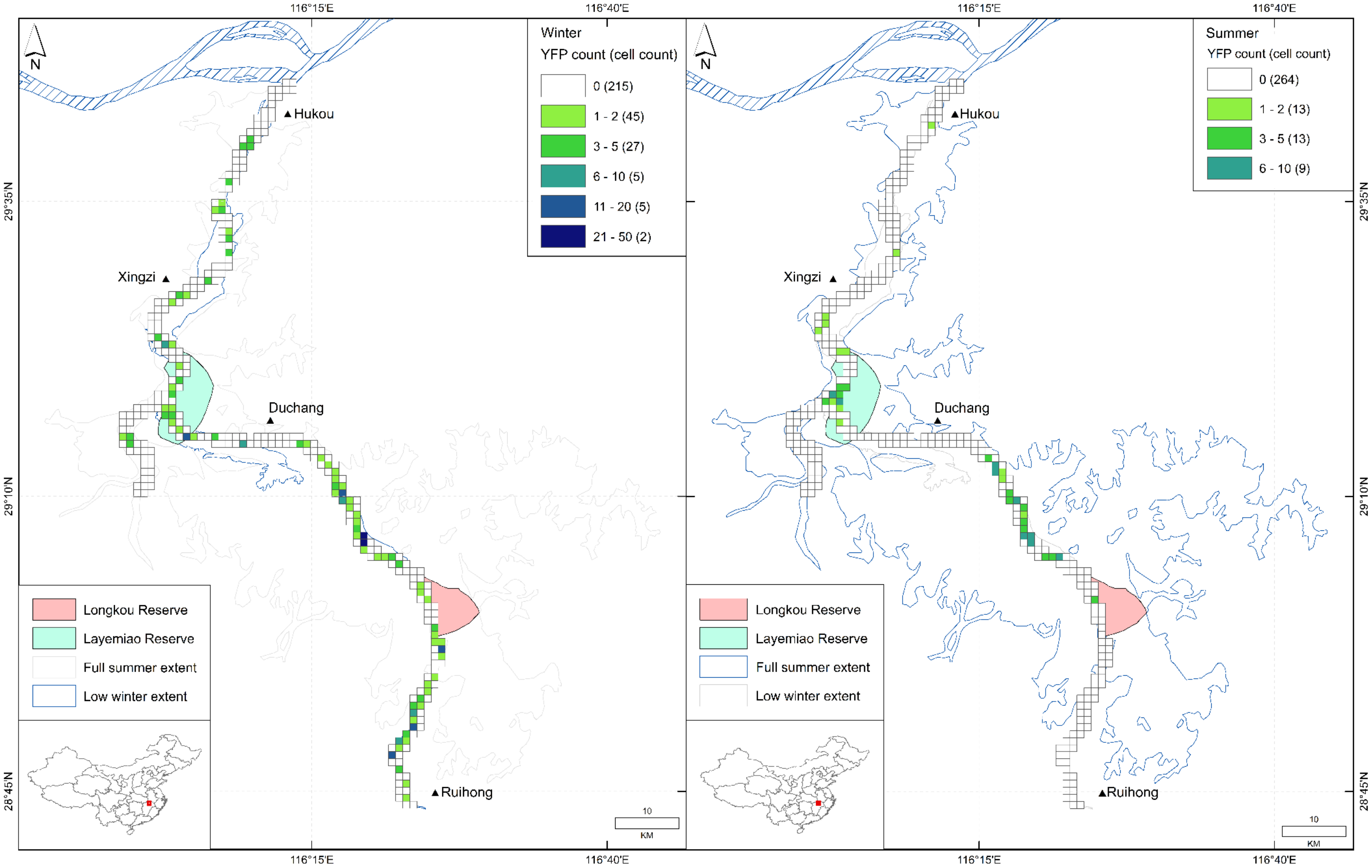


Figure 3.5: Distribution of YFP observations in Poyang Lake from the winter survey (left, number of groups = 148, total number of individuals = 334) and summer survey (right, number of groups = 52, total number of individuals = 133). Squares represent approximate 1km^2 areas covering a mid-line survey route following the centre of the northward and southward survey paths +300m to cover all observation points. Map made in ArcMap (ESRI, 2014).

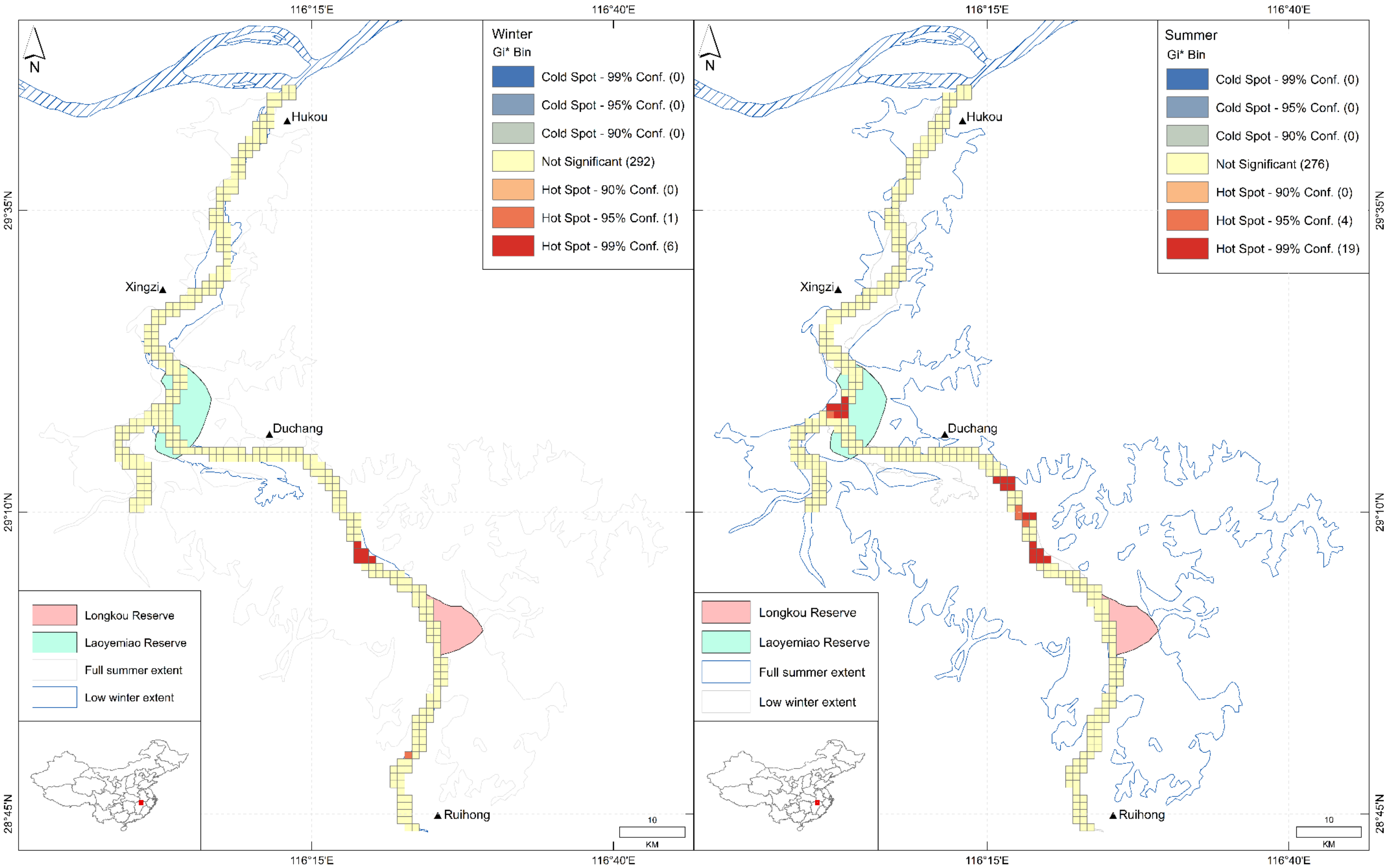


Figure 3.6: Statistically significant hotspots of YFP presence observed during the winter (left) and summer (right) surveys. Hotspots were calculated using the Getis-Ord* statistic in ArcGIS. Map made in ArcMap (ESRI, 2014).

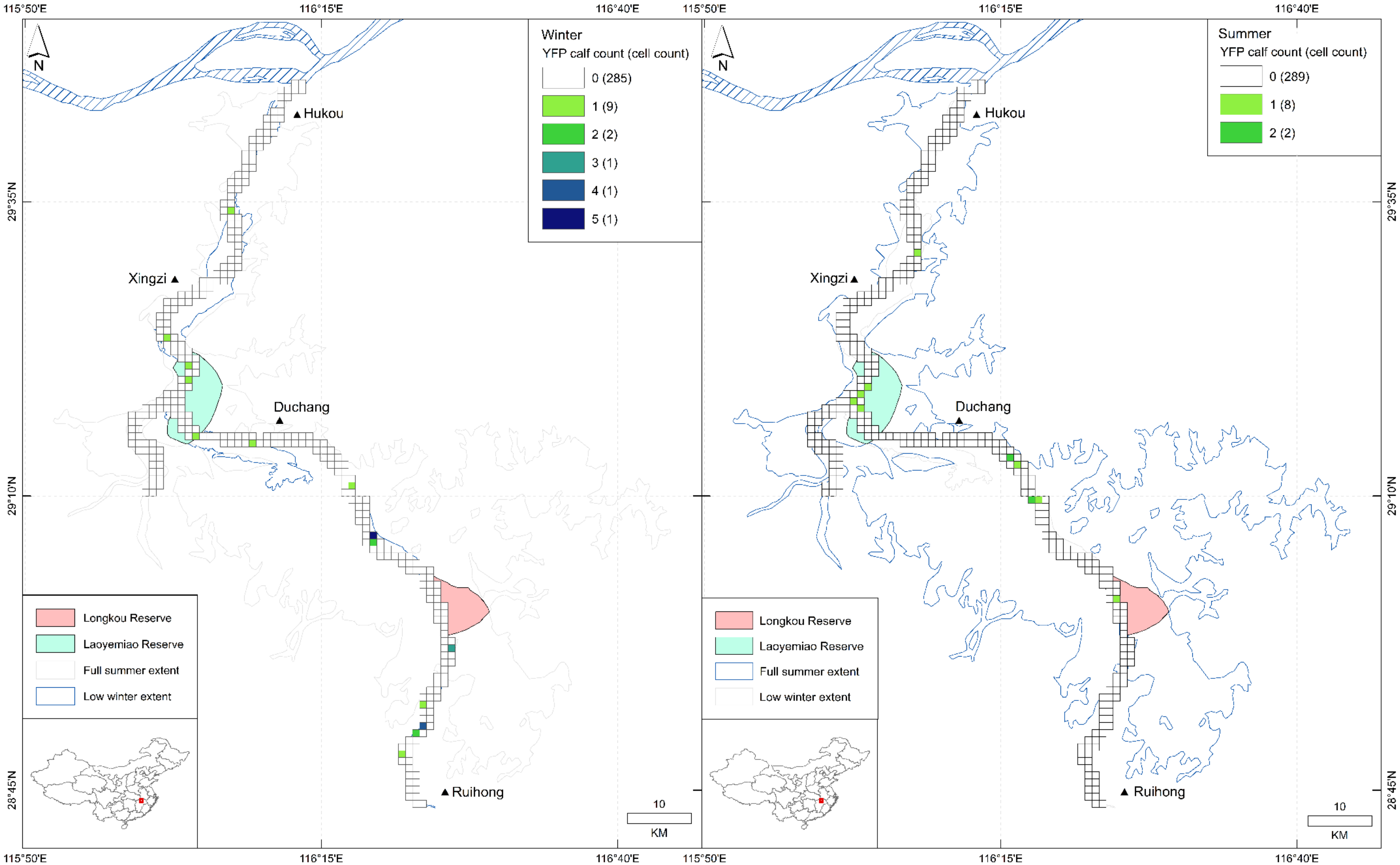


Figure 3.7: Distribution of YFP calf observations in Poyang Lake from the winter survey (left, number of groups with calves = 20, total number of individuals = 27) and summer survey (right, number of groups containing calves = 10, total number of individuals = 12) Squares represent approximate 1km^2 areas covering a mid-line survey route following the centre of the northward and southward survey paths +300m to cover all observation points. Map made in ArcMap (ESRI, 2014).

3.4.3 How are threats distributed spatially and temporally?

Fishing activity was more frequently observed in summer than in winter (Figure 3.8), with 93 observations in summer and 56 observations in winter. In both seasons, fishing activity was densest in the north of Poyang Lake between Duchang and Hukou, and in the far south of the lake near Ruihong (Figure 3.8). In winter, there were three significant hotspots in the north of the lake and one in the south near Ruihong (Figure 3.9). In summer, a significant hotspot was also present near Ruihong, but a significant hotspot was also detected between Duchang and Longkou reserve (Figure 3.9).

Sand-mining activity was also more frequently observed in summer (50 observations) than in winter (18 observations) (Figure 3.10). In both seasons, sand-mining predominantly occurred in the north of Poyang Lake, with most vessels observed near Xingzi port. Hotspots of sand-mining activity were present around Xingzi and between Xingzi and Hukou in both summer and winter (Figure 3.11). In summer, sand-mining activity occurred further south in the lake compared to winter.

Fishing activity was observed within both Longkou and Laoyemiao reserves in summer and winter (Figure 3.8, Figure 3.9), with a large number of observations of fishing activity were observed within Laoyemiao reserve in particular in both seasons (Figure 3.8). Sand-mining activity was observed in Laoyemiao reserve in winter, and in both reserves in summer (Figure 3.10, Figure 3.11). No patrols or enforcement activity was observed during the surveys.

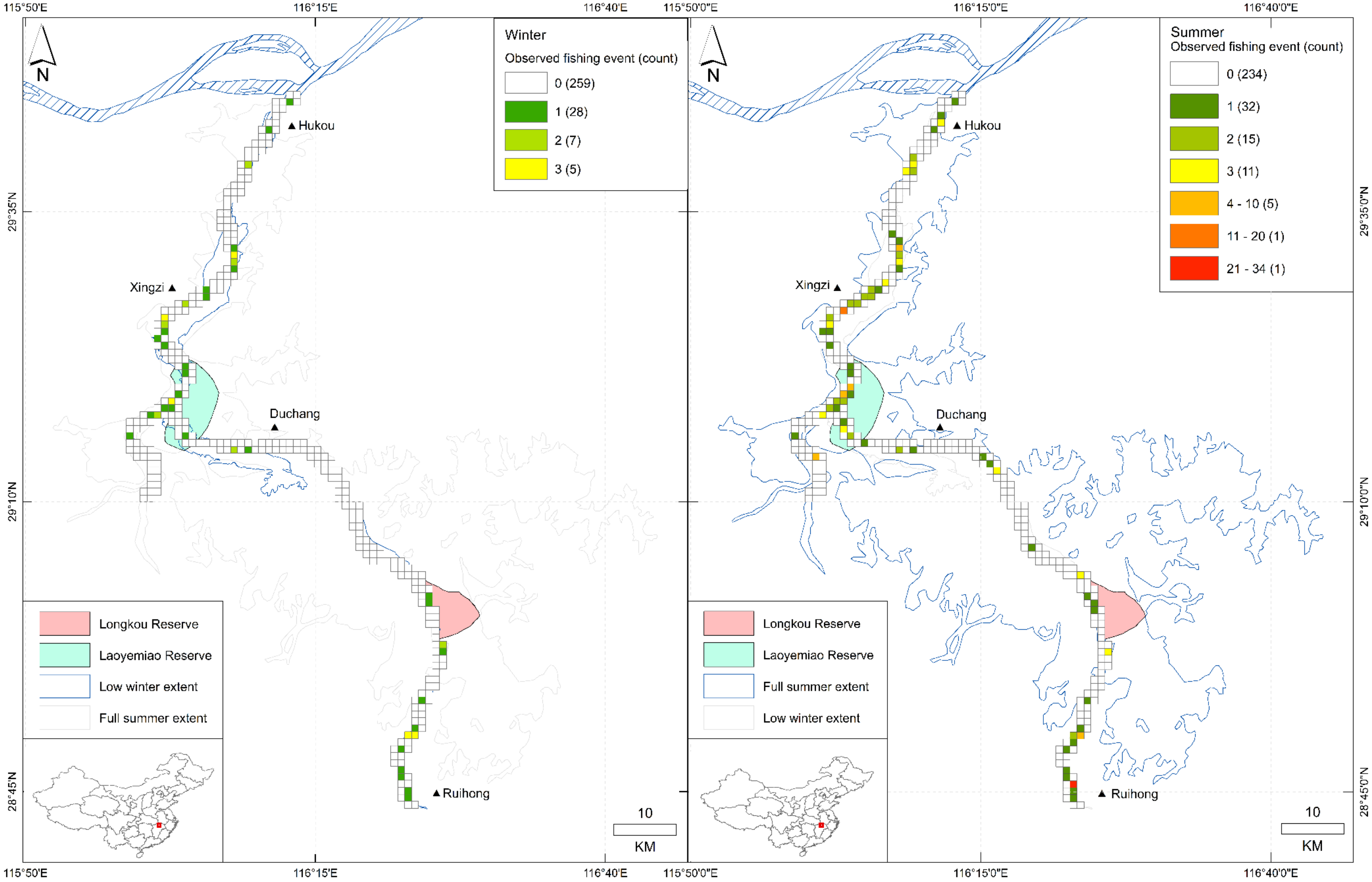


Figure 3.8: Observed incidences of active fishing vessels or equipment in Poyang Lake during the winter (left) and summer (right) surveys within the 250m buffer. Map made in ArcMap (ESRI, 2014).

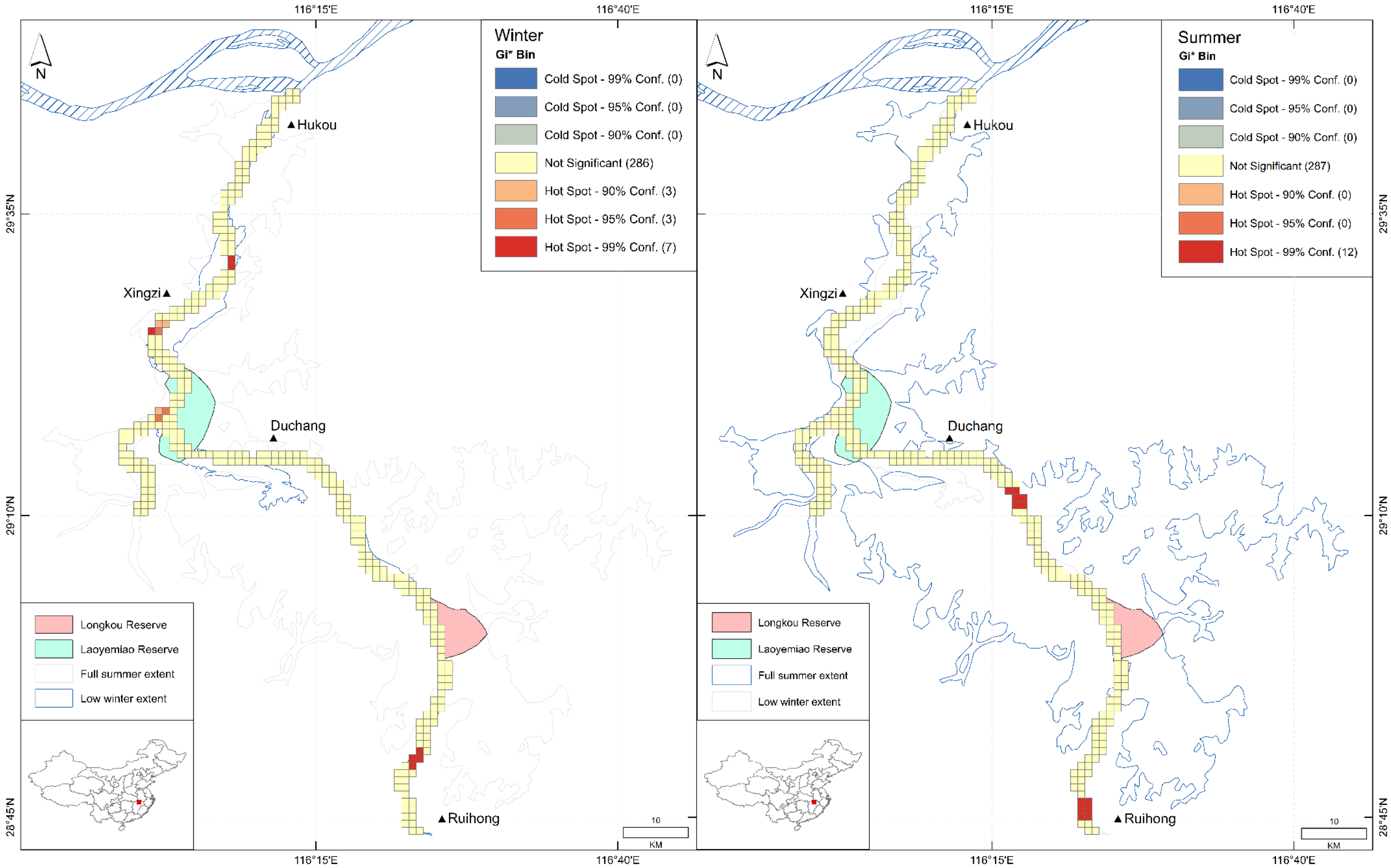


Figure 3.9: Statistically significant hotspots of fishing activity observed during the winter (left) and summer (right) surveys. Hotspots were calculated using the Getis-Ord* statistic in ArcGIS. Map made in ArcMap (ESRI, 2014).

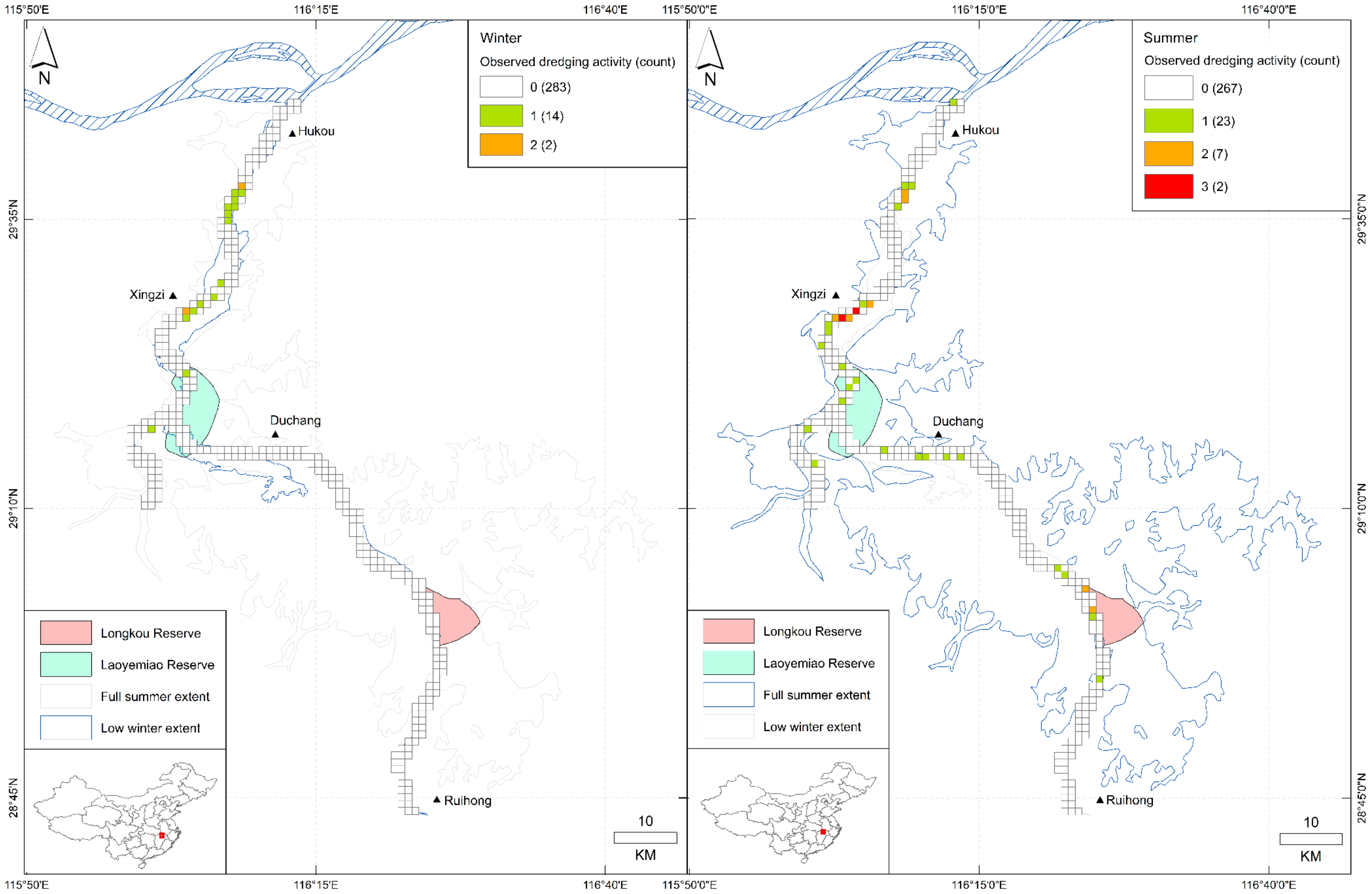


Figure 3.10: Observed incidences of active sand mining vessels and sand mining activity in Poyang Lake during the winter surveys within the 250m buffer. Map made in ArcMap (ESRI, 2014). Map made in ArcMap (ESRI, 2014).

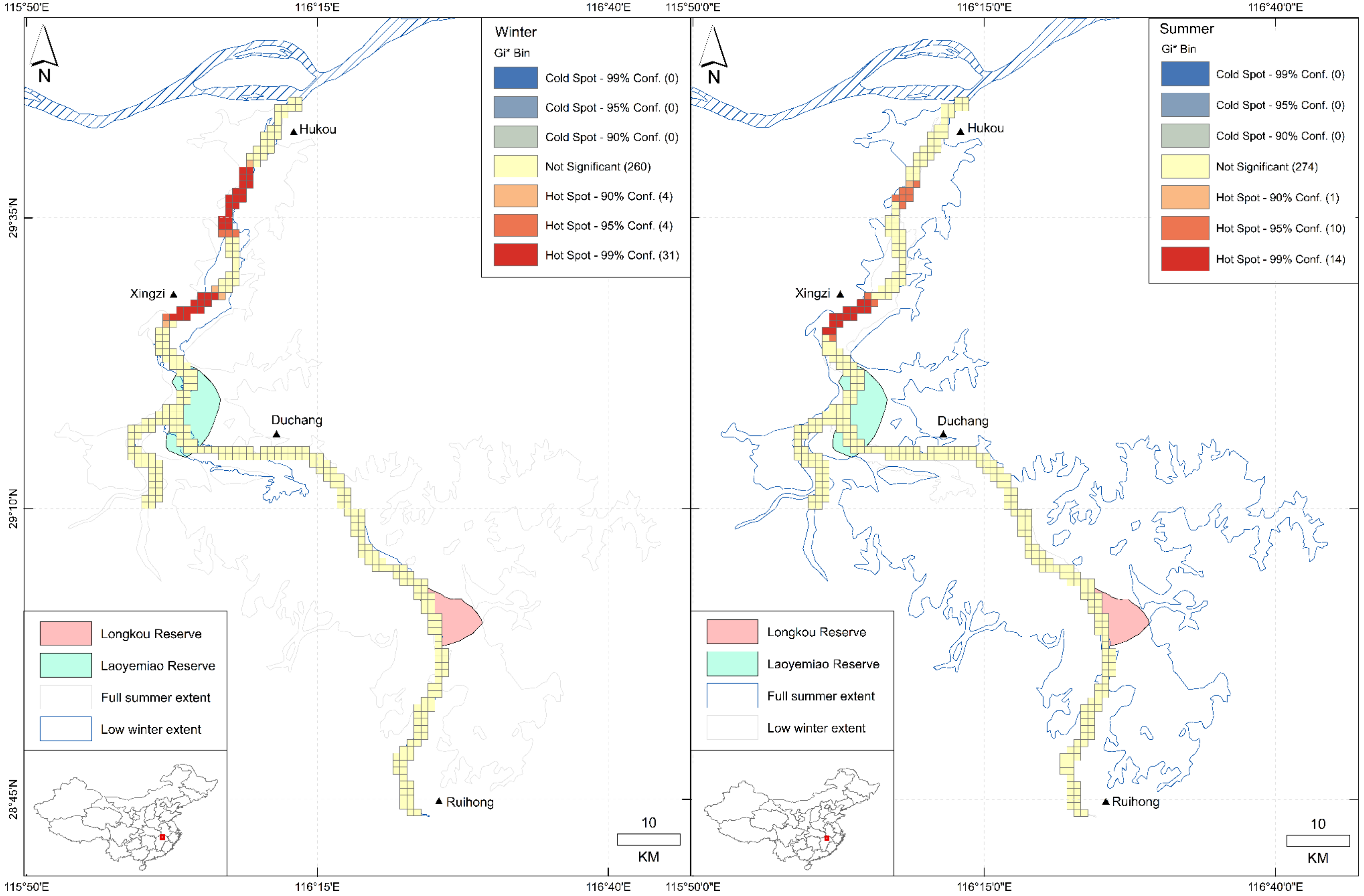


Figure 3.11: Statistically significant hotspots of sand-mining activity and vessels observed during the winter (left) and summer (right) surveys. Hotspots were calculated using the Getis-Ord* statistic in ArcGIS. Map made in ArcMap (ESRI, 2014).

3.4.4 Distance to threat analysis

YFP observations were significantly further away from sand-mining activity in winter than would be expected with a random null distribution (p<0.001), and were significantly closer to fishing activity in summer than would be expected with a random null distribution (p<0.001, Figure 3.12). There was no significant difference between YFP observations and null distributions for summer sand-mining activity (p=0.1326) or winter fishing activity (p=0.1348, Figure 3.12).

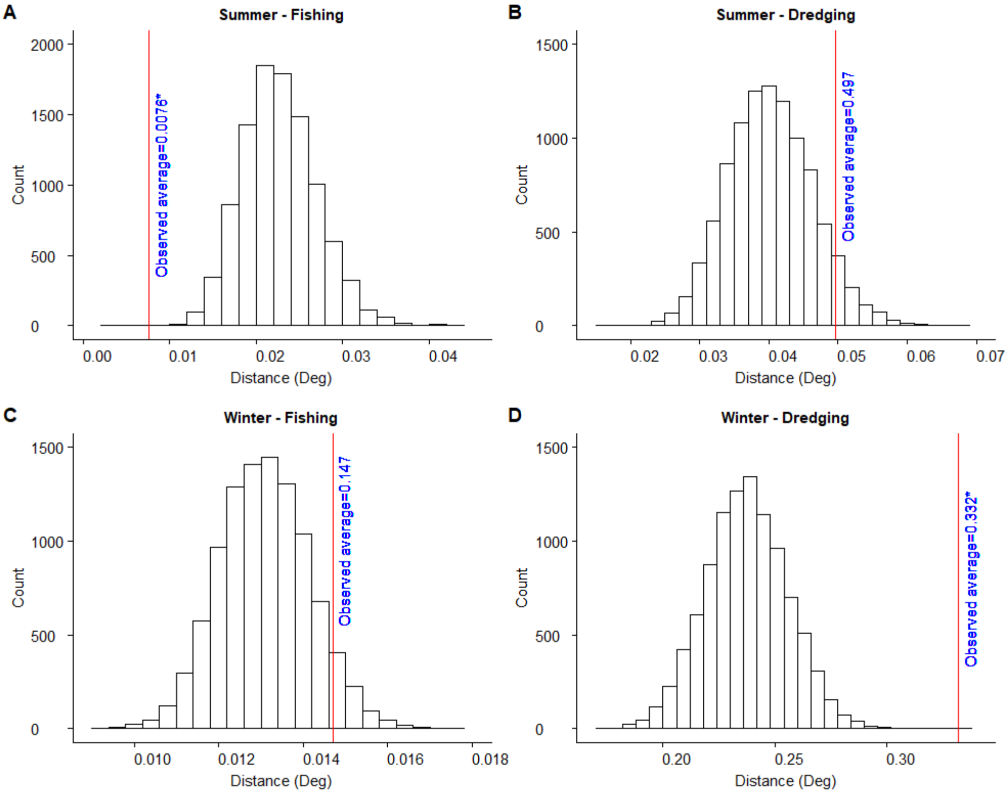


Figure 3.12: Histograms of simulated null distributions from randomly generated distance data for each season and threat. Each histogram also shows the value of the observed mean distance from actual survey data for the corresponding season and threat, and asterisks (*) denote significant difference at the 99% confidence level.

3.5 Discussion

3.5.1 Habitat preference and seasonal variability of YFP distribution in Poyang Lake

The new data presented in this study have shown that there are seasonal changes in distribution of YFP across the key remaining habitat of Poyang Lake between winter low water and summer high water. The encounter rate analysis demonstrated that in winter, YFP are distributed across Poyang Lake from the furthest north to furthest south section, whereas in summer, YFP are restricted mostly to central parts of the lake. Poyang Lake is highly seasonal in extent; the area of the lake can range from 714.1km^2 during winter low-water season to a maximum of 3162.9km^2 at summer high-water season (Feng *et al.*, 2012). The new data presented in this study demonstrate that the distribution of YFP in Poyang Lake varies between these significant seasonal changes in lake extent, showing areas of higher and lower YFP density as the lake expands and contracts. These analyses demonstrate a seasonal movement pattern of YFP away from central Poyang Lake in summer to further reaches of north and south Poyang Lake in winter.

Previous studies in semi-captive oxbow lake conditions have indicated that YFP prefer habitat with a moderate water depth of between 7 and 12m, flat benthic slope and high fish density (1.2 ind/m^3) (Mei *et al.*, 2017). In Poyang Lake, biotic and abiotic factors that are likely to influence distribution will be highly variable between seasons. The observed changes in YFP distribution in Poyang Lake are likely a reflection of seasonal habitat change as a result of these preferences. Unfortunately, bathymetric data and data on the density of fish across Poyang Lake are not available, so this cannot be tested empirically.

These seasonal patterns in YFP distribution have conservation implications, as these data can be used to identify seasonally and spatially appropriate conservation measures within this habitat. In the Yangtze mainstem, areas of high conservation value (HCV) have been recognised, most notably in a central Yangtze region between Ezhou and Anqing (Zhao *et al.*, 2013). There are also many low conservation value areas (LCVs) where there are very few YFP remaining (Zhao *et al.*, 2013), mostly located towards the upper reaches of the Yangtze. The results presented here indicate that there are more localised areas within Poyang Lake that should also be designated HCV and LCV areas. For example, an area of high YFP density was observed in central Poyang Lake in both the summer and winter surveys. This central area between Duchang and Longkou Reserve represented a key hotspot of YFP presence in both winter and summer, showing both very high encounter rates and significant hot spots in the Getis-Ord* HotSpot analysis. This area should therefore be noted as having high conservation value for the YFP. However, this area is not currently covered by either of the Poyang Lake YFP reserves (discussed further in section 3.5.3). An area of LCV in this habitat would be the channel, which had IER values significantly lower than some other sections in both seasons.

3.5.2 Seasonal variability in threat distribution and YFP overlap in Poyang Lake

The novel analyses presented in this study have provided new insight into the overlap of YFP and potential threats on both a seasonal basis and on two different spatial scales; on a system-level scale for Poyang Lake as a whole (distance to threat analysis) and on a smaller, localised scale within the lake (threat-specific maps on a 1x1km scale). This is the first time that threats to the YFP have been investigated in this way, and these multi-scale analyses have demonstrated clear temporal and spatial variation in the overlap of sand-mining and fishing activity with YFP distribution.

The results presented here indicate that fishing activity in Poyang Lake is highly seasonal and is predominantly conducted in the summer. This matches the seasonal pattern of the intensity of fishing activity observed in data from fisher interviews in chapter 4 of this thesis. The distance to threat analysis indicates that fishing activity overlaps strongly with YFP habitat use in summer but not in winter. This overlap is probably due to shared resources; YFP are known to prefer medium to high fish density areas (Mei *et al.*, 2017) and fishers will also target such areas. Similar patterns have also been found in other cetacean species; for example, hotspots of high bottlenose dolphin density are linked to foraging for fish-based prey (Hastie *et al.*, 2004), and spatial overlap of fishing activity and cetacean presence has been observed for Ganges river dolphins (*Platanista gangetica gangetica*) (Kelkar *et al.*, 2010). In winter, fishing activity in Poyang Lake is reduced and often limited to trap-type gears that target crab and shrimp (Chapter 5, this thesis). As YFP eat fish, not crustaceans, this could explain why seasonal fishing activity does not overlap as strongly with local YFP distribution. The likelihood of fishing activity causing YFP bycatch is therefore arguably lower in winter, as there is less overlap with YFP distribution.

In the previous chapter it was demonstrated that fishing activity is unlikely to be a predominant cause of YFP mortality by presenting two analyses (the correlation of threats with observed YFP-mortality and the overlap on the across-river scale). Combined with the analysis presented here, these three analyses represent the first investigations into the overlap and interaction of fishing activity and YFP distribution, and it has been done on three different spatial scales: on a mainstem Yangtze-wide scale (GLM based analysis in chapter 2); on a scale of the onshore-offshore profile (interview data and YFP survey data analysis in Chapter 2); and on a Poyang Lake wide scale (this chapter). The latter has also been investigated for seasonal patterns in YFP and fishing activity overlap. Combined, these analyses represent a powerful assessment of the interactions of fishing activity and YFP distribution on multiple spatial scales and also on a seasonal scale. All three analyses have demonstrated that there is minimal overlap of YFP and fishing activity on any spatial scale, and seasonal overlap is higher in summer and significantly lower in winter in Poyang Lake. These combined results indicate that fishing is not a key threat to YFP, but that there are particular areas (e.g. mid-channel depths, onshore-offshore analysis in chapter 2) and seasonally important regions of overlap (e.g. hotspot areas of fishing that overlap with high YFP density in central Poyang

Lake in summer in summer, this chapter) where some bycatch may occur. This information can be used to inform future fishing-based conservation efforts. Interventions should be focussed in these areas; types of fishing known to cause FYP bycatch should not be restricted in mid-depth areas, and patrols should be focussed in areas of higher YFP-fishing overlap. Enforcement should also be increased to focus on seasonal areas of high-risk; the regions of high YFP density in summer should be targeted to reduce risk of YFP bycatch.

In both seasons, sand-mining activity was predominantly observed within the north of Poyang Lake, with hotspots around Xingzi and in a section between Xingzi and Hukou. From the data presented here, it is clear that sand-mining vessels move further northward in the lake in winter. It is likely the deep draft of these vessels restricts them from entering the narrower, shallower parts of south Poyang Lake once water levels drop between autumn and winter. These new data match previous reports that sand mining activity is predominantly restricted to the north of the lake (de Leeuw *et al.*, 2010). This movement northward, combined with the spread of YFP to more southerly reaches of Poyang Lake, explains why sand-mining activity was significantly further away from YFP observations in winter than would be expected for a random distribution. Both the spatial distribution mapping and the distance to threat analyses indicate there is likely to be very little overlap or interaction with key sand mining areas and activity.

This is the first study to assess the seasonal overlap of sand mining activity and YFP distribution in a key area of YFP habitat. There have so far been no published studies investigating the potential impact of sand mining activity on YFP, and it is not known whether this activity can cause direct or indirect mortality. The results shown here indicate that sand-mining activity is unlikely to be a key driver of YFP population decline through direct interactions. What is still not known is whether this lack of overlap is due to active avoidance behaviour by YFP, or simply due to natural underlying differences YFP distribution.

However, sand-mining could be severely affecting the habitat and water and sediment regime of Poyang Lake, which could be having indirect effects on fish stocks and habitat quality (de Leeuw *et al.*, 2010; Lai *et al.*, 2014; Li *et al.*, 2014b). In addition, sand-mining activity is very loud and involves pile driving, which is also very loud underwater and can travel over large distances. Excessive sound is a deterrent to aquatic mammals, as it can cause permanent injury or reversible threshold shifts in hearing (Popov *et al.*, 2011; Finneran, 2015), and it can also confound hunting and social behaviour (Kastelein *et al.*, 2015; Dyndo *et al.*, 2015; Wisniewska *et al.*, 2016, 2018). In porpoises species specifically, noise can disrupt foraging (Wisniewska *et al.*, 2018), cause more general behavioural disruptions (Kastelein *et al.*, 2015), and result in avoidance behaviour (Kastelein *et al.*, 2017). These effects mean that noise can have sub-lethal effects, even at a distance (National Research Council, 2005; Nabi *et al.*, 2018). Quantifying the noise made by sand-mining activity should be investigated urgently, including the distance at which the noise dissipates to acceptable levels that do not cause injury or distress to aquatic mammals. This investigation has therefore indicated that sand-mining is not a direct threat, but there are still data gaps relating to sand-mining as an indirect or sub-lethal threat to YFP.

3.5.3 Current reserve placement within Poyang Lake

Marine protected areas are effective at achieving marine mammal conservation goals if they designed and managed correctly (Gormley *et al.*, 2012), a trend that should also be observed for freshwater mammals. However, protected areas targeting aquatic mammal species are at risk of being arbitrarily placed if reserve design and placement is not informed by robust data on the ecology and threats of the target species. For example, Cleguer *et al.* (2015) found that marine protected areas in New Caledonia had failed to take into account species distribution data for dugongs (*Dugong dugon*). Poor spatial allocation of the reserves meant that they had very low coverage of key habitat with high dugong density, meaning their effectiveness in reducing threats to this species was minimal.

Mobile species are often more vulnerable to extinction pressures and conservation of such species can be challenging as it involves multiple habitats and dynamic temporal and spatial considerations when choosing interventions (Runge, 2014). Detailed understanding of the distribution patterns of migratory or highly mobile species such as cetaceans is essential to ensure protection is sufficient in all key areas of occupancy (Singh & Milner-Gulland, 2011; Runge, 2014). Long and short-term temporal movements of target species are also an important factor in reserve design; highly mobile species can move relatively large distances over a range of time scales, so they may be periodically vulnerable to uncontrolled threats if they move outside of a reserve area (Wilson *et al.*, 2004). For example, modelling of habitat use by harbour porpoise (*Phocoena phocoena*) populations in north-west Scotland has been used to recommend priority areas of protection based on high density and habitat use (Embling *et al.*, 2009). In addition, understanding both interactions with threats and key habitat use is vital for effective reserve allocation (Ashe *et al.*, 2010). However, even in data poor situations such as with the YFP, reserve selection can still be effective if carried out correctly using all available information (Gaston & Rodrigues, 2003).

The analyses shown here suggest that current YFP reserve placement in Poyang Lake is inappropriate given the seasonal distribution patterns of YFP. Laoyemiao reserve arguably covers an area of relatively high YFP density, but there are other areas of higher density such as the central Poyang Lake section that may be more effectively targeted for protection, and neither of the reserves in Poyang Lake are placed in areas that cover the highest density of YFP in either season. In addition, fishing activity, a known cause of YFP mortality, is still present within both reserves. High density of fishing activity was observed inside Laoyemiao Reserve in both seasons, and a significant hotspot of fishing activity was also observed between Duchang and Longkou Reserve in the summer survey, in an area that overlaps with a significant YFP hotspot in the same season. Sand-mining activity was also observed in both reserves during the summer survey. It is highly likely the density of YFP relates to prey abundance and habitat suitability, but from this survey it is not possible to determine why a lower YFP density was observed in the reserves. These results demonstrate that the reserves are not suitably placed to match areas of high YFP density and that they are not effective at removing potential threats.

From personal correspondence with in-country YFP researchers, these reserves were arbitrarily placed in areas where high numbers of YFP have reportedly been observed (IHB, pers. comms). In addition, protected areas are generally more effective if there is one large reserve rather than multiple smaller reserves (Claudet *et al.*, 2008), and the specific design of having two smaller YFP reserves rather than one large reserve in Poyang Lake has not been justified in any published literature. The new results of this study demonstrate that reserves have not been placed either (1) where YFP occur at the highest densities in the Poyang Lake system, or (2) where fishing activities occur at their highest density (in order to reduce this as a potential cause of YFP mortality). It is also not clear whether enforcement occurs within these reserves. If enforcement is taking place, it is evidently not effective at removing potential threats to YFP, and if it not being conducted then the purpose of these reserves is unclear.

Our findings suggest that current YFP conservation measures in Poyang Lake (and, by extension, possibly other in-situ YFP reserves elsewhere across the wider Yangtze drainage) may not be well informed or appropriately designed, and they may even be entirely ineffective at mitigating potential causes of YFP mortality and population decline. As seasonal habitat use by YFP and the distribution of threats in Poyang Lake has not been investigated until the present study, these reserves cannot have taken that factor into account within their spatial allocation or design. This is typical in protected areas globally; allocated reserve areas are often ineffective at achieving the intended conservation goal in both marine protected areas (MPAs) (Edgar *et al.*, 2014) and terrestrial protected areas (Rodrigues *et al.*, 2004) due to inappropriate design, insufficient management, and poor compliance with rules. Protected area allocation and design for mobile species is more targeted and effective when based on robust, empirical evidence (Schofield *et al.*, 2013), and when sufficient areas are included that cover all stages of the species life-history and spatial movements (e.g. Runge *et al.*, 2015). In addition, inadequate capacity for enforcement and management is common in MPAs and causes sub-optimal conservation outcomes in MPAs (Gill *et al.*, 2017). Even though these issues with reserves are pervasive globally, they should not be overlooked with the YFP; these reserves (and other Yangtze mainstem reserves) are the only form of in-situ YFP conservation currently active so ensuring their effectiveness is a major component of protecting the remaining YFP population in the Yangtze drainage. An urgent assessment of the current conservation interventions is therefore needed, as it possible that the presence of these ineffective reserves has led to complacency with regards to the need for further in-situ conservation measures. A thorough evidence-based assessment of potential conservation options for YFP in Poyang Lake is also needed, including identification of key target areas and threats based on these and other available data.

Strategic adaptive management (SAM) or adaptive management (Williams, 2011) has been recommended for freshwater protected areas (Kingsford, Biggs & Pollard, 2011). Within conservation, this is a process in which specific and detailed conservation goals are set, multiple potential management options are thoroughly assessed and then selected from, and ongoing evaluation and adaptation of management is carried out over the lifetime of a project. For protected areas specifically, this method ensures that an explicit decision-making process is applied to protected area allocation and design, as well as ensuring that structured assessment and feedback is used to continually improve and adapt reserve management to address identified areas of progress or failure. SAM has successfully been applied to habitat-specific conservation (e.g. McCarthy & Possingham, 2007; McCook *et al.*, 2010; Weeks & Jupiter, 2013) as well as species-specific conservation (Rout, Hauser & Possingham, 2009; Runge, 2014), including for cetacean species (Wintle, 2007; Higham, Bejder & Lusseau, 2008). By integrating all available evidence on the Poyang Lake YFP population (including the new evidence presented here on the spatio-temporal movements of YFP and key areas of overlap with threats) into a SAM process, a more informed and iterative protected areas design can be formulated, with strategic goals and measures of success that can then be used for adaptation and improvement of management. This would ensure that there is a means of measuring success of the YFP reserves, and addresses the risk of complacency that is associated with “paper-parks” (Minin & Toivonen, 2015).

3.5.4 Wider implications of this study and this survey methodology

Methods commonly used for mapping cetacean distribution such as habitat suitability modelling (HSM, or species distribution modelling (SDM), Elith & Leathwick, 2009) require small-scale resolution data on biotic and abiotic parameters such as bathymetry and fish density (e.g. Gomez & Cassini, 2015; Breen *et al.*, 2017; Giannoulaki *et al.*, 2017), which are not readily available for the very complex habitat of the Yangtze River. Additionally, using satellite tagging techniques (e.g. Rayment *et al.*, 2009; Hauser *et al.*, 2007) has never been successful on the YFP and it is not possible to recognise YFP individuals for capture-recapture sighting surveys. The rapid observational surveys used within this study have revealed conservation relevant data and improved understanding of the distribution of both YFP and threats on multiple spatial scales and on a seasonal basis, addressing key data gaps partly caused by these significant difficulties in studying this species. This agrees with similar studies (e.g. O’Hern *et al.*, 2014; Marcoux *et al.*, 2016; Braulik *et al.*, 2017) that have used rapid visual surveys of cetaceans to gather conservation relevant data to fill in key knowledge gaps. In other studies, these kinds of presence-only data perform well compared to presence-absence data when investigating aquatic mammal occurrence (e.g. harbour porpoise, *Phocoena phocoena,* Macleod *et al.*, 2008). By using the same survey method and route, relative patterns of species distribution and of overlap with threats have been quantified between seasons and over a large habitat on multiple spatial scales. These kinds of techniques could prove vital in the fight to conserve data poor cetacean species that are difficult to observe.

3.6 Conclusions

The analyses presented here have revealed multi-scale spatial patterns and seasonal change in the movement of YFP in the key habitat of Poyang Lake, as well as patterns of overlap of YFP presence with fishing activity and sand-mining activity as potential threats. These results indicate that both sand-mining and fishing activity overlap minimally with key YFP habitat but that fishing activity overlaps more with YFP presence in the summer season. This study has demonstrated for the first time that sand-mining is not likely to be a significant cause of direct YFP mortality. Additionally, this study has demonstrated that fishing is less likely to be a significant cause of YFP population decline, but that seasonal conservation mitigation may be required for fishing activity in summer high water. From these analyses, we can better understand local movements of YFP between summer and winter seasons within the key habitat of Poyang Lake, which can be used to inform reserve placement and design. In addition, these data have demonstrated that the current YFP protected areas could be better allocated and require a review about their design and spatial allocation. In addition, enforcement within the reserves needs to be improved to remove potential threats to YFP. There are still significant data gaps surrounding conservation of this at-risk species, but this study has demonstrated that rapid seasonal surveys can generate conservation-relevant data that can be used to inform conservation of this data-poor species.

4 Chapter 4: Fishing for answers: drivers of Yangtze finless porpoise bycatch and illegal fishing behaviour in artisanal fisheries in the Yangtze drainage

Typical fishing gear shop near Tongling, East China

4.1 Abstract

Bycatch is a key threat to cetaceans worldwide and is a known cause of mortality for the Critically Endangered Yangtze finless porpoise. Mitigation of Yangtze finless porpoise bycatch is severely limited by large data gaps surrounding fishing activity and porpoise bycatch. The research presented here characterises the types of gear that cause bycatch related mortality, the spatial and temporal distribution of those gear types, the drivers of legal and illegal fishing gear use, longitudinal changes in gear use, and the effectiveness of current fishing-based mitigation on changing gear use habits of fishers in key habitats. Socio-economic drivers of gear use and the status of species-specific fish stocks are also presented. The results shown here demonstrate that (a) there are further fishing gear types that require legislative attention and (b) enforcement of illegal fishing requires further improvements. In addition, generational length changes in fishing gear use are demonstrated, with fishers converting from hook-based fishing to more potentially harmful modern methods such as electric fishing. These changes in gear use are demonstrated to be a response to unpredictable water levels and dwindling fish stocks and an effort by fishers to mitigate for unstable income. The results have implications for fish stocks in the Yangtze River, for the sustainability and wellbeing of local fishing communities in the Yangtze River, and for understanding porpoise bycatch in this key remaining habitat. These results also demonstrate that local ecological knowledge (LEK) can be an effective method of gathering fishing and bycatch related information for a data-poor species in an artisanal fisheries system.

4.2 Introduction

4.2.1 Why do we need to understand cetacean bycatch?

Bycatch is generally understood to be the unintentional catch of non-target organisms from fishing activity (Alverson, 1994). In some cases, bycatch is kept and sold even though it is unintentional, but often bycatch is discarded. There is some contention towards dividing the definition of bycatch into unintentional catch that is discarded (bycatch) and unintentional catch that is retained and sold (non-target catch, for more details of the definitions see Reeves, McClellan & Werner, 2013). For the purposes of this research, the term bycatch is used to cover all unintentional catch of YFP in fishing gear, predominantly where it causes direct mortality of the individual.

Bycatch of cetaceans often results in mortality through drowning, as the caught individual is usually trapped within underwater fishing gear and so cannot reach the air to breathe (Alverson, 1994). As well as causing direct mortality, the presence of fishing activity can result in sub-lethal effects in aquatic mammals; behavioural alteration, energetic costs, reduction in fitness, and non-lethal injury can all occur after escaping or being freed from fishing equipment (Gilman, Brothers & McPherson, 2006; Wilson *et al.*, 2014). As a result of these effects, bycatch can have significant effects on marine mammal populations (D'Agrosa, Lennert-Cody & Vidal, 2000; Reeves *et al.*, 2003, 2005).

Bycatch of cetaceans in marine fisheries is relatively well documented (DeMaster *et al.*, 2001; Read, 2008), and represents a key threat to marine cetaceans worldwide (Read, Drinker & Northridge, 2006; Read, 2008; Reeves, McClellan & Werner, 2013). However, bycatch in freshwater systems is poorly understood, studied or quantified relative to the marine environment (Raby *et al.*, 2011) despite it being a common problem in river systems globally (Loch, Marmontel & Simões-Lopes, 2009; Kelkar *et al.*, 2010). Bycatch of Amazon river dolphin species, Boto (*Inia geoffrensis*) and Tucuxi (*Sotalia fluviatilis*), occurs across their respective Amazon River ranges (Iriarte & Marmontel, 2013b), and they are also intentionally targeted for use as bait within local artisanal fisheries (Iriarte & Marmontel, 2013a; Mintzer *et al.*, 2013). Conflict has also occurred between these two cetacean species and local fishing communities due to competing resources (Loch, Marmontel & Simões-Lopes, 2009; Mintzer *et al.*, 2015). Bycatch of freshwater cetaceans is also a significant problem in Asian river systems, with bycatch implicated as a significant cause of decline and driver of extinction for the baiji (Zhou & Wang, 1994; Zhou *et al.*, 1998; Turvey *et al.*, 2007), and a cause of mortality of the Ganges river dolphin (*Platanista gangetica gangetica*) (Mansur *et al.*, 2008; Waqas, Malik & Khokhar, 2012). From the limited publications available, bycatch therefore represents a key potential threat to freshwater cetaceans through direct mortality or indirect conflict or sub-lethal affects (Hall, Alverson & Metuzals, 2000).

Bycatch of marine porpoises occurs across their respective species ranges (Jefferson & Curry, 1994). This includes the now Critically Endangered vaquita (*Phocoena sinus*, D'Agrosa *et al.,* 2000), the endangered marine subspecies of narrow-ridged finless porpoise

(*Neophocaena asiaeorientalis sunameri*), and other porpoise species around the world (Jefferson & Curry, 1994). Bycatch is the leading cause of marine Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) mortality in the nearby South China Sea (Jefferson, Curry & Kinoshita, 2002) and bycatch is a key cause of mortality in marine mammal populations in China (Wang, Li & Waerebeek, 2015). Bycatch is therefore a key threat to porpoises globally.

The likelihood of bycatch incidence caused by a specific type of fishing gear depends on a range of features; environmental, operational, technical and behavioural factors all influence the potential for bycatch to occur (Northridge *et al.*, 2017). For cetaceans specifically, gear design, soak duration, water depth, seasonality, and wind and weather are correlated with bycatch rate (Northridge *et al.*, 2017). Assessment of the types of gear present in a system, as well as identifying and quantifying those that cause mortality, is therefore necessary to understand how to mitigate for cetacean bycatch. If there are temporal or spatial patterns in specific fishing gear use, this may affect the seasonality or spatial patterns in the likelihood of bycatch occurring (Leeney *et al.*, 2008; Fernández-Contreras *et al.*, 2010). Further to this, understanding socio-economic or biological drivers of gear use is key to designing appropriate mitigation that is targeted to key user groups in overexploited fisheries (Cinner, Daw & Clanahan, 2008). Without robust understanding of bycatch, mitigation for bycatch cannot be targeted to key areas and it is less likely to be effective.

4.2.2 The importance of LEK and socio-economic knowledge to manage sustainable fisheries and bycatch

As with many threatened species, prioritising threats and implementing effective conservation-based interventions is often restricted by a lack of long-term census data to inform conservation. As mentioned in Chapters 1&2, Local Ecological Knowledge (LEK) is an undervalued source of information that can be utilised for species where data are otherwise unavailable (e.g. Bender *et al.* 2014; Turvey *et al.* 2015; Nash *et al.* 2016; Gray *et al.* 2017). Within conservation, LEK based studies have successfully been used to confirm the presence of cryptic species (Turvey *et al.*, 2014, 2017; Cullen-Unsworth *et al.*, 2017), assess threats (Nash, Wong & Turvey, 2016; Turvey *et al.*, 2014), detect population trends and status (Gray *et al.*, 2017; Nash, Wong & Turvey, 2016), and provide information relating to social dimensions of species conservation (Miard, Nekaris & Ramlee, 2017). However, LEK should not be used without a certain level of caution as it may contain sources of bias, and an awareness of the quality of data should be considered with its applications (Gilchrist, Mallory & Merkel, 2005).

LEK has specific uses in the field of aquatic conservation and cetacean research. It has successfully been used to inform marine protected area management (Mellado *et al.*, 2013; Zappes *et al.*, 2014) and inform population status and recovery of cetacean populations (Frans & Augé, 2016), and can also be used to gather data relating to threats and causes of decline in cetacean species (Carter & Nielsen, 2011). Particularly relevant here is the use of LEK to understand bycatch. LEK has successfully been used to investigate bycatch in a number of regions including artisanal fisheries from various countries in Africa (Moore *et al.*, 2010; Leeney, Dia & Dia, 2015); small-scale fisheries in South America (Alfaro-Shigueto *et al.*, 2018) and the South China Sea (Liu *et al.*, 2017); and modern industrial fisheries in the Canadian Atlantic (Carruthers & Neis, 2011). LEK has also been used to assess bycatch of porpoises specifically (narrow-ridged finless porpoise*, Neophocaena asiaeorientalis sunameri*, in Japanese waters, Shirakihara & Shirakihara, 2013), and LEK data have previously been used within the Yangtze system to gather information relating to the YFP (Turvey, Hao & Ding, 2012; Turvey *et al.*, 2013). The interview survey in Turvey *et al.* (2013) demonstrated that annual YFP mortality rate may have quadrupled over the two decades prior to the study and that mortality caused by vessel strikes has increased more than bycatch caused mortality. The interview survey detailed in Turvey, Hao & Ding (2012) investigated illegal and legal fishing gear use, attitude and awareness data and some information of livelihoods and incomes. Gathering LEK via interview surveys is therefore a useful data gathering method in otherwise data-poor environments such as for the YFP; however, further data gaps still remain with respect to the dynamics of bycatch mortality, socio-economic factors relating to bycatch, and drivers of bycatch caused YFP mortality.

Fish biodiversity and stocks in the Yangtze have declined rapdily with the advent of intensive fishing, large damming projects and habitat modification (Fu *et al.*, 2003; Huang, Wu & Li, 2013; Ye *et al.*, 2013; Zhang *et al.*, 2017a). As noted in Chapter 2, this may be affecting the YFP. LEK has been shown to concur with fishing statistics (Sáenz-Arroyo & Revollo-Fernández, 2016), can be used to reconstruct past fish stocks and fish stock decline (e.g. Neis *et al.* 1999), and can identify where overexploitation of fishing stocks has occurred (Bender *et al.*, 2014). LEK has also successfully improved understanding of the status of data-poor fish species (Beaudreau & Levin, 2014), and qualitative interview data have previously been used to improve assessment and mitigation in fisheries (Carruthers & Neis, 2011). It can therefore provide useful information about the spatial and temporal patterns in fishery resources (Sergio *et al.*, 2017).

LEK and interview-based surveys are therefore a potentially useful source of information for the data-poor YFP; bycatch of YFP is poorly understood; spatial and temporal dynamics of fishing activity are poorly quantified; stocks of YFP prey species have not been quantified; and mitigation of bycatch is very difficult given the limited data available. In addition, LEK is an untapped resource of information relating to fishing-based livelihoods, and there is potential for LEK to be used to better understand the impact of over-fishing and current mitigation methods on local fishing communities in the Yangtze River.

4.2.3 The impact of conservation on local communities

There has been an increasing call for conservationists to consider the impact of wildlife conservation on human well-being as many conservation interventions directly or indirectly affect resident communities (Milner-Gulland *et al.*, 2014). This represents a significant challenge to the conservation community; how can we implement effective conservation efforts whilst also preserving the integrity of local communities? Improving understanding of the human social dimensions of environmental issues (Bower *et al.*, 2017), as well as integrating LEK to conservation decisions can improve conservation outcomes by accounting for the effect conservation may have on local human populations (Raymond *et al.*, 2010). Research on the perceptions of local stakeholders can also be used to inform mitigation choices, and integrating evidence across the social and natural sciences can provide a more holistic assessment of conservation and environmental management (Bennett, 2016). In addition, local cultural and social context should also be considered when designing interventions (Waylen *et al.*, 2010) and using community participation in decision making can increase effectiveness of interventions, as well as incite attitudinal changes in local communities (Waylen *et al.*, 2010; Sterling *et al.*, 2017). Other stakeholders involved in conservation (separate to LEK) can also be a useful alternative source of information (Haenn *et al.*, 2014), and stakeholder engagement can result in improved decision making (Beierle, 2002).

The conservation approaches currently used for YFP protection include protected areas (PAs), alternative livelihood schemes, and restriction of certain activities perceived as threats (for example, specific fishing gears). These interventions can result in detrimental impacts on local communities and local economies through the removal or restriction of livelihood or by physical relocation out of or away from protected areas, and can therefore cause population displacement and a risk of further impoverishment of communities already struggling to maintain basic income (e.g. West & Brockington, 2006; Adams & Hutton, 2007). In the context of the YFP, fishers in the Yangtze basin represent key stakeholders that are affected by or even specifically targeted as part of ongoing YFP-based (or, by extension, fish stock based) conservation efforts, including banning of certain fishing gears and implementation of seasonal or spatial limits on fishing activity. Although local communities have been used as a source of conservation-relevant YFP LEK (Turvey *et al.*, 2013), the effect of interventions designed to protect both YFP and fish stocks on these local communities has never been assessed in any published material and they are large data gaps with respect to the socio-economic context of current intervention measures.

4.2.4 Current understanding of Yangtze finless porpoise bycatch

Global priorities for reduction in cetacean bycatch have been identified in Reeves *et al.* (2005):

(1) situations that are especially critical (e.g. a species' or population's survival is immediately at risk from bycatch) and are not being addressed adequately;

(2) circumstances where rapid progress could be made with a modest investment of resources;

(3) situations in which bycatch is believed to pose a threat to cetaceans but a quantitative assessment is needed to verify the risk; and

(4) fisheries in which a currently available solution (technical, socio-economic, or a combination) appears feasible.

The current IUCN status of the YFP means that it easily falls into priority (1). Arguably, rapid progress could be made given better investment in managing causes of mortality and improving mitigation efforts, and so this case also falls into priority (2). Poor quantification of causes of YFP mortality means it also falls into priority (3). Modest investment in mitigation schemes by the government could possibly reduce fishing pressure, and there are possible solutions to bycatch (4), but this needs further assessment. The YFP is therefore a global priority for reduction in bycatch under these guidelines.

Anecdotal reports of YFP being killed by fishing gear appear sporadically in local news reports and have been reported in published literature (Table 4.1). To date, reported YFP bycatch mortality has been caused by rolling hook, electric and fixed nets (Table 4.1). Some studies have noted bycatch of YFP as a key driver of population decline (Turvey *et al.*, 2013; Liu *et al.*, 2017), with a focus on rolling hook and electric based fishing as key specific gear types (Zhou & Wang, 1994; Turvey *et al.*, 2013). Despite this, there is no systematic reporting or post-mortem system to assess bycatch of YFP, and so a more thorough assessment of the gear types and quantification of YFP bycatch has not yet been possible. Some information on the spatial distribution of fishing gear use has been demonstrated in Turvey *et al.* (2013), but there are still major data gaps. Detailed understanding of the seasonal and spatial variation in the use of specific gear types has not yet been investigated, and longitudinal changes in specific gear use over longer time periods has never been assessed.

Table 4.1: Reports of YFP bycatch in published literature, adapted from Turvey *et al.* (2013)

Publication	Type of fishing gear	Year	Number of incidents or individuals reported
Reeves, Wang & Leatherwood (1997)**,** Zhou & Wang (1994)	› Fixed pound nets and gill nets	› 1983	› 11 individuals
Wang *et al.* (2000) Wang & Zhao (2010)	› Rolling hook	› 1990 - 1992	› 2 individuals in Tian'e-zhou semi-natural reserve
Wang, Li & Waerebeek (2015)*****	› Not specified	› 2000 - 2006	› 24 incidents: 8 x bycatch, 6 x unspecified injuries, 10 x unspecified strandings.

* The original data from this study was requested to investigate seasonal or temporal patterns but this request was denied.

Bycatch mitigation must take into account the multi-faceted drivers of small-scale fishing behaviour in artisanal fisheries (Teh *et al.*, 2015). Some types of fishing gear have been made illegal in parts of the Yangtze River (Turvey, Hao & Ding, 2012). However, illegal behaviour is continuing; fishing still occurs within protected areas (chapter 3, this thesis) and potentially lethal fishing gear types are still used (Turvey, Hao & Ding, 2012). There have been very few studies investigating the socio-economic dynamics and drivers of megafauna bycatch in fisheries systems (e.g. Teh *et al.*, 2015) and no studies in freshwater systems. Understanding what drives the choice of gear use is therefore poor, and drivers of illegal gear use has not been investigated. As bycatch is a known cause of YFP mortality, ongoing mitigation to prevent the use of potentially lethal fishing gear types is required. To effectively understand how to mitigate further illegal or destructive fishing behaviour, understanding reasons for ongoing fishing gear use is key.

This study aims to address key data gaps with respect to YFP bycatch related mortality. To be able to mitigate for bycatch in this system, a more robust understanding of the causes of bycatch mortality are needed, including identifying the specific types of gear that are commonly implicated in bycatch, and an assessment of the spatial and temporal patterns in the use of these types of fishing gear. In addition, an assessment of the drivers of continued illegal fishing (noted in Wang, 2009; Mei *et al.*, 2012; Zhao *et al.*, 2013) is needed to improve understanding of how to counter illegal behaviour that may be affecting both fish stocks and YFP. This requires a better understanding of the socio-economic context of fishing and bycatch, and assessment of the change in patterns of gear use.

4.2.5 Research Questions

Basis of chapter/key questions:

- What are the defining characteristics of fishing activity in key Yangtze finless porpoise habitats?
- What types of fishing equipment are causing Yangtze finless porpoise mortality?
- What are the spatial and temporal dynamics of the use of these fishing methods?
- Have fishing habits changed over time and why, and how may this be affecting the remaining Yangtze finless porpoise population?
- How does the choice of fishing gear type relate to biological, social and economic factors in key Yangtze finless porpoise habitats?
- What are the key drivers of illegal fishing and Yangtze finless porpoise bycatch?

4.3 Methods

4.3.1 Study area

To investigate fishing activity and YFP bycatch, an extensive interview-based survey of fishers was conducted between 12th September and 14th November 2016 (hereafter referred to as the "2016 survey"). This survey aimed to investigate and quantify current and past gear use; fishing seasonality and temporal patterns in fishing gear use; spatial patterns of fishing gear use; fishing-based economic data; fisher attitude and awareness information; and observations of YFP bycatch. As Poyang Lake represents almost half the remaining population of wild YFP (Mei *et al.*, 2014), this was chosen as first priority area for targeted interviews. A comparative section of mainstem habitat was also surveyed between Hukou and Anqing (hereafter referred to as H-A mainstem section). Previous studies have indicated a relatively high YFP population in this section (Zhao *et al.*, 2008), and this section was surveyed in both the 2008 and the 2011/12 fisher interview surveys conducted by Turvey *et al.* (2012, 2013). Fishing communities based in all the towns adjacent to Poyang Lake and the H-A mainstem section were targeted for interview, comprising 12 towns in these two key areas (Figure 4.1, Table 4.2).

4.3.2 Sampling design and interviewee selection

A stratified random sampling design was used as a guideline to target representative numbers of fishers from each county. Information about the numbers of registered fishers in each town was taken from data previously collected in the 2011/12 interview survey of Yangtze fishers (some results published in Turvey, Hao & Ding, 2012). A guideline of 3% of the registered fisher community was targeted in Poyang lake-based towns, with a cap at 50 and a minimum of five individuals for logistical and statistical reasons, respectively. Yangtze River mainstem towns had fewer registered fishers overall, and so 10% of the registered fishing community was sampled. In some cases, the number of registered fishers was small enough to collect more than 3% due to varying logistics within each town; in Hukou, for example, 5% of the known fisher population was captured. In three of the towns, very few fishers were present during the field season, and the target was not met (Table 4.2).

A total of 265 interviews were conducted across 12 towns. Eight of these interviews were incomplete as the interviewee was too busy to complete the full interview or left the interview for other personal reasons. These data have still been included where they are available. In some cases, participants refused to answer a question or answered "don't know", so there are differences in the sample size for some of the results presented.

Table 4.2: Tally of fisher interviews conducted in towns centred around Poyang Lake and the Yangtze River mainstem from Hukou to Anqing

	Registered fishers	*3%*	*10%*	*Aim*	*Incomplete Interviews*	*Complete Interviews*	*Total*
Poyang Lake							
Duchang	1022	30.66	-	31	-	34	34
Poyang	1564	46.92	-	35	2	50	52
Yugan	1097	32.91	-	33	1	38	39
Jiujiang	53	1.59	-	5	-	2	2*
Xingzi	553	16.59	-	17	5	18	23
Yongxiu	852	25.56	-	26	-	30	30
Hukou	183	5.49	-	10	-	10	10
P. L. total	5324	159.7	0	157	8	182	*190*
Mainstem							
Pengze	37	-	3.7	5	-	5	5
Susong	83	-	8.3	9	-	7	7*
Wangjiang	108	-	10.8	11	-	6	6*
Anqing	420	-	42	35	-	45	45
Chizhou	158	-	15.8	12	-	12	12
Mainstem total	806	0	80.6	72	0	75	*75*
Total	*6130*	*159.7*	*80.6*	*229*	*8*	*257*	*265*

Note: Registered fisher numbers are taken from Turvey *et al.* (2013).
"Incomplete interviews" are those that started but the participant chose to not finish or ran out of time.
* indicates not achieving the target number due to lack of available fishers during the survey period.

Interviewees were selected using a number of methods dependent on the location and resources available. A key representative for each community0was contacted through the IHB or through known local YFP-focussed NGOs. Each representative was familiar with local fishing communities, fish markets, and ports and assisted with finding interviewees. Where a representative was not available, a key known port was initially targeted to find fishers, after which each fisher was asked to identify local fishing villages and ports for further interviews. All interviews were conducted in person on a one-to-one basis in Chinese by four local students. Each interviewer received training in how to conduct the interview and followed a written protocol as a guideline to ensure that the interview technique was as uniform as possible, including protocol aimed at keeping the interviews impartial and neutral. The interviews were translated into English directly into an Excel database by students.

The interview survey comprised 56 questions divided into six groups; personal details, personal fishing gear use and fishing-based questions; YFP-based questions; income and economic based questions; questions aimed at assessing fish stock status; and finally questions about sensitive or illegal fishing behaviours. The survey was a mix of categorical questions (e.g. "yes", "no" and "don't know"), quantitative questions, and qualitative open-ended questions designed to provide further insight outside the bounds of direct questioning. The full questionnaire is given in appendix C.

Interviewees were asked to assess the stock status of nine species of fish as Increasing, stable or decreasing (and an opt-out option of “don’t know”). The nine species used are fish species known to be YFP prey from previous studies and from direct communication with researchers based at the IHB (IHB, Wuhan, pers. comms.).

As discussed in the introduction to this chapter and in chapter 2 of this thesis, two fisher interview surveys have previously been conducted in the Yangtze River that aimed to investigate a range of aspects relating to fishing activity, YFP conservation, and threats to YFP using LEK. These data were gathered during a Yangtze-wide interview survey in 2008 and a “hotspot” interview survey in the middle-lower Yangtze River and Poyang Lake between 2011 and 2012 (hereafter referred to as the “2008 survey” and the “2011/12 survey”, respectively, see chapter 2 of this thesis for full survey details). Some of the results from these surveys have previously been published in Turvey, Hao & Ding (2012) and Turvey *et al.* (2013). Some questions used in one of or both of these surveys have been included in the 2016 survey. These data have been used in this chapter to complete longitudinal analysis of fishing in the Yangtze between the three survey periods of 2008, 2011/12, and the present survey completed in 2016.

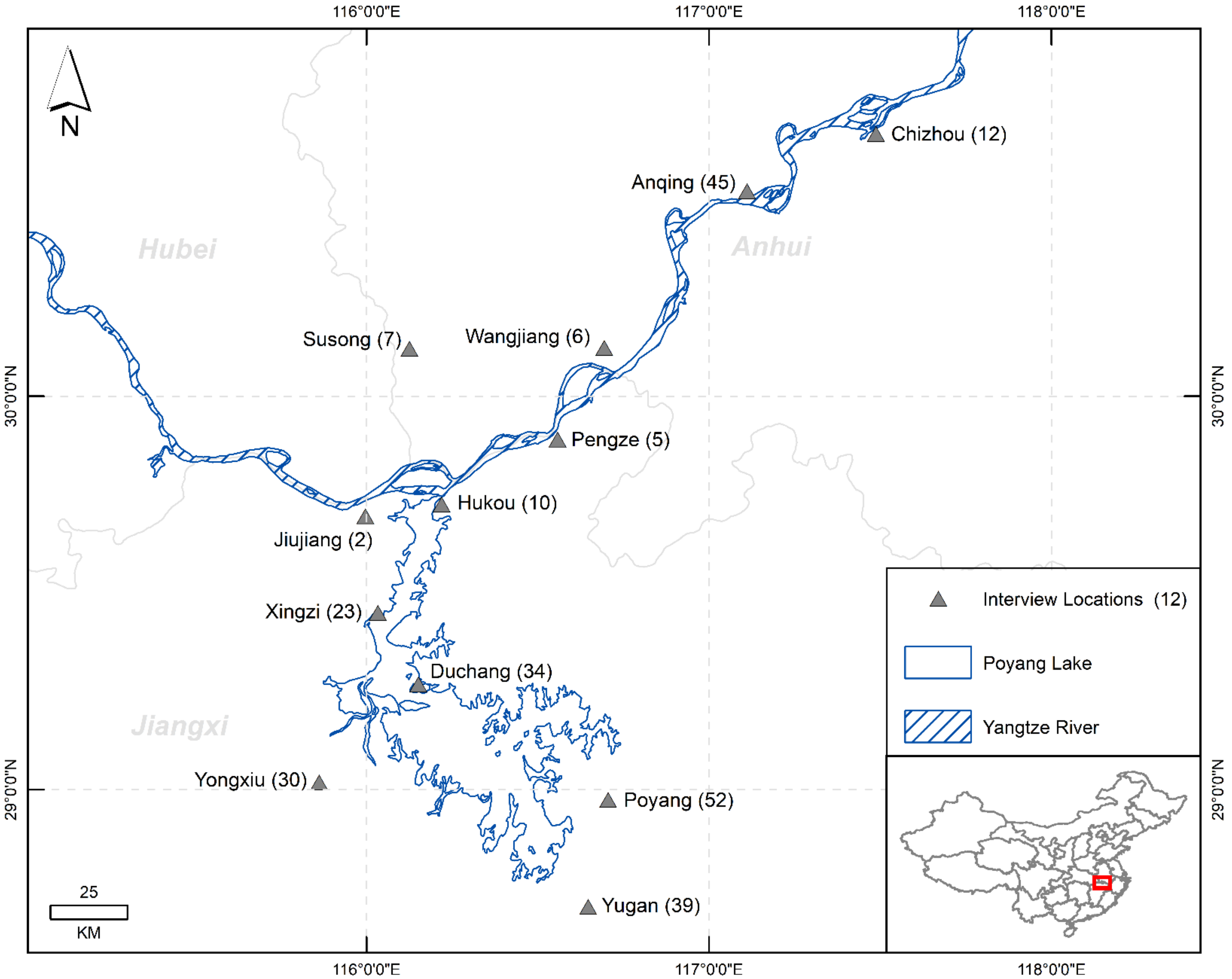


Figure 4.1: Location and quantity of all fisher interviews in both Poyang lake and the Yangtze River mainstem section from Hukou – Anqing for the 2016 interview survey. **Note**: Xingzi, Duchang, Yongxiu, Poyang, and Yugan constitute Poyang Lake results, all others are for the Yangtze mainstem. Lake shown is summer extent to show proximity to the Lake. Map made in ArcMap (ESRI, 2014).

4.3.3 Pilot interview survey

Prior to the main interview survey, a small pilot interview survey was conducted on 22nd September 2016 in fishing markets in the city of Wuhan, Hubei, central China. Two local volunteers conducted five interviews with randomly selected fishers at a fish market, which allowed the interviewers to familiarise themselves with the interview protocol, in addition to checking local names, the quality of the translation from English to Chinese, and to test the structure, content, and questionnaire style. From this pilot, several points were noted and were addressed. After the interview structure was altered appropriately it received an appraisal from a separate Chinese-fluent reviewer.

4.3.4 Ethical considerations

An ethical review was carried out prior to the interview survey, and the project was approved by ZSL's Ethics Committee on 11th March 2016. To ensure protection of participants, all willing respondents have been kept anonymous and interviews were only conducted following verbal consent of participants. Interviewees were informed of their option to opt out of questions if they were not comfortable answering prior to commencing the interview.

4.3.5 Data analysis

Fisher demographics, boat types used, and types of fishing gear used in the study areas are presented as summary data to characterise fishing practices in the study area. To quantitatively analyse fishing gear types in the study area, the fishing gear data were grouped by functional type and summarised by location. Groups were "net based gear", "pot and trap type gear", "fixed net gear", "hook-based gear", "electric gear", "cormorant fishing", and "other" (Figure 4.2). All further analyses of fishing gear types use these categories.

Specific fishing gear types used in the 2008, 2011/12, and 2016 surveys are presented, as well as fishing gear types specifically identified as having caused mortality in fisher-observed YFP mortality events in each survey year. These data are not directly comparable for trends, neither are they to be taken as absolute values, as the three surveys covered different spatial regions and used slightly different questions, and each survey comprised a different sample number of interviews. These data have also not been controlled for replicate reports of the same observed mortality events by different interviewees. However, these data are presented here as an indication of the specific gear types that do cause YFP mortality, and which have not been observed to cause YFP mortality.

All statistical analyses and data visualisation were completed in R v3.4.3 (R Core Team, 2017).

Figure 4.2: Groups of fishing gear used by fishers interviewed in this survey. **A**: Net based gear, **B**: pot/trap types gear, **C**: fixed gear, **D**: hook-based gear, **E**: electric fishing, **F**: cormorant fishing.

4.3.5.1 Investigating spatial and temporal patterns in fishing activity and gear use

To investigate spatial differences between fishing gear types used in Poyang Lake and the H-A mainstem section, differences in the proportion of fishers using each functional group of gear were investigated using the two-proportion Z-test, which uses the chi-squared statistic. The test was run individually for each fishing gear type. Where counts were less than five, a Bonferroni continuity correction was applied. As Poyang Lake is a key YFP habitat, spatial variation in fishing gear use has also been presented separately for all Poyang towns. Differences between Poyang Lake towns were investigated using the chi-squared goodness of fit test for proportions, where possible (this test requires a count of > 5 for all observations). To investigate possible differences between the two systems data have been shown separately for Poyang Lake and mainstem fishers throughout, where appropriate.

Temporal dynamics in fishing activity were investigated for both (1) seasonal patterns and (2) longitudinal patterns in fishing gear use over time. Seasonality in fishing activity is presented as a monthly percentage of fishers that are active, which has been divided into separate data from Poyang Lake and the H-A mainstem section. Months where illegal fishing activity continues during the fishing ban were identified for both systems; fishing is banned in the mainstem from April 1st until the end of June, and from 20th March until 20th June in Poyang Lake. To investigate differences in seasonal fishing activity between the H-A mainstem section and Poyang Lake, each month was compared using the z-test for proportions.

To investigate longitudinal patterns in the use of potentially lethal or damaging gear types, the use of hook-based and electric fishing gear was investigated using two methods. Firstly, in the 2016 survey, fishers were asked to estimate the proportion of their local community that uses hook type fishing gear and electric type fishing gear for “now” (representing 2016), and additionally for “~ five years ago” and “~ ten years ago”. This provides a coarse index of change over roughly the previous decade to the year 2016. The responses were categorical: “none”, “very few”, “<25%”, “<=50%”, “>50%” or “all”. Change in use of these gears over time was investigated using the three- or two-proportion Z-test. Firstly, all three year intervals were compared using a three-proportion z-test. If there was no significant difference between all three periods, a two-proportion z-test was carried out between the “now” and “10 years ago” data to investigate change between the two furthest apart years.

To investigate the validity of the responses given in the above longitudinal analysis, and to further investigate longitudinal patterns in the use of hook-based fishing, an analysis using the data from the 2008 survey and the 2011/12 survey was also conducted. In all three surveys, the proportion of interviewed fishers using hook-based gear was assessed. Differences between the overall proportions given in the three survey years were tested using the Z-test for proportions. Unfortunately, the same data for electric based fishing are not available for the 2008 or 2011/12 survey, so this analysis is restricted to hook-based fishing only. In the absence of these longitudinal data for electric fishing, the proportion of fishers that have observed a YFP death caused by electric fishing was used as an indirect metric instead. These data were collected in both the 2011/12 interview survey and the 2016 survey and differences between survey years were investigated using the Z-test.

4.3.5.2 Quantifying longitudinal changes in income and fish catch

Income from fishing was assessed in both the present 2016 survey and in the 2011/12 interview survey. In the 2016 survey, fishers were asked to quantify their yearly income for the previous year (2015) and for five and ten years prior (equating to 2010 and 2005, respectively). To investigate longitudinal changes in income, mean income data from 2016 as well as the mean income from the 2011/12 survey data were compared within an ANOVA framework, with post-hoc Tukey tests for specific differences between years. In addition, the proportion of fishers who use fishing as their sole source of income was compared between the 2016 survey and the 2011/12 survey using the two-proportion Z-test.

Similar to the longitudinal analysis presented for income above; changes in fish catch over the three time periods of 2005, 2010, and 2015 were analysed using an ANOVA framework. Fish catch is locally weighed in “jin”, which roughly equates to about 2.5kg. In addition to overall fish catch, the status of the stocks of the nine fish species included in the present survey was quantified through time. These species are known to be prey for YFP, and so these data can provide insight about limited fish stocks as a potential threat to YFP.

4.3.5.3 Identifying drivers of illegal fishing gear use and fishing activity

To investigate demographic and socio-economic drivers of fishing gear use and illegal gear choice, fishing gear data were analysed in relation to age and income within a generalised mixed model framework (GLMM, [1]).

[1] $$glmm(fishing\ type \sim income + age + (1|location))$$

By adding location as a fixed effect, the model structure controlled for any differences in mean gear use between locations (Harrison *et al.*, 2018). Location in this model is by the town the interview was conducted in. Individual GLMMs were run for each of the grouped fishing types: net based gear, pot and trap type gear, fixed net gear, hook-based gear, electric gear, cormorant fishing, and other gear types. The variation in income and variation in age were on very different scales (one parameter ranged from 2500 to 15000 and the other ranged from 25 to 77) and so income was scaled to have a mean of zero and a range of -1 to 1 to remove the large variation between variables.

4.4 Results

4.4.1 Interview statistics

The mean time taken to complete the interview was 47 ± 5 minutes (n=193 as some interviews did not record the time). The mean age of participants in the survey was 50.8 ± 10.1 years, ranging from 25 to 77 years old (n= 264). The mean age of participants in this survey was not significantly different to either the 2008 or 2011/12 fisher interview surveys (52 ± 12.8 years, ANOVA, $F_{(2,\ 1202)} = 7.198$, $p=0.377$; and 49.1 ± 10.9 years $F_{(2,\ 1202)} = 7.198$, $p=0.147$, respectively). Mean age of participants was higher in the 2008 interview survey compared to the 2011/12 survey ($F_{(2,\ 1202)} = 7.198$, $p<0.05$).

4.4.2 Characterising fishing practices in the Yangtze River and Poyang Lake

Fishermen work on 1 - 6 fishing boats but most commonly own two vessels. The most common type of vessel used is a small open boat (*A,* Figure 4.3*,* 74.2% of fishers own at least one of these boats), with the larger, sheltered boat owned by slightly fewer fishers (*B,* Figure 4.3*,* 66.7% of fishers own at least one of these boats). Only 11 individuals interviewed used the large, barge-like vessels that are commonly used as permanent or seasonal accommodation (*C,* Figure 4.3, 4.2% of fishers own at least one of these boats). There were no reports of the use of modern, high-speed vessels used for fishing.

Figure 4.3: Fishing vessels used in the Yangtze River and Poyang Lake. **A**: small, open fishing boat, **B**: medium sized fishing vessel with shelter and sleeping quarters, and **C**: larger, sheltered vessels used for fishing and as more permanent accommodation.

The types of fishing gear use in the 2016 survey and the two previous interview surveys are presented in Table 4.3. The fishing gear used in the survey areas can be characterised into functional types; fixed net type gear which is semi-permanently fixed into the river bed; gill and drag net type gear that are cast into the water by hand; hook type gear which typically constructed of a long fishing line with interspersed hooks attached; electric type gear of varying form; and a category of "other" types that are relatively unique and otherwise not grouped. This "other" group includes "AiWei", a type of moat constructed to trap fish, and traditional cormorant fishing, amongst others.

The number and range of fishing gear types and methods used is high; 56 types of gear have been identified across all three survey years but some are only noted once (Table 4.3). It is highly likely that some of the less commonly used names (in the group "unknown/undefined) are names in vernacular or local Chinese dialects for gear types more commonly used in the other groupings. It is also possible that some of these gear types are only used in specific areas only surveyed in one of the three survey years.

Of 260 respondents, interviewees used 1 - 4 different types of fishing gear; 23.2% used only one type of gear, 44.3% used two types, 27.1% used three types and 5.3% used four types. The most frequently used type of gear was gill and drag net type gear (74.8% used at least one type of this category of gear), followed by pot and trap type gear intended to catch crabs, shrimp and small fish (65.3% used at least one type of this category of gear). These were followed by fixed gear (17.9%), cormorant fishing (6.5%), hook type gear (3.4%), and electric gear (0.4%).

Observations of YFP mortalities by fishers from all three interview surveys (2008, 2011/12, and the present 2016 survey) are presented in Table 4.3. As each of the three surveys contained a different number of interviews across differing localities, the data are not to be taken as absolutes but do provide information about which fishing gears have previously been observed to cause YFP mortality. These data demonstrate that YFP can be killed in at least 14 gear types (Table 4.3). When the reported YFP mortality data from all three interview survey years were combined, there was a significant difference in the proportion of observed YFP mortalities from each gear grouping (X^2 = 39.1, df = 4, $p < 0.001$, Table 4.3), with rolling hook gear, electric gear, and maze-type fixed gears (MiHunZhen) the predominant gear types that caused fishing-based YFP mortality. In addition, three types of free-floating and gill net type gears have also caused a number of reported YFP mortalities from these surveys (LaWang, SiWang, and SanCenWang, Table 4.3).

Table 4.3: Names of fishing gear types used in the Yangtze basin (interview locations vary year-to-year) and number of directly related YFP mortalities noted during fisher interview surveys in 2008, 2011/2012, and 2016. Values are not absolutes and only indicate types of gear that cause YFP mortality.

Functional Group	Fishing Equipment Type	Description	Present and used during interview survey			Number of cases of YFP mortality noted			Total
		Year interview study conducted	2008	2011/12	2016	2008	2011/12	2016	
		Number of interviews conducted during survey	499	400	265	499	400	265	1164
Drag net type gear	TuoWang	Large drag net	*	*	*	1			1
	FengWang	Large drag net	*	*	*				
	WeiWang	Large drag net	*	*	*	3		2	5
								Drag net type gear total reported mortalities	***6***
Free-floating gill net type gear	SiWang	Large net type gear	*	*	*	4		10	14
	SanCenWang	Three-layered gill net	*	*		10			10
	DaoYuWang	Gill net	*	*	*	3			3
	LaWang	Gill net		*	*			17	17
	TongYuWang	Gill net	*						
	MaoHaoWang/HaoWang	Gill net	*	*	*				
	PiaoWang	Gill net			*				
	DanCenWang	Single layer gill net	*						
	ShenShuiWang	Gill net	*			1			1
	ShiYuWang	Gill net	*			2			2
	HaiZiWang	2 boats with a net dragged between	*						
	TangWang	Gill net		*	*			1	1
	LiuCiWang	Gill net		*					
	DaWang	Gill net	*						
	GaoWang	Gill net		*	*				
	Xuan/XianWang (drag)	Unknown		*					
								Free-floating gill net type gear total reported mortalities	***48***
Hook based gear	GunGou	Rolling hook	*	*	*	34		7	41
	DiaoGou	Diao Hook – smaller hook.	*	*					
	TieGou	Hook type gear		*	*				
	KaZi/QiaZi	Bamboo “hook”		*	*				
	ChengGanWang/GanWang	Rod/ pole and line type	*	*					
								Hook based gear total reported mortalities	***41***
Electric type	Electric fishing	Electric current passed through net or poles	*	*	*		9	19	28
	Electric & cormorant fishing	Two separate boats working together	*	*					

								Electric type gear total reported mortalities	***28***
Fixed Nets	MiHunZhen	“Maze” type fixed net.	*	*	*	4	5	10	19
	Fyke Net	“Fixed” net.	*	*	*		2		2
								Fixed net gear total reported mortalities	***21***
Other	Cormorant fishing	Traditional fishing using cormorant birds			*				
	BanZeng/BanZheng	Large “scoop” net.	*	*	*				
	XiaLong	Shrimp/crab/lobster traps	*	*	*				
	DiLong	Lobster/crab pot/trap			*				
	TaiWang	Large rectangular net held up from above	*						
	AiWei	Moat fishing	*		*				
	BianWang	Throw nets	*						
	ShiYuWang	Throw nets	*						
								Other gear total reported mortalities	***0***
Unknown/ undefined	Miwang	Unknown			*				
	KouDaiWang	Unknown			*				
	ZhenGongWang	Unknown			*				
	ZhangWang	Unknown			*				
	NiLongWang	Unknown			*				
	DingZhiWang	Unknown			*			1	1
	WenSiWang	Unknown			*				
	PaWang	Unknown		*	*				
	LuNiao	Unknown		*					
	JiWang	Unknown		*	*				
	XieWang	Unknown		*	*				
	DiChan	Unknown		*					
	FuWang	Unknown		*	*				
	TianWang	Unknown		*					
	HaiWang	Unknown	*		*				
	GaoMiZhen	Unknown		*					
	HuaWang	Unknown	*						
	TaiWang	Unknown	*						
	DuanWang/DianWang	Unknown		*	*				
	JiaoWang	Unknown	*						
	Xuan/XianWang	Unknown	*	*					
								Other gear total reported mortalities	***1***
Total			*31*	*33*	*34*	*62*	*16*	*67*	*145*

Note: 2008 interviews were Yangtze wide (Yichang-Shanghai), but did not include Poyang or Dongting Lakes; 2011/12 covered Dongting Lake and a main stem section from Hukou-Anqing; 2016 interviews covered Poyang Lake and Yangtze mainstem Hukou – Anqing. “Wang” translates to “large net”, “Gou” translates to “hook”.

4.4.3 Spatial variation in fishing gear use in Poyang Lake

There was some spatial variation in fishing gear use between the H-A mainstem section and Poyang Lake (Figure 4.4). The most commonly used fishing gear in the mainstem was net type fishing gear, followed by pot/trap type gear and fixed fishing gear. The most commonly used fishing gear in Poyang Lake was pot/trap type gear, followed by net type gear and hook type gear. No interviewees in the H-A mainstem section reported using cormorant or electric fishing gear.

Significantly more fishers are using net-based gear in the H-A mainstem section than in Poyang Lake (X^2 =19.3, df =1, p<0.001, Figure 4.4). Significantly more fishers use pot/trap type gear (X^2 =13.6, df =1, p<0.001), electric type gear (X^2 =7.7, df =1, p<0.05), and cormorant fishing (X^2 =9.4, df =1, p<0.05) in Poyang Lake than the H-A mainstem section. There were no differences in fixed gear, hook gear or "other" types of fishing gear used between Poyang Lake and the H-A mainstem section (X^2 =0.5, df =1, p= 0.50, X^2 =2.2, df =1, p=0.14, X^2 =0.5, df =1, p=0.48).

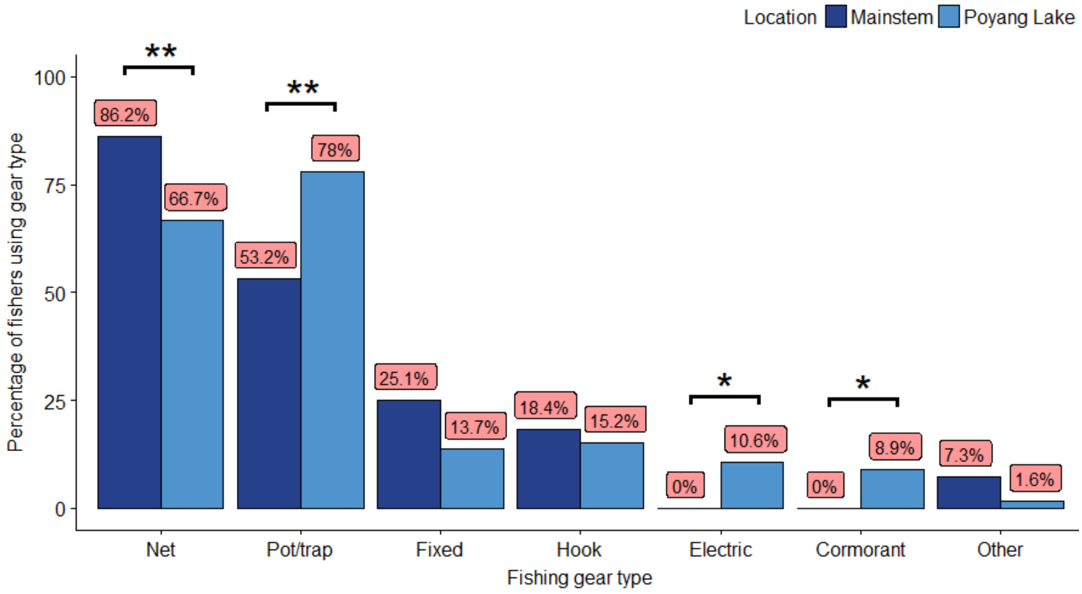


Figure 4.4: Percentage of fishers using functional types of fishing equipment from Poyang Lake towns (Xingzi, Yongxiu, Poyang, Duchang, Yugan, N=176) and from H-A mainstem section towns (Anqing, Pengze, Wangjiang, Chizhou, Susong, Hukou, N=84). Asterisks indicate significant differences: 5% level (*), 1% level (**).

There were no significant differences in the use of net type gear, (, X^2 =1.1, df =4, p=0.90) or pot/trap types gear (X^2 =3.5, df =4, p=0.47) between Poyang Lake towns (Figure 4.5). All other types of gear contained at least one value below a count of 5, so the statistical tests could not be run. For example, hook-based gear was used by 43.5% of fishers interviewed in Xingzi but no interviewees from Poyang town. Electric fishing gear was used by 23.1% of fisher interviews in Yugan but only 3.3% in Yongxiu. All reports of cormorant fishing were restricted to Duchang, Yugan, and Poyang town.

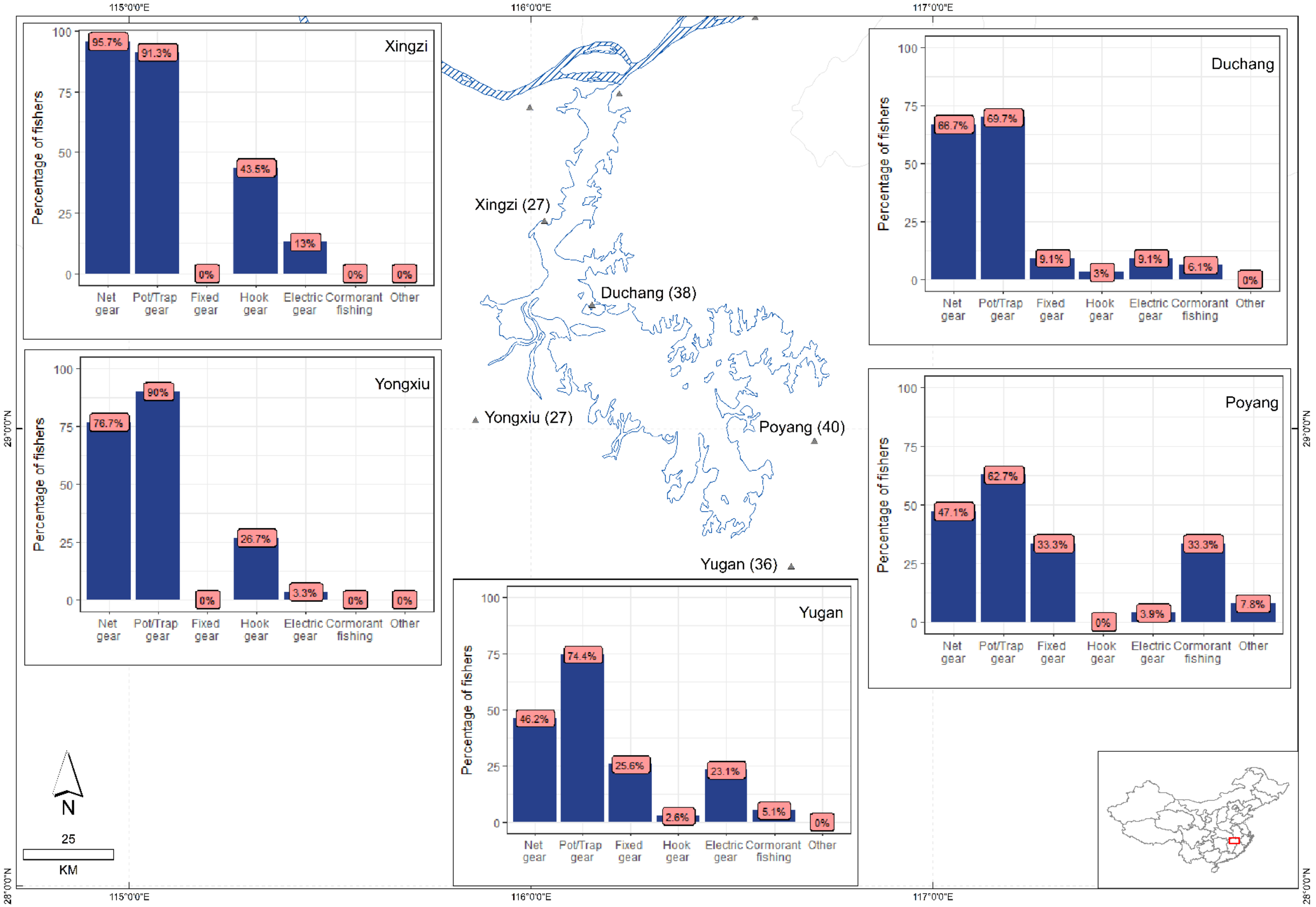


Figure 4.5: Spatial variation in percentage of fishermen using fishing gear types across major towns in Poyang Lake. Number of interviews represented in brackets. Note: fishers from Hukou not included as it could not be distinguished whether they fish in Poyang Lake or the H-A mainstem section.

4.4.4 Temporal patterns in fishing activity

4.4.4.1 Seasonal patterns in fishing gear use

Although fishing occurs throughout the year, the intensity of fishing practices is highly seasonal in Poyang Lake and in the H-A mainstem section (Figure 4.6). Fishing activity within Poyang Lake shows distinct peaks in the summer months from June to September (Figure 4.6). The H-A mainstem section shows a similar pattern but the peak fishing season begins a month later in July, and more fishers continue fishing well into the winter months (Figure 4.6). In Poyang Lake, June is the busiest fishing month (89.7%), and in the H-A mainstem section the highest fishing activity is in September (82.9%). The month with the lowest fishing activity is April in the H-A mainstem section (10.5%) and January in Poyang Lake (11.9%).

There are spatial differences in fishing activity between the two systems: the proportion of active fishers between Poyang Lake and the mainstem is significantly different in January ($X^2 = 8.6$, df = 1, $p < 0.05$), February ($X^2 = 13.7$, df = 1, $p < 0.001$), May ($X^2 = 4.4$, df = 1, $p < 0.05$), June ($X^2 = 1.1$, df = 1, $p = 0.90$), July ($X^2 = 15.1$, df = 1, $p < 0.001$), September ($X^2 = 8.8$, df = 1, $p < 0.01$), October ($X^2 = 25.8$, df = 1, $p < 0.001$), November ($X^2 = 27.5$, df = 1, $p < 0.001$) and December ($X^2 = 13.3$, df = 1, $p < 0.001$). In Poyang Lake, fishing was reported from April (21.6% of fishers are active) and May (27.6%, Figure 4.6), months that are supposed to be covered by a complete ban on fishing. Only part of March and June is covered by a fishing ban in Poyang Lake, so fishing is allowed for part of these months. In the H-A mainstem section fishing was reported from the fishing ban months of April (10.5%), May (14.5%), and June (15.8%, Figure 4.6). In comparison, when asked to estimate the proportion of the local community that continues to fish during the fishing ban, the mean estimate was 8.5% (n=210) for all interviews over both Poyang Lake and H-A mainstem section, with estimates ranging from 0% to 100%. The mean estimate of the proportion of fishers who fish during the fishing ban was significantly higher in Poyang Lake than in the mainstem (Poyang Lake = 10.2%, mainstem = 4.3%, $t = -2.9$, d. f. = 197.1, $p < 0.001$).

When individual informants were asked how much of the surrounding community fished at night, the mean estimate was 21.6% (n=210), ranging from estimates of 0% to 100%. However, when asked individually if a participant fished at night, 34% said yes and 64% said no (n=229). Significantly more interviewees stated that they fish at night in the H-A mainstem section than in Poyang Lake (44.6% in H-A, 30.2% in Poyang Lake, $X^2 = 4.2$, df = 1, $p < 0.05$). Some interviewees reported that it is too dangerous and so no one fishes at night, and others reported that only fishers who use fixed maze nets (MiHunZhen) and gill net (SiWang) fish at night, and others yet stated that everyone conducts fishing at night in the peak fishing season in summer months.

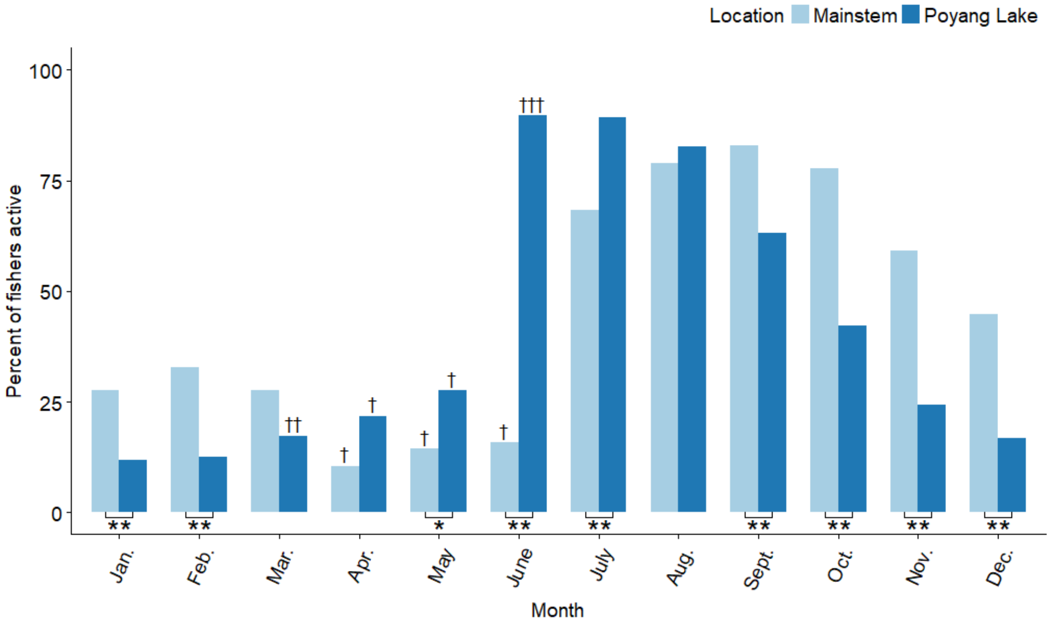


Figure 4.6: Seasonality of fishing activity in the H-A mainstem section (n=76) and Poyang Lake (n=185) represented by the % of fishermen carrying out any fishing activity in each calendar month. † indicates months where fishing is banned for the entire month. †† indicates months where fishing is banned from the 20th onwards ††† indicates months where fishing is banned up until the 20th of the month. Asterisks indicate significant differences between locations at the 5% level (*) and 1% level (**) (z-test for proportions using the chi-squared statistic).

4.4.4.2 Longitudinal patterns in fishing gear use: changes in fishing gear use between 2008, 2011/12, and 2016 surveys

The interviewees were asked to estimate the proportion of the local community that conducts hook-based fishing currently, five years ago, and ten years ago. The mean percent of responses within each of the six categories provided changed between each of the three time periods queried (Figure 4.7). The number of respondents choosing the categories “none” and “very few” increased over the three progressive time periods (X^2 =21.6, df =2, p<0.001, and X^2 =12.2, df =2, p<0.05, respectively), whereas the number of respondents choosing the categories “<25%”, “<=50%”, “>50%” and “100%” decreased over the three progressive time periods (X^2 =6.2, df =2, p<0.05, X^2 =12.0, df =2, p<0.05, X^2 =17.5, df =2, p<0.05, X^2 =23.7, df =2, p<0.05, respectively).

The proportion of hook-based fishers was 36.1% in the 2008 fisher interview survey, 27.3% in the 2011/12 fisher interview survey, and 12.7% in the 2016 fisher interview survey. The proportion of fishers using hook-based fishing significantly decreased between each of the three interview survey years (X^2 =47.5, df =2, p<0.001).

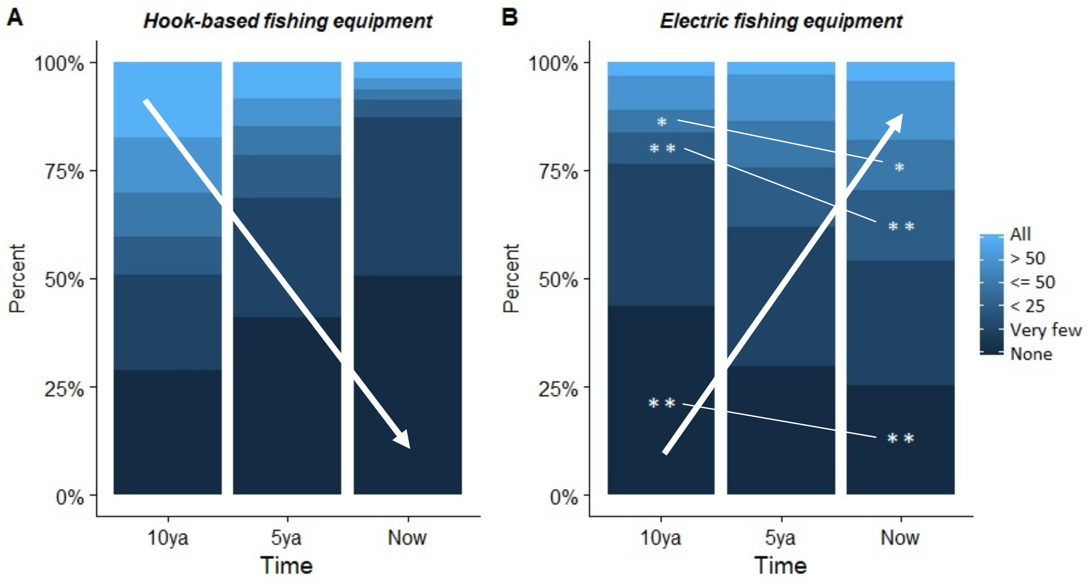


Figure 4.7: Changes in perceptions of hook type fishing gear use (A) and electric fishing gear use (B) by the local community. Data are summarised information from respondents when asked what percentage of the local community uses electric fishing currently (“Now”, n=209), 5 years ago (“5ya”, n=212) and 10 years ago (“10ya” n=207) and for hook based fishing currently (“Now”, n=228), 5 years ago (“5ya”, n=227) and 10 years ago (“10ya” n=218). These years roughly equate to 2016, 2011, and 2006, respectively. Asterisks on B indicate significant differences within the same categories between years at the 5% level (*) and 1% level (**) e.g. “none” category between “10ya” and “now”. For A, all years and all groups are significantly different, and so are not marked. For clarity, white arrows indicate decreasing trend in use (A) and increasing trend in use (B).

Conversely, for the same question structure, fisher estimations of electric gear use indicate an increase in use over the last decade (Figure 4.7). The number of respondents choosing the category “none” decreased between “10ya” and “now” estimations (X^2 =14.3, df =1, p<0.001), whereas the number of respondents choosing the categories “<25%” and “<=50%” increased between “10ya” and “now” (X^2 =7.3, df =1, p<0.001, X^2 =4.4, df =1, p<0.05, respectively). In addition, the proportion of fishers that have observed a YFP killed by electric fishing has increased from 7.7% in the 2011/12 survey to 12.8% in the 2016 survey (X^2 =3.9, df =1, p<0.05). The reason for changing to electric fishing provided most often was that “there are fewer fish now” (44.6% of interviewees), followed by “it’s easier” (13.4%) and “I can make more money” (10.2%).

4.4.5 Has catch or income changed over time?

Mean income was lowest in 2005 and highest in 2015, as would be expected with inflation (Figure 4.8). Mean income significantly differed between survey years ($F_{3,833}$ = 15.14, p<0.001). Post-hoc Tukey test results show that mean income has significantly increased from 2005 to all later years of 2010 (p <0.001), 2011/12 (p<0.001), and 2016 (p<0.001). No significant differences were present between other years.

In total, 67.3% of fishers interviewed used fishing as their sole source of income in the 2016 survey, with the remaining 32.7% using other forms of additional income. This is a significantly lower proportion than interviewees in the 2011/12 interview survey, which was 94.5% of interviewees (X^2 = 80.9, df= 1, p < 0.001).

A total of 60.1% of respondents reported that their income is unstable (n= 248). The main reasons interviewees gave for unstable income was “fish stocks have decreased” (20% of interviewees), “unstable fish catch” (16.4%) and “water level fluctuations” (10%). Out of 237 respondents, 86.5% stated they would be willing to take on alternative livelihoods to fishing if offered, with the remaining 12.2% and 1.3% stating they would not or that they did not know, respectively.

Although mean and median values for mean daily catch were progressively lower from 2005 to 2015 (Figure 4.8 B), there was no significant difference ($F_{1,513}$ = 1.276, p= .259). This is possibly due to the very high variation in results, as standard deviations were of an order of twice the mean catch for 2015.

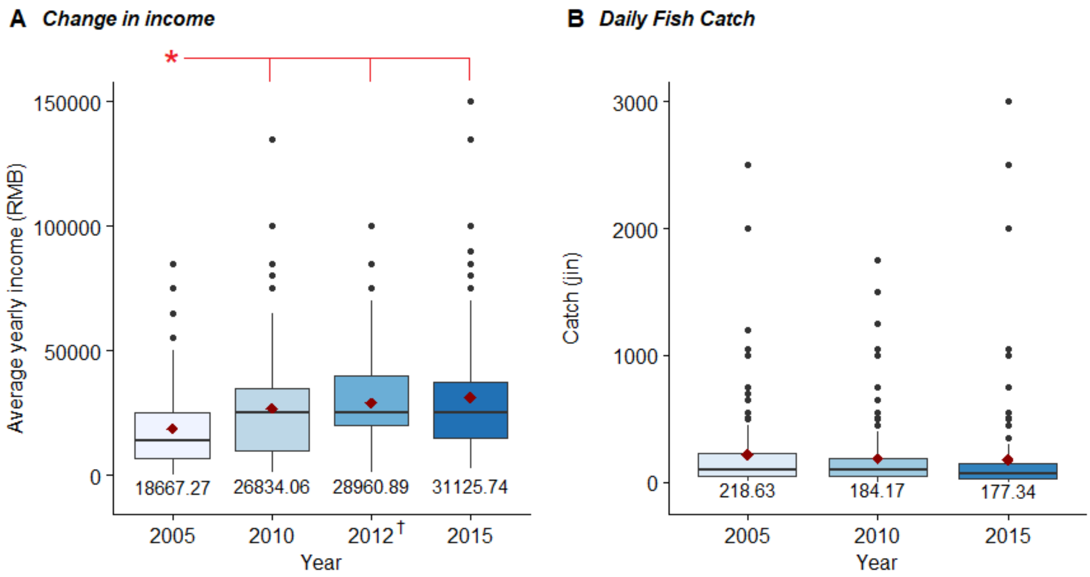


Figure 4.8 Boxplots of change in income and fish catch from 2005 to 2015 reported by fishers in interviews. Income: Mean yearly income for 2005 (n= 194), 2010 (n= 229), 2012 (n= 179), 2015 (n= 235) in RMB. Fish catch: mean estimated daily catch reported by fishermen for the previous year (equating to 2015, n=194), 5 years ago (2010, n=174) and 10 years ago (2005, n=147). † the “2012” data are from the 2011/12 interview survey. All other data are from the 2016 interview survey conducted for this study. * indicates significant differences between years – 2005 mean is significantly different to all other years.

For eight of the nine fish species included in the fish stock questions, the predominant answer for the stock status was “declining” (Figure 4.9). For all responses for all species of fish combined, 68.9% of responses were “decreasing”, 19.6% were “stable”, 7.9% were “decreasing” and the remaining 3.6% of responses were “don’t know”. The stocks of shad (*Tenualosa reevesii*) were most commonly noted as declining (91%) and common carp was noted as declining by the least number of interviewees (45.7%, Figure 4.9). The highest number of “don’t know” responses was 5.3% received for *Xenocypris davidi*, so confidence in answering the fish stock based questions was relatively high.

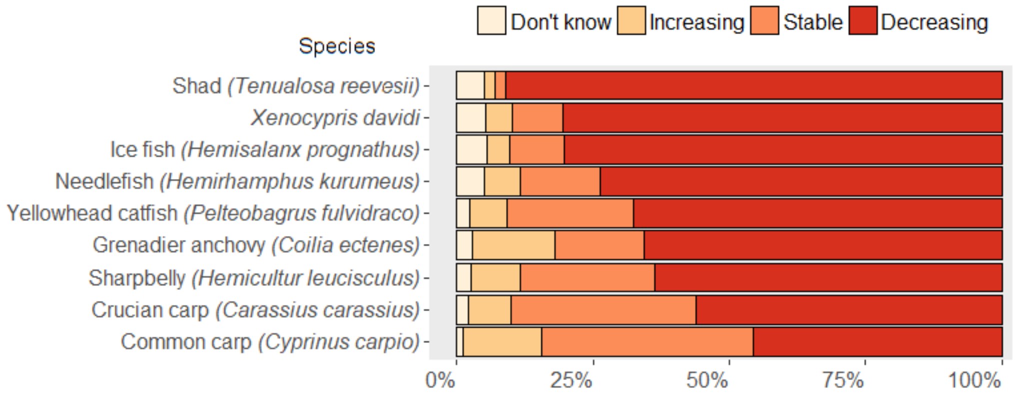


Figure 4.9: Fisher responses to stock status of nine YFP prey-specific fish species in the Yangtze River (in order from top to bottom, n=212, n=227, n=218, n=216, n=238, n=238, n=231, n=232, n=243).

4.4.6 Drivers of illegal or potentially lethal gear use

Results of the GLMM indicate that that hook-based fishing is positively associated with age, indicating that older fishers are more likely to use this fishing gear types (Table 4.4). Pot or trap type gear is negatively associated with age, meaning that younger people are more likely to use this group of fishing gear (Table 4.4).

Table 4.4: Results of a GLMM investigating income and age as predictors of specific fishing gear type use

Fishing gear type		**Effect size**	**Error**	P value
Net type gear	Income	0.234	0.187	0.209
	Age	-0.019	0.017	0.257
Hook type gear	Income	0.350	0.201	0.082
	Age	0.076	0.024	0.002*
Fixed gear	Income	0.237	0.179	0.184
	Age	0.005	0.021	0.825
Cormorant fishing	Income	0.086	0.381	0.822
	Age	0.050	0.035	0.155
Electric fishing	Income	0.044	0.248	0.858
	Age	-0.026	0.027	0.337
Pot or trap fishing	Income	0.162	0.164	0.325
	Age	-0.054	0.017	0.002*

* indicates 1% significance level

When asked why they choose their primary gear type, the predominant answer fishers gave was that "it catches the species that they want" (20% of responses, n=240). This was followed by "it catches the most fish" (12.9%), "because it is legal/ because other types are illegal" (12.1%), "because it is traditional/because it was handed down to me/because I have always used it" (10.83%), and "there are no fish left so now I use shrimp fishing" (5.8%). When these data were broken down into specific gear types, the main reason for choosing a gear type differed. The predominant reason for choosing hook-based gear was “it has been passed down through generations/it is traditional” (35.3%, n=34), followed by “it catches the bigger fish” (17.65%). The predominant reason for choosing MiHunZhen (a type of fixed net) is that “it is permitted/all others are illegal” (29.7%, n=37), followed by “it catches the small fish” (21.6%). It was not reported whether this refers to smaller species of fish or just smaller sized juveniles. Users of electric equipment most often cited that “other cannot catch fish anymore” (33%, n=12) and “fish stocks are too low for other types” (25%).

4.5 Discussion

4.5.1 Characterising fishing activity and Yangtze finless porpoise bycatch

The results shown here demonstrate that fishing practices in Poyang Lake and the H-A mainstem section are artisanal in their nature, dominated by gill and drag net-based fishing gears deployed by hand from relatively small fishing boats. This is similar to many other fishing based communities in rural areas around the world such as West Africa and Brazil (Campredon & Cuq, 2001; Schafer & Enir, 2008). There is a wide variation in the gear types used and a range of local names, possibly indicating minor differences in their design, which makes understanding and quantifying fishing activity in this system very complex. Fishers commonly use multiple types of fishing gear and boats. Despite being relatively small scale and low-tech, artisanal fisheries can still have significant environmental impacts (Ruttenberg, 2001; Lloret, Muñoz & Casadevall, 2012; Bender *et al.*, 2014) and can still cause cetacean bycatch (e.g. Mangel *et al.*, 2010; Iriarte & Marmontel, 2013b). In addition, although fishing in this region is relatively artisanal it is now enhanced by use of electric fishing equipment, which is known to be lethal to YFP.

Although it has been argued in chapter 2 and 3 of this thesis that bycatch-caused mortality of YFP is probably less of a threat than has previously been asserted, YFP bycatch does still occur and the results presented here implicate specific gear types. Observations of YFP mortalities by fishers from the three interview survey years reinforce previous assertions that rolling hook and electric fishing are likely to be key causes of YFP bycatch-caused mortality (Zhou & Wang, 1994; Turvey *et al.*, 2013). In addition to these gear types, the results shown here indicate that maze nets (e.g. mihunzhen) and specific types of gill net (specifically siwang, sancenwang, lawang) have also contributed to many of the bycatch-based mortalities observed by fishers. Although previous publications have reported YFP bycatch in “fixed pound nets” (Table 4.1) the names of specific gear types were not reported. The new data presented here are therefore the first time that many of these specific gear types have been implicated as having caused a significant number of YFP mortalities. As mentioned in the methods, these data are not to be taken as absolute levels of mortality because they cannot be adjusted for the possibility of multiple reports of the same mortality event, and the data are also subject to the typical informant biases found within LEK data (McKelvey, Aubry & Schwartz, 2008). However, the data do indicate that these types of fishing gear can cause YFP mortality and therefore that they may require interventions aimed at reducing the likelihood of YFP bycatch.

Legality of specific fishing gears is based on either national level or more localised province level legislation (Turvey, Hao & Ding, 2012). Electric fishing is currently illegal at a national scale, but hook based fishing is not illegal in Poyang Lake (Turvey, Hao & Ding, 2012). In chapter 5 of this thesis, it is shown from interviews with fisheries bureaus that maze nets such as mihunzhen are illegal in only 35.3% of sampled towns. Some gill nets are illegal in some towns (23.5% of fisheries bureaus interviewed in Chapter 5), but the specific gear types were not used in this question and so we cannot compare these data to specific gear types. In order to reduce the likelihood of YFP bycatch and to improve prospects for this Critically Endangered species, these newly identified bycatch-causing types of gears (i.e. mihunzhen, siwang, sancenwang, lawang) should be the target of legislative mitigation.

Further to the need to make these gear types illegal, the results here indicate there are issues with enforcement of the fishing ban and of illegal fishing gear types. As demonstrated by the continued use of electric fishing gear, legislation and enforcement is failing to stop all use of this gear type despite a national level ban on this fishing equipment. Further to this point, despite few fishers directly admitting to using this gear type, the results of the indirect question analyses (proportion of the local community using the gear now, five years ago, and ten year ago) indicate that electric fishing has significantly increased in use over the last decade. This indirect questioning method is demonstrated to be reliable by the corroboration of both the direct longitudinal analysis and indirect hook-based fishing gear use questions. In addition, the significant spatial variation in gear use within and between survey areas, specifically illegal or detrimental gear types, demonstrates spatial non-uniformity in both the gear types used and spatial variation in the effectiveness of enforcement. For example, electric fishing is illegal at a national level, yet fishers in the present survey used significantly more electric fishing gear in Poyang Lake than in the H-A mainstem section. In addition, more interviewees fish during the fishing ban in Poyang Lake than in the H-A mainstem section. Although it is not illegal, fishing at night evades daytime fisheries bureau patrols and mean that illegal fishing types would not be controlled for, and more interviewees fished at night in the H-A mainstem section. These observed patterns match spatial non-uniformity patterns in illegal gear use and illegal behaviours observed in other systems (Shova & Hubacek, 2015). Poor enforcement against illegal fishing activity is pervasive globally (Pitcher *et al.*, 2008) and the continuation and increase in use of illegal fishing gear demonstrated here indicates that enforcement is not sufficient to reduce illegal activity. This fishing gear is known to cause YFP mortality (Turvey *et al.*, 2013, and results shown here). A more uniform approach to banning certain gear types, as well as uniformity in enforcement, may increase the effectiveness of YFP bycatch and overfishing mitigation efforts. This could be facilitated through increased communication between fisheries bureaus about YFP enforcement, and a reassessment and strengthening of the current enforcement in place to address areas needing improvement.

The same pattern is observed with the seasonality of fishing activity observed here; there are seasonal patterns in both legal and illegal fishing activity and fishing is continuing during all months that the fishing ban is in place in both systems studied. Although the fishing ban is predominantly in place to protect fish stocks, not YFP, these findings demonstrate that illegal activity is occurring and that YFP bycatch mortality may still occur in the fishing ban months. Compliance is a crucial component of conservation programmes (Gore, 2011) and is key to the success of any conservation project (Kahler & Gore, 2012). Non-compliance impacts conservation programmes for endangered species (Burton, 1999; Koch *et al.*, 2006; Dinerstein *et al.*, 2007) and protected areas (Hilborn *et al.*, 2006). This non-compliance therefore undermines efforts to reduce overfishing and to control fishing types that are potentially threats to YFP. Combined with the results of the fish-stock based questions, these two results demonstrate that the fishing ban is not effective at either stopping fishers at the intended time or at preventing further fish stock decline.

The information presented here can be used to target key problem areas where illegal or possibly lethal gear types need to be addressed. Such mitigation could be conducted through education and awareness programmes for fishers, or enhanced patrols and enforcement from local fisheries bureaus. Reduction in the intensity of illegal and potentially lethal fishing types would address YFP bycatch and would also reduce the negative impacts of these fishing types on fish stocks. To understand YFP bycatch further, these results should be compared to a low YFP density area. This may highlight possible causative reasons for low YFP density.

4.5.2 Understanding the effect of fish stock decline on YFP

Whilst only indicative of general trends, the fish-stock questions do indicate that YFP-specific fish prey species are predominantly in a state of decline. These data match conclusions from other studies that have demonstrated severe fish-stock decline across the Yangtze River as a result of damming projects, pollution and over-fishing (e.g. Fu *et al.*, 2003; Huang, Wu & Li, 2013; Ye *et al.*, 2014). Although these results are on a relatively coarse scale (i.e. declining, stable, increasing), the concurrence with published fish stock data further supports the use of LEK as a method of rapidly assessing population trends in understudied species (e.g. Beaudreau & Levin, 2014; Nash, Wong & Turvey, 2016).

Similar species such as the harbour porpoise (*Phocoena phocaenoides*) are known to have high energetic demands and exhibit almost continuous hunting behaviour (Wisniewska *et al.*, 2016), making them susceptible to starvation (Read, Wiepkema & Nachtigall, 1997; Lockyer & Kinze, 2003). Prey depletion is a primary driver of decline in other cetaceans (Bearzi *et al.*, 2006, 2008) and is also a key limiting factor to recovery in other cetacean species (Lacy *et al.*, 2017). Although fish stock decline in the Yangtze River has been documented, this is the first evidence of a declining population of YFP-specific fish species. These results do not empirically demonstrate fish-stocks to be a limiting factor on population recovery, but by comparing the observed fish stock decline patterns to other similar species, we can conclude that prey depletion is highly-likely to be detrimentally affecting the YFP population by severely limiting their prey base. To empirically assess this threat, further investigation is needed to quantify fish stock decline by, for example, assessing the biomass of fish stocks in key habitats (such as Poyang Lake) using fish-finder technology. This research would be strongly complemented by the much-called-for YFP post-mortem system, which can directly detect starvation in deceased individuals.

4.5.3 Understanding drivers of illegal fishing behaviour

Bycatch mitigation must take into account the multi-faceted drivers of small-scale fishing behaviour in artisanal fisheries (Teh *et al.*, 2015) and qualitative interview data such as those presented here have previously been used to improve assessment and mitigation in fisheries (Carruthers & Neis, 2011). As noted, the results from this survey indicate that illegal fishing activity is occurring across the Yangtze drainage, and that it varies on both spatial and temporal scales. Understanding what is driving this illegal fishing behaviour is key to targeting mitigation and better reducing the likelihood of YFP bycatch. In other systems, for example, the likelihood of an individual participating in bushmeat hunting is dependent on time availability, poverty, and gender-based influences in communities (Nuno *et al.*, 2013). Motivations for illegal behaviour may also be related to socio-psychological factors, including historical factors (Inskip *et al.*, 2014). Drivers of illegal gear use therefore constitute a complex issue.

In this system, hook-based fishing is continuing to be used by mostly older fishers. This is logical given the reasons for choosing that gear type; our results here demonstrate that many of these fishers continue to use the traditional gears they are familiar with and that have been passed down through generations. As hook-based fishing is now illegal in many parts of the Yangtze River (Turvey, Hao & Ding, 2012) and awareness campaigns are being run by fisheries bureaus (chapter 5, this thesis), awareness that this is an illegal and destructive fishing gear is likely to be increasing. Younger fishers are instead more likely to use pot and trap types gears. A generational shift is therefore occurring, with fishers potentially changing their gear choice based on illegality and generational changes in fishing gear choice. This demonstrated the effectiveness (if possibly a little delayed) in banning certain types of fishing gear. In addition, it is clear from the reasons given that the increase in the use of electric fishing has been driven by resource depletion; low fish stocks and poor catch from other gear types were the predominant reason fishers have chosen to use this gear type. In addition, stocks of larger fish species have decreased significantly in the Yangtze River in recent decades (Fu *et al.*, 2003; Zhang *et al.*, 2006) and fishers stated that they chose hook-based fishing as it catches larger fish. The observed decrease in hook-based fishing shown here may therefore be a result of decreasing stocks of larger fish species.

The results presented here demonstrate that key YFP prey species are predominantly in a state of decline, and also that fishers are struggling to maintain a stable income and that income is not continuing to significantly rise compared to previous years. As demonstrated here by the successful application of LEK data to assess relative trends in fishing practices, these fish stock data are likely to be representative of relative trends. In addition, the minimal data available on fish stocks in the Yangtze from other studies also demonstrate significant overall declines (Sun *et al.*, 2012; Gao *et al.*, 2010; Huang *et al.* 2013). The only possible disparity of note is that the shad (*Tenualosa reevesii*) is thought to be possibly extinct (Turvey *et al.*, 2010b) yet 1.9% of fishers responded that this fish stock was either stable or increasing.

However, 91% correctly identified that this fish species is declining, which was the most appropriate of the response categories provided. This further enforces the assertion that LEK data can be effectively used to assess relative trends in biological systems.

It is important to consider trade-offs between conservation and human wellbeing (McShane *et al.*, 2011), and conservation should not impoverish people and communities (IUCN *et al.*, 2003). Securing the economic, social and cultural rights of small-scale artisanal fishing communities should be a priority when mitigating for fish stock loss and YFP bycatch (Sharma, 2011). Artisanal fisheries are particularly vulnerable (Mills *et al.*, 2009; Kittinger, 2013) and are easily subject to overexploitation of resources (Cinner, Daw & Clanahan, 2008; Bender *et al.*, 2014). The declining fish stocks demonstrated here represent a complex conservation challenge and failures shown here are potentially worsening the loss of fish stocks. Fishers are converting to using more destructive fishing methods such as electric fishing to maintain their income. As these are more indiscriminate fishing methods, they are likely contributing to further fish stock loss. The failure of mitigation methods to help improve fish stock status (for example with fishing continuing during the seasonal fishing ban) means that this intervention is not as effective as it could be if fishing were stopped entirely for the intended period. Improvement of interventions and enforcement is therefore vital to improve fish stocks, support these local communities, and ensure the prey base for the YFP is sustained.

Fishers across the Yangtze region are having to resort to alternative streams of income, which is common in unstable artisanal fisheries (Allison & Ellis, 2001). There are a number of mitigation methods aimed at financially assisting fishers in the Yangtze region, including reimbursements for fishers for complying with the fishing ban and alternative livelihood schemes to reduce the number of fishers in the region (some information in Zhang *et al.*, 2014; WWF, 2017). The effectiveness of these schemes has not been assessed or published. This is a common issue with livelihood schemes worldwide; they are not monitored for their effectiveness and no results are ever reported, meaning the schemes cannot be adapted or improved (Roe *et al.*, 2015). The results presented here indicate that these have not been entirely effective and may need reviewing as part of ongoing monitoring of YFP conservation. Further alternative livelihood schemes and government investment in aquaculture and other income streams should be explored as possible options to sustain these communities and economies and to allow restoration of fish stocks. Improving the state and sustainable management of fish stocks would help both these local fishing communities and also the YFP population. For example, in other systems, targeting alternative employment opportunities to the poorest fishers reduces fishing effort in overexploited fisheries (Cinner, Daw & Clanahan, 2008), an approach which could also be investigated further in the Yangtze region.

4.5.4 How does this information translate into effective bycatch mitigation?

Bycatch mitigation efforts in marine environments are typically through acoustic deterrents (Mangel *et al.*, 2013; Tom *et al.*, 2012; Götz & Janik, 2013), modifications to fishing gear (Broadhurst, 2000; Wang *et al.,* 2010; Afonso *et al.*, 2011; Larocque *et al.,* 2012), and possibly exclusion of fishing from key areas. However, methods of reducing bycatch specifically in freshwater systems are chronically understudied (Raby *et al.*, 2011). Although the likelihood of bycatch is probably comparable to shallow marine systems, the deterrent methods in these latter systems are usually only feasible for large, industrial sized fishing fleets with nets where it is possible to install escape traps for larger non-target fauna. Deterrence using methods such as pingers (e.g. Mangel *et al.*, 2013; Dawson *et al.*, 2013) is more difficult given the density of fishing activity in the Yangtze River, and also given the narrow, shallow habitat that comprises much of the catchment in Poyang Lake. Any pinger would be effective to a distance that would likely cover a very large proportion of the surrounding habitat and cause considerable distress to the animal as there is less space to move away than in a marine environment. These mitigation methods are therefore not considered feasible options in the Yangtze River.

Design modification of net type fishing gears can go some way to reduce the likelihood of bycatch (Northridge *et al.*, 2017), for example by reducing the use of monofilament type mesh and altering the height of the net in the water. Operational changes may be more effective; making discard of fish bycatch whilst fishing could be made illegal so as not to encourage YFP to associate “free” food with fishing gear, which is a common problem for other cetaceans (Northridge *et al.*, 2017) but has not yet been investigated for the YFP. Education and awareness programmes targeting awareness of the destructive implications of using certain fishing gears should also be considered. Other options include:

- Making fishing illegal in high YFP density areas,
- Making all fishing illegal during YFP calving season (summer months),
- Banning fixed nets, maze nets, and trap nets that are likely to be “ghost fishing” and causing more bycatch whilst not being observed.

Many of these options require legal enforcement of rules, without which any intervention is likely to be ineffective. Improved enforcement of illegal fishing types that may cause YFP bycatch should be a priority. In addition, spatially targeting areas of high illegal or detrimental gear use as identified in this study would make awareness campaigns more effective, as well as targeting key demographic groups identified here as using more potentially harmful gear types (e.g. older fishers that continue to use hook-based fishing).

Another option for further YFP bycatch mitigation in the Yangtze region is for the Chinese government to invest in more alternative livelihood schemes. Most fishers in this survey were open to changing their livelihoods, and indeed the results here show that more fishers now are already having to increase their income from additional work outside of fishing. The Chinese government could potentially invest further in aquaculture, farming and other food production programmes as an alternative to fishing, both to restore natural fish stocks in the Yangtze and to also reduce the likelihood of YFP bycatch.

4.5.5 LEK as a method of assessing bycatch and fishing practices

LEK is gathering momentum as an alternative method of collecting conservation-based information in otherwise data poor environments. However, assessing illegal behaviour based on such data is subject to bias from a fear of prosecution (McKelvey, Aubry & Schwartz, 2008; Gavin, Solomon & Blank, 2010). In this survey, illegal fishing during the fishing ban was assessed both directly (asking what month each fisher fished) and indirectly (asking fishers to give a percentage of the local community that fishes in the fishing ban period). Indirectly assessing illegal fishing during the ban resulted in a much lower mean percentage than the assessment derived from asking fishers directly what months they fish (mean of 8.5% from indirect method, compared to a range of 10.5% to 27.6% for the direct assessment for the fishing ban months of March – June). It would typically be expected that direct questioning regarding illegal or sensitive activities would result in an underestimation of that behaviour due to false negatives from those that do not want to admit participating in such behaviour. This suggests that the data collected here by direct questioning may be reasonably accurate, and that informants had a poor grasp of the level of illegal behaviour in their surrounding community. The range of indirect estimates was also very large, further indicating that informants had a poor estimate of the level of illegal activity.

Specific interview methods can be used to counter for biases in admitting illegal behaviour in interviews (Razafimanahaka *et al.*, 2012; Nuno *et al.*, 2013) but they are generally more time consuming and require more complex lines of questioning and explanation. For this reason, and because there was a large amount of other data to gather to achieve the aims of this survey, these techniques were not employed here. However, the more simplistic and quicker questioning technique used here demonstrates that interview-based data are an effective way of assessing general trends in fishing gear use over time and for collecting data on patterns of illegal fishing activity. For example, the pattern of declining of hook-based fishing over the last decade reported in the 2016 survey matched the quantitative data on reported use of this gear type across the three interview surveys conducted between 2008 and 2016. Although this type of interview question method only provides relative trends, it can successfully be used more widely to ascertain long term patterns in fishing gear use if used appropriately, even when illegal or sensitive behaviour is involved. In addition, the LEK based data gathered and presented here enforces the assertion from previous studies that LEK can be useful to assess aspects of cetacean bycatch (Manzan & Lopes, 2015; Liu *et al.*, 2017), including identifying specific and broad groups of fishing gear that cause bycatch, and also assessing spatial and longitudinal trends in the use of specific gear types.

4.6 Conclusions

This research has demonstrated effective use of LEK data to assess fish stock status, quantify spatial and temporal patterns in fishing gear use, to quantify illegal fishing behaviour, and conduct a rapid assessment of causes of bycatch for a data-poor freshwater cetacean. The results demonstrate that (a) there are further fishing gear types that require legislative attention and (b) enforcement of illegal fishing requires urgent improvement. The results here have specifically demonstrated that YFP-specific prey species are in a state of decline, which could be limiting YFP recovery. In addition, the spatial and temporal patterns in gear use demonstrate the need for spatially targeted mitigation programmes, as well as a more uniform approach to banning specific gear types that are known to cause YFP mortality. Fishers within this system are choosing their fishing gear based on whatever fishing gear type will catch the most fish, which is possibly contributing to further fish stock loss. Drivers of illegal and detrimental gear use are dominated by poor adaptation to change and an adherence to traditional fishing techniques passed down through families, meaning that shifts in gear use are delayed by generational length alterations in behaviour. The fishing communities within the study area are struggling to maintain basic income and most individuals are willing to change to an alternative livelihood, which requires further intervention through governmental programmes to promote alternative livelihood programmes, and possibly also development of aquaculture as an alternative to extractive fishing-based livelihoods. Reducing the over-extraction of fishing resources would help the recovery of depleted fish stocks in the Yangtze River, as well as reduce the use of specific gear types known to cause YFP bycatch. Incorporating these patterns into mitigation efforts is vital to maintain the well-being and economic viability of local fishing communities, as well as reducing the likelihood of YFP bycatch and improving the status of declining fish stocks in the Yangtze River.

5 Chapter 5: Use it or lose it: the use and misuse of evidence-based conservation and mitigation selection in the management of a Critically Endangered species

The unsuccessful baiji breeding centre, Tongling (now houses YFP)

5.1 Abstract

Evidence-based conservation for populations in rapid decline is often impeded by a lack of knowledge surrounding the causes of mortality and often an absence of reliable, long-term data to inform effective conservation. Once intervention choices have been made and implemented, conservation efforts should be continually monitored to ensure mitigation is effective, and additionally updated and improved as new information becomes available. Ensuring each stage of the conservation process is met ensures that mitigation is having the desired outcome and avoids complacency. To assess whether current conservation efforts for the Critically Endangered Yangtze finless porpoise are appropriate and effective and to investigate whether evidence-based conservation is being used in mitigation choice, a bibliometric review of current research has been presented and an interview survey was conducted with relevant stakeholders in the Yangtze River region. The bibliometric review assessing the current focus of research into this species demonstrates that current research is not appropriately targeted to improve conservation outcomes for this species. The results presented here demonstrate that the current perception of key causes of decline do not reflect current understanding of porpoise mortality. In addition, current perception of causes of decline have not informed current intervention choices being applied by key stakeholders. A further issue is that perceptions of conservation success for this species are over-inflated despite continued population decline and key stakeholders are basing their decisions on personal observations rather than empirical data, which could be causing complacency with regards to conservation of this species. Evidence-based conservation is therefore not being applied to current conservation efforts for the Yangtze finless porpoise, which risks further population decline. To counter this, recommendations have been made to improve the mitigation process.

5.2 Introduction

5.2.1 How do we optimise conservation outcomes?

A growing body of research aiming to optimise conservation outcomes has emerged over recent decades. This research has covered various aspects of the species recovery process, beginning with optimising data collection and evidence use (e.g. Pullin & Knight, 2001; Haenn *et al.*, 2014), through to ongoing evaluation and adaptation of mitigation to ensure continued improvements and success (e.g. McCarthy & Possingham, 2007; Keith *et al.*, 2011).

Within conservation science there is now a strong emphasis on ensuring that each stage of species recovery is met, including monitoring and continued adaptation and improvement of interventions. The International Union for the Conservation of Nature Species Survival Commission (IUCN-SSC) have summarised this management process in the Species Planning Conservation Cycle (Figure 5.1). This cycle is divided into 'planning' and 'implementation and adaptation'. Key parts of the first section of this process include setting conservation goals, a thorough assessment of threats, and structured planning of actions. Continual evaluation, re-assessment and adaptation of interventions is key to the second stage of this process. This process ensures that conservation goals are being achieved and mitigation is continually updated and adapted based on new information and areas identified for improvement.

Specific techniques aiming to optimise outcomes in this process have emerged in recent decades. Outcome monitoring is one way of assessing the effectiveness of each intervention (e.g. Leverington *et al.*, 2010). However, reporting of outcomes is often predominantly qualitative (Hockings, 2003; Hockings *et al.*, 2009), which is limited in use when making management decisions (Pullin & Knight, 2005; Timko & Innes, 2009; Lindenmayer & Likens, 2010). Other methods of monitoring include including adaptive management (Holling, 1978; Walters, 1986; McCarthy & Possingham, 2007) and "good management practices" such as the IUCN framework for assessing the management of protected areas (Hockings *et al.*, 2006). There is ongoing conflict between conservation practitioners as to the effectiveness of either of these approaches (Black, Groombridge & Jones, 2013), but continued re-assessment and adaptation of conservation efforts should still be an integral a part of the conservation process (Mascia *et al.*, 2014; IUCN - SSC, 2017). If these types of structured conservation methods are not applied, there is the risk of interventions being poorly informed, planned, and implemented.

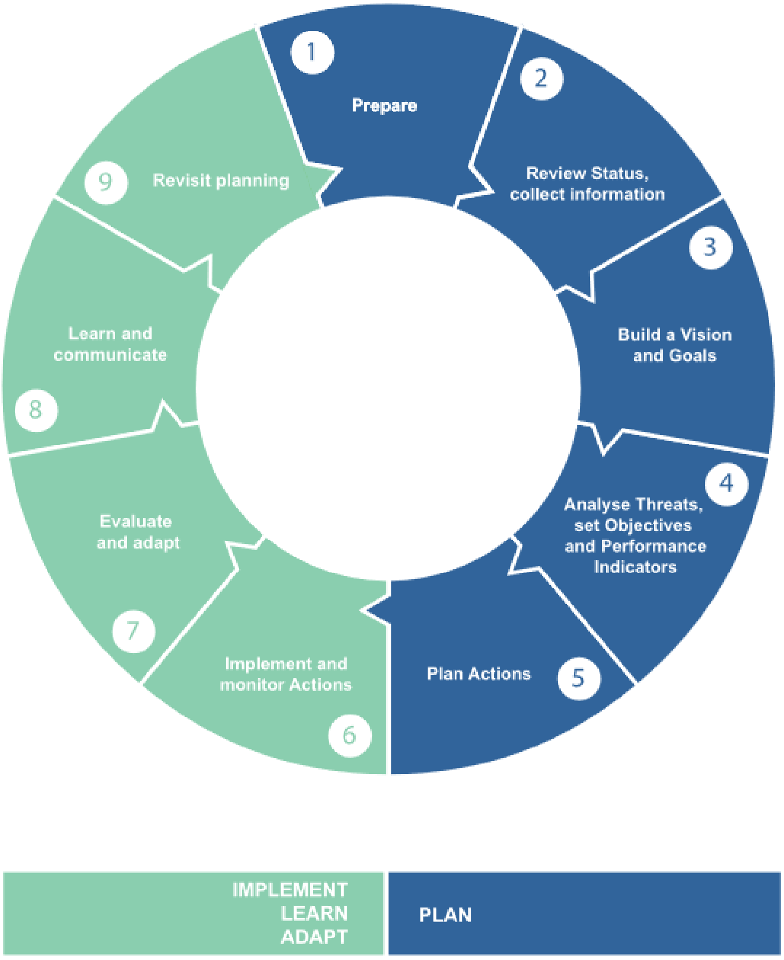


Figure 5.1: The IUCN-SSC Species Planning Conservation Cycle

5.2.2 The importance of evidence-based conservation

Achieving conservation goals in practice is often limited by ineffectively bridging the knowledge-action boundary and effectively translating scientific research into policy, management and interventions (Cook *et al.*, 2013). A crucial part of the conservation planning process is choosing the most effective course of action from a range of potential mitigation options, which requires effectively using all relevant knowledge and research available. However, it is nearly impossible to fully understand any environmental system, meaning that there is uncertainty in our knowledge of it. That uncertainty is translated into any decision made relating to that system. Using scientific evidence is the most effective way to support management decisions (Pullin & Knight, 2003; Sutherland *et al.*, 2004). Evidence-based conservation can help to guide decision making by integrating the best available data to evaluate conservation requirements, causes of population decline and threats, and the likely effectiveness of potential intervention options (Pullin & Knight, 2003; Sutherland *et al.*, 2004; Pullin *et al.*, 2004). Evidence in this case may be in many forms, and may comprise quantitative or qualitative data, as well as information from a range of sources (e.g. quantitative scientific surveys through to more qualitative local ecological knowledge or LEK; Adams & Sandbrook, 2013).

As a significant part of this evidence-base, a thorough assessment of threats is essential to understand and mitigate causes of decline (Carwardine *et al.*, 2012). Threats are often complex and the treatment of each is likely to be different; each of these courses of action raises potential risks and represents a financial and resource burden. Selecting the most effective course of action and avoiding ineffective mitigation is imperative in order not to waste limited resources. Typically, once causes of population decline are well understood, management actions can be implemented to alleviate threats and facilitate recovery of a population. In depleted marine animal populations, for example, major drivers of successful recovery have been reduction of human impacts, reduction of habitat loss and pollution, and improved environmental conditions (Lotze *et al.*, 2011). Awareness, legal protection, and enforcement of management plans are also noted as being crucial to successful conservation of marine animals (Lotze *et al.*, 2011). However, for data-poor species, understanding of significant causes of decline may be limited so choosing appropriate mitigation is restricted by an inadequate evidence-base.

Despite the support for evidence based conservation, conservation managers frequently make decisions based on personal experience rather than empirical evidence (Pullin & Knight, 2001; Pullin *et al.*, 2004; Sutherland *et al.*, 2004). In addition, decision makers often rely on current or traditional practices or secondary literature (e.g. books or guides) to inform decision making, rather than referring to primary scientific publications (Pullin *et al.*, 2004). Although experiential knowledge has some uses (Fazey *et al.*, 2006), personal experience is subjective and open to potential bias. If information is from secondary sources, the data may be outdated or may have been subject to further bias as they are not primary peer-reviewed scientific material. In addition to decisions being poorly informed, often each potential conservation option is poorly evaluated or not empirically evaluated at all (Pullin *et al.*, 2004). Management decisions are therefore commonly made without making full use of the information available, and evidence based practice is not being applied to ensure optimisation of mitigation choices (Pullin & Knight, 2001; Pullin *et al.*, 2004).

Although it is preferable that management decisions are supported with robust evidence, decision makers must often assign resources based on limited or minimal information when conserving data-poor threatened species. For example, in cases of rapid population decline and high extinction risk, time is very limiting and gathering further evidence to support intervention options may not be viable. In such cases, there is a risk of "counting books whilst the library burns" (Lindenmayer, Piggott & Wintle, 2013), which can occur when any population decline is being monitored but there is very little or no intervention to prevent it. This concept has been cited as an ongoing issue with the Critically Endangered vaquita (*Phocoena sinus*, Jaramillo-Legorreta *et al.*, 2007), and was a contributing factor to the extinction of the baiji (*Lipotes vexillifer*, Turvey *et al.*, 2007; Turvey, 2008). The vaquita is now at imminent risk of extinction (Thomas *et al.*, 2017; Taylor *et al.*, 2017). In these cases, the time to extinction is more critical than gathering further data to inform any intervention. In such cases a pro-intervention stance would be arguably preferable, as not intervening at all will almost certainly lead to extinction. Whether to take a pro-intervention or evidence-based stance therefore depends on the species and case-by-case situation. However, interventions should still be based on all available evidence.

5.2.3 Current YFP conservation efforts

Current conservation efforts for the YFP include a system of in-situ reserves, a system of semi-natural oxbow reserves with managed YFP populations (Figure 5.2), and a number of other interventions aimed at managing fishing activity and fish stocks. Other conservation interventions have also been put in place in the Yangtze River. A 3-month Yangtze-wide seasonal fishing ban has been enforced by the Ministry of Agriculture since 2002. The start date varies from March to May, but the ban usually ceases on June 30th to cover the fish spawning season. Fishing is also entirely banned in some protected areas of the Yangtze where there is thought to be a high density of YFP, for example in the Anqing in-situ reserve (Figure 5.2). Part of China's national response to dwindling fish stocks is a series of annual fish fry releases into the Yangtze River to encourage recovery of key commercial species. The fishing ban and the fry release are not specifically intended for YFP conservation as the key species are commercially bred species for human consumption (personal observation and communication with fisheries within country).

The conservation process applied to YFP has not been well documented in the published literature. For example, to what degree evidence-based conservation has been used is not known, and the process from data to intervention choice has not been strategically assessed. Very little constructive valuation or ongoing assessment of current YFP conservation efforts is available in the published literature, and information on the reserve network is sporadic and scattered across multiple publications. Without such evaluation, the effectiveness and limitations of current YFP conservation action cannot be determined. The ongoing rapid decline (Zhao *et al.*, 2008; Mei *et al.*, 2012) and the risk of extinction (Mei *et al.*, 2014; Huang *et al.*, 2017) means that interventions have to be effective to avoid extinction of another Yangtze River cetacean species.

There are various stakeholder groups involved with YFP conservation in China. This includes local YFP conservation-based NGO's, academic researchers and research institutes, fisheries bureaus (with fishing representing one potential threat to YFP), and YFP reserve managers (for both in-situ and semi-natural reserves). There are currently (as of 2018) four semi-natural oxbow lake YFP reserves along the Yangtze River, as well as eight in-situ reserves in the mainstem and lake systems (Figure 5.2). To varying degrees, these stakeholders are involved in decision-making for YFP conservation efforts, including carrying out conservation research for the species, setting up public awareness programmes, or leading on-the-ground mitigation efforts. Below, the responsibility and involvement of each of these groups with YFP-relevant activity and conservation efforts is detailed.

Fisheries bureaus

- In control of fishing related law enforcement and regulation

- Issue fishing permits and carry out fisheries management activities
- Conduct patrols to enforce fishing laws and protected area boundaries
- Conduct general monitoring and reporting of the state of the Yangtze River
- Conduct some government-led YFP mitigation efforts
- Collect some information on YFP mortalities

Local NGO's

- Predominantly conduct YFP awareness raising programmes
- Collect some data of observed YFP mortalities

Reserve managers

- Manage their respective YFP reserve areas and YFP populations
- Responsible for enforcing the laws of their reserve (some reserves have different legal status and zoning systems, as well as varied rules about extractive activities)
- Under the authority of the local fisheries bureau

Research institutions and researchers

- Conduct independently led YFP based research
- Communicate research findings directly to in-country stakeholders and through publications

Further details of the YFP-relevant interventions that these organisations conduct are not publicly available to outside researchers and there is no systematically gathered information to identify the basis on which priority YFP conservation activities have been chosen. In addition, the predominant goals of the research conducted into YFP has never been assessed, and it is not known whether these goals are successful at filling in key conservation gaps for the species. These stakeholders are also a key source of information relating to current and future management of the Yangtze river and the remaining YFP population. What mitigation work they are conducting, as well as the effectiveness of any interventions carried out by them, is not well understood. Dissemination of information and data from scientific organisations and communication between all stakeholders has also not been assessed to determine whether communication is effective in assisting YFP conservation efforts.

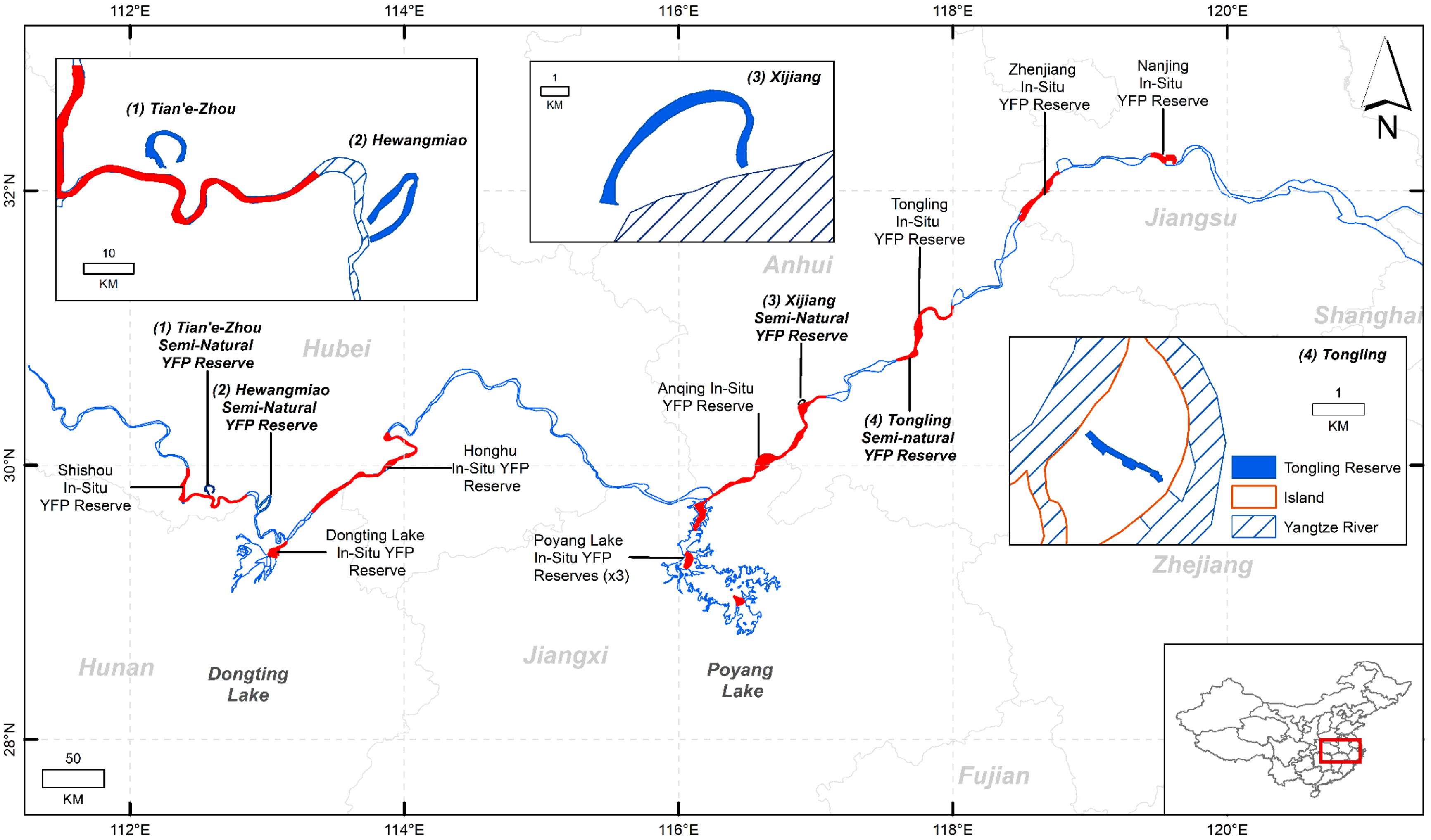


Figure 5.2: Location of all in-situ (8) and semi-natural (4) YFP reserves in the Yangtze River (as of 2017). Map made in ArcMap (ESRI, 2014).

5.2.4 Research Questions

This chapter is comprised of two parts. The first is a bibliometric review investigating the current focus of YFP research and whether there are research gaps. The second part of this chapter describes a structured interview survey of stakeholders that aimed to assess the thought processes and level of evidence-based management that is currently being applied to YFP conservation in China, as well as the identifying current mitigation practices. This survey aimed to understand what parts of conservation planning process are being fulfilled, and to identify where there are gaps for ongoing improvement in YFP conservation efforts.

- Are current research priorities improving the knowledge base surrounding YFP conservation? If not, what are they key remaining research gaps?
- Are current mitigation choices appropriately informed and designed? If not, how might they be better improved?
- Is evidence-based conservation currently being used to inform YFP intervention choice?
- Is current YFP conservation practice adequately accounting for the species conservation planning cycle? If not, what key steps should be improved?

5.3 Methods

5.3.1 Assessment of current research efforts

To assess the extent to which current YFP research is conservation focussed, a bibliometric assessment of recent relevant research was conducted. All published studies covering any aspect of YFP research from the last 10 years (including 2008 to July 2018) were reviewed. The academic search engine used was Google Scholar, and the only search term used was “Yangtze finless porpoise”. This is and has always been the common nomenclature for the species (or previous sub-species designation) and is the accepted common name for the taxon in peer-reviewed papers from the past 10 years. This returns literature written in English as the predominant language but also returns many Chinese research papers that commonly have their abstract and title written in English.

Each publication was grouped into a category according to the predominant topic of the study. Five categories were chosen based on the overarching topics observed within this body of current YFP research; conservation; physiology and biology; ecology; genetics; and survey techniques. The proportion of publications in each group has been used here as an indication of the current focus of YFP research, and to highlight where there are urgent gaps in YFP based research. As a relevant local comparative species, a similar bibliometric assessment was conducted for the baiji or Yangtze River dolphin. The search terms were “baiji” and “Yangtze River dolphin”, within the years 1977 to 2007. This date range represents the period when significant baiji research began through to the year that functional extinction of the species was declared (Turvey *et al.*, 2007). Each publication was grouped using the same categories as for the YFP.

5.3.2 Stakeholder interview survey

To investigate current conservation practice and processes and whether evidence-based conservation is being used for YFP, an interview survey was conducted with 28 stakeholders. The interviews were conducted sporadically between the 12th September and 14th November 2016 alongside the fisher interview survey presented in chapter 4. This survey gathered information about current management and mitigation efforts relating to YFP conservation, and the data sources, justifications, and expectations for carrying out different activities. These data have been used to assess the current level of evidence-based conservation applied to the YFP. In addition, the interview survey aimed to evaluate perceived success of current mitigation activities and identify specific aspects of current conservation efforts that could be improved or require reassessment. The questionnaire is described in more detail in section 5.3.2.1. These data reveal the current level of research, practical conservation action, and public awareness and engagement activities that are currently being conducted or planned relating to YFP, and the reasons why different actions are being carried out. They also provide a comprehensive new baseline to assess the use of evidence at each stage of conservation planning, and insight into the reasons for choosing current mitigation methods, and the flow of information that is currently informing mitigation choice.

These stakeholders comprised fisheries bureaus (n=17), YFP-focussed in-country NGOs (n=4), YFP reserve managers (n=4) and YFP research bodies based along the Yangtze River (n=3). The 17 fisheries bureaus interviewed covered an area of 1300km of the Yangtze River, representing a large proportion of the YFP habitat. Not all fisheries bureaus within this region agreed to be interviewed, so spatial coverage is not complete; those that did choose to participate chose to remain anonymous. Interviews were sought with managers of all four semi-natural reserves but were refused for the national level reserve due to political restrictions. Three local level semi-natural reserves were therefore interviewed, and one in-situ reserve manager also agreed to be interviewed. The reserves have not been named to preserve anonymity.

5.3.2.1 Survey design

The interview survey was written by the author. The interview survey design comprised a total of 79 questions divided into 3 sections (A, B and C). Section A comprised 34 questions used in all 28 stakeholder interviews. Section B was specific to all non-fisheries organisations including all NGOs, research organisations and reserve managers (n=11) and comprised 14 questions. Section C was specific to only the fisheries bureaus (n=17) and comprised 29 questions. The full questionnaire is given in appendix D.

Section A included basic questions about the stakeholder, such as the geographical area covered by their work, information about all YFP related mitigation activities, and opinions on the level of success of current mitigation types. To investigate the use of evidence in decision making, stakeholders were questioned about the perceived causes of YFP decline. In addition, they were asked to rank their noted responses from one (most significant cause of decline) to n (least significant cause of decline out of those given). Stakeholders were asked to select optimal choices for future YFP mitigation from a given list. Each stakeholder was also asked to detail their current YFP related activities. Stakeholders were asked to rank the success of ex-situ (including semi-natural) and in-situ YFP conservation efforts on a Likert type scale (i.e. completely unsuccessful, partly unsuccessful, don’t know (neutral answer), partly successful, completely successful). Stakeholders were also asked to rank the success of their own YFP conservation efforts as well as overall YFP conservation efforts on the same Likert type scale.

Section B (non-fisheries bureaus only) included questions about the specific aims of the organisation, covering surveys and patrols, legal powers, and factors that limit each stakeholder’s ability to conduct YFP conservation activities.

Section C (fisheries bureaus only) focused on gathering data relating to fisheries in the Yangtze. This included quantifying fishing activity, quantifying fish stock status, and their assessment of the effectiveness of current mitigation methods, which include patrolling and prosecuting for illegal fishing, compensation schemes for fishers, alternative livelihood schemes, and fish stock management. To assess the status of fish stocks in the Yangtze River, fisheries bureau representatives were asked to categorise 9 species of fish as "declining", "stable", or "decreasing", with an additional opt-out answer of "don't know". The 9 fish species chosen were the same fish species as fishers were questioned about in the fisher interview survey detailed in chapter 4 of this thesis. These species are known to be prey for YFP, and so these data can provide insight about limited fish stocks as a potential threat to YFP. To investigate any differences in data from fishers and fisheries bureaus, the proportion of responses given in each category for all 9 fish were calculated for fisher interview data.

Four questions used a 5 point Likert based scale as a measure of success (Likert, 1932). These questions aimed to quantify the success of YFP conservation, ranging from "very successful" to "completely unsuccessful". Other questions were a mix of categorical responses (e.g. "yes", "no" and "don't know") and open-ended questions designed to provide further insight outside the bounds of direct questioning.

One pilot interview was conducted with an anonymous representative of a YFP research body. Some questions were adjusted for the final survey based on the responses given in this interview.

Interviews were conducted and transcribed by local student volunteers in Mandarin Chinese and were subsequently translated into English. All interviews were conducted in person on a one-to-one basis with the author present. The volunteers were all native Mandarin Chinese speakers that also had a very good conversational level of English. The volunteers were trained prior to conducting any interviews and followed a written protocol. This training ensured that the intention and meaning of each question was well understood by the interviewer, that the questions were asked using the same wording without deviation, and that no leading language or questions were asked outside of the standard interview questions. The detailed training and predominance of multiple-choice questions were both targeted methods used to limit the bias and to ensure uniformity between interviews and in the translation process.

5.3.2.2 Data analysis

Trends in the interview data were assessed based on the structure of the question. Ranked data were tested as non-parametric data and so were analysed within the appropriate frameworks as detailed below.

To assess whether the most regularly identified cause of decline matches the cause regarded as most significant, responses for these two questions were compared using Spearman's rank correlation. To assess whether perceptions of decline match where conservation efforts are currently focussed, stakeholder perceptions of optimal YFP mitigation choices were compared using Spearman's rank correlation between the two questions. A Wilcoxon signed rank was used to investigate whether there was a difference in perceived success of in-situ and ex-situ conservation. A Wilcoxon signed rank test was also used to investigate differences in perceived personal YFP conservation success and perceived success of overall YFP conservation.

For fish stock questions, the responses from fisheries bureaus were compared to responses for the same question in the fisher interview in chapter 4. To calculate whether the responses had statistically similar proportions in each of the fish stock status categories, these proportions were applied to the total count of responses given by fisheries bureaus (n= 153 responses for all fish species from n = 17 fisheries bureaus). This gave expected counts for each category under the assumption of similarity between fishers' interviews and stakeholder interviews. These two sets of values were compared within a chi-squared goodness of fit framework. To investigate specific differences between categories, standardised residuals were calculated for each pairwise comparison and tested at the 5% significance level. To adjust for multiple testing, the significance value was adjusted using a Bonferroni correction for the number of tests (n=4). Adjusted z-scores were calculated in R.

Additional data are reported as percentages or presented as quotes or summaries. Multiple choice questions and yes/no responses have been reported but not statistically analysed. Means were calculated based on the number of respondents (fisheries bureaus n=17, other stakeholders n= 11). In some interviews participants opted out of answering the question; sample size varies for some questions as a result.

5.3.2.3 Ethical considerations

Ethical review was carried out prior to carrying out the interview survey, and the project was approved by ZSL's Ethics Committee on the 11th March 2016. To ensure protection of participants, all willing respondents have been kept anonymous and interviews were only conducted following verbal consent of participants. All interviewees were informed of their right to not answer any given question if they did not want to.

5.4 Results

5.4.1 Is there sufficient YFP based conservation research?

A bibliometric assessment of published research in the last 10 years (since 2008) found 76 YFP-specific studies (Table 5.1). This research has predominantly been focused on physiology, biology and ecology of YFP, as well as some investigation of genetics and survey techniques. Only 14.7% of published studies relating to YFP have been broadly conservation based. This category includes any publication that directly addressed conservation of the YFP or threats to the species. None of the conservation-based studies from this period have investigated the success of any in-situ intervention options beyond anecdotal comments.

The other studies within this conservation group include four publications that aimed to quantify the YFP population or the rate of population decline (Zhao *et al.*, 2008; Zhao & Wang, 2011; Mei *et al.*, 2012, 2017), two that investigated distribution of YFP (Zhao *et al.*, 2013; Dong *et al.*, 2014b), two that described current YFP conservation efforts in specific areas (Wang, 2009; Jiang, Huang & Yu, 2010), one that studied the effect of transfer of individuals to reserves (Hao *et al.*, 2009) and one that investigated how to detect population trends for YFP and other cetaceans (Huang *et al.*, 2012). Only one study, Turvey *et al.* (2013), attempted to investigate or quantify threats to YFP (Table 5.1). None of the studies specifically quantify spatial or temporal overlap of YFP and threats and no studies attempted to strategically assess conservation options either pre- or post-implementation.

The bibliometric assessment of the baiji (*Lipotes vexillifer*) is presented in Table 5.2. There were 50 studies relating to the baiji published between 1977 and 2007 (prior to its extinction). Conservation based studies made up 30% of these publications but the main topic of research was physiology and biology (50%, Table 5.2). Only four of the published studies attempted to assess threats or mitigation, and only one study attempted to strategically assess conservation options for the Baiji, but this was in 2006, when the population was likely to have already been too small to actively conserve. There have been 14 further studies published post-extinction, which investigated a range of aspects of baiji physiology, genetics, and extinction dynamics in hindsight of the fact.

Table 5.1: Comparison of the types of published studies relating to YFP since 2008, grouped by category

Category	Conservation	Physiology & biology	Ecology	Genetics	Survey techniques
1	Zhao *et al.* (2008)	Lin, Hao & Din (2008)	LI *et al.* (2008)	Zheng *et al.* (2008)	Akamatsu *et al.* (2008)
2	Wang (2009)	Li *et al.* (2009)	Wu *et al.* (2010c)	Chen *et al.* (2010a)	Kimura *et al.* (2009)
3	Hao, Zhao & Wu (2009)	Wu *et al.* (2010a)	Zhao & Wang (2011)	Xu *et al.* (2010)	Li *et al.* (2010a)
4	Wang & Zhao (2010)	Wu *et al.* (2010b)	Xian *et al.* (2010)	Du *et al.* (2010)	Li *et al.* (2010b)
5	Jiang, Huang & Yu (2010)	Popov *et al.* (2011)	Wang & Wang (2011)	Wang *et al.* (2011)	Kimura *et al.* (2010)
6	Zhao *et al.* (2011)	Mooney *et al.* (2011)	Kimura *et al.* (2011)	Chen *et al.* (2014b)	Dong *et al.* (2011)
7	Huang *et al.* (2012)	McLaughlin *et al.* (2011)	Xiong & Zhang (2011)	Liu *et al.* (2015)	
8	Mei *et al.* (2012)	McLaughlin *et al.* (2012)	Kimura *et al.* (2012)	Bi *et al.* (2015)	
9	Turvey *et al.* (2013) †	Pei *et al.* (2012)	Xian (2012)	Chen *et al.* (2016)	
10	Zhao *et al.* (2013)	Mooney *et al.* (2014)	Zhang *et al.* (2013)	Ruan *et al.* (2016a)	
11	Dong *et al.* (2014b)	Guo *et al.* (2014)	Zhang *et al.* (2013)	Ruan *et al.* (2016b)	
12	Huang *et al.* (2017)	Zhou *et al.* (2013)	Wang *et al.* (2014)	Chen *et al.* (2017)	
13		McLaughlin *et al.* (2013)	Wang *et al.* (2015)	Yuan *et al.* (2018)	
14		Wei *et al.* (2015)	Zhang *et al.* (2015)	Zhou *et al.* (2018b)	
15		Fang *et al.* (2015)	Wang, Zhitao *et al.* (2015)		
16		Yu *et al.* (2016)	Fang *et al.* (2016)		
17		Zhang *et al.* (2016)	Chen *et al.* (2016)		
18		Wan *et al.* (2016a)	Platto *et al.* (2017)		
19		Wan *et al.* (2016b)	Mei *et al.* (2017)		
20		Nabi *et al.* (2017)	Zhang *et al.* (2018)		
21		Zeng *et al.* (2017)	Chen *et al.* (2018)		
22		Zheng *et al.* (2018)			
23		Wei *et al.* (2018)			
24		Xiao *et al.* (2018)			
Percent of total (N=77)	***n=12 15.9%***	***n=24 31.2%***	***n=21 27.3%***	***n=14 18.2%***	***n=6 7.8%***

† denotes studies that specifically aim to assess threats and prioritise threats to the YFP, * denotes studies that specifically address conservation options for the YFP

Table 5.2: Comparison of the types of published studies relating to the baiji, or Yangtze River dolphin (*Lipotes vexillifer*) between 1980 and 2007 (the year it was declared functionally extinct), grouped by category

Category	Conservation	Physiology & biology	Ecology	Genetics	Survey techniques
1	Lin, Chen & Hua (1985)	Zhou, Li & Qian (1979)	Zhou, Qian & Li (1977)	Chen *et al.* (1996)	Hua (1994)
2	Zhou (1986)	Zhou, Qian & Li (1979)	Zhou, Pilleri & Li (1980)	Yang *et al.* (2005)	
3	Hua & Chen (1992) †	Anon (1980)	Renjun *et al.* (1994)	Yan *et al.* (2005)	
4	Hua & Wu (1993) †	Zhou, Pilleri & Li (1980)	Akamatsu *et al.* (1996)	Du *et al.* (2007)	
5	Hua & Zhang (1993)	Zhou & Qian (1981)	Yu & Wang (1999)		
6	Liu & Liu (1993) †	Zhou & Li (1981b)			
7	Zhang *et al.* (1995)	Zhou & Li (1981a)			
8	Hua *et al.* (1995)	Chen, Liu & Lin (1982)			
9	Zhou *et al.* (1998) †	Liu & Lin (1982)			
10	Zhang *et al.* (2003)	Li (1983)			
11	Dudgeon (2005)	Lin, Liu & Chen (1985)			
12	Yang *et al.* (2006)	Chen, Lin & Hua (1985)			
13	Reeves & Gales (2006)	Wang *et al.* (1989)			
14	Wang *et al.* (2006a) *	Wang *et al.* (1989)			
15	Wang *et al.* (2006b)	Wang *et al.* (1992)			
16		Gao & Zhou (1992)			
17		Wu *et al.* (1994)			
18		Wang, Wang & Liu (1995)			
19		Chen, Zhao & Liu (1995)			
20		Wang & Liu (1998)			
21		Akamatsu *et al.* (1998)			
22		Ding *et al.* (1999)			
23		Yang, Wang & Liu (2001)			
24		Liu & Zhang (2001)			
25		Chen *et al.* (2002)			
% of total (N = 50)	***n = 15 30%***	***n = 25 50%***	***n = 5 10%***	***n = 4 8%***	***n = 1 2%***

† denotes studies that specifically aim to assess threats to the baiji, * denotes studies that specifically address mitigation options for the baiji

5.4.2 The use of evidence-based conservation for the YFP

5.4.2.1 Does perception of causes of decline and the focus of conservation efforts match? (all stakeholders)

The most frequently noted causes of YFP population decline by stakeholders were pollution, propeller collision, and YFP habitat loss or degradation, respectively (Figure 5.3 A). The most commonly cited primary causes of YFP population decline by stakeholders were firstly pollution; then habitat loss or degradation, decline of fish stocks due to dams, and “other” (all joint second); followed thirdly by fisheries bycatch (Figure 5.3 B). When the responses from these two questions were compared (Figure 5.3 A and B), the order of categories between the two questions did not match ($\rho = 0.599$, $p = 0.04$), indicating that the perceived primary significant cause of decline is not necessarily the one noted most frequently by stakeholders.

When questioned about the best future mitigation options, stakeholders most frequently chose “reduction of fishing intensity”, “strengthened management of reserves” and “reducing or better regulating sand-mining activity” (Figure 5.3 C). The most commonly adopted mitigation activity was “increasing public awareness (59.3%, Figure 5.3 D), followed by improving management of current reserves and control of fishing activities (Figure 5.3 D). Public awareness campaigns mentioned by stakeholders included posters, activities, training and awareness days, and sponsored running activities. The responses given here significantly differed to the current types of YFP mitigation activities being conducted by stakeholders (Figure 5.3 D, $\rho = 0.751$, $p = 0.008$).

Even though pollution was both the most selected cause of decline and the most selected key cause of decline (Figure 5.3 A and B, respectively), no stakeholders were carrying out any activities aimed at reducing pollution sources as a potential cause of decline (Figure 5.3 D, denoted with a *), and when asked to select the best future mitigation options, focusing on reducing pollution was ranked 7th out of the 11 options presented (Figure 5.3 C). A similar pattern was observed with propeller collision; although it was the second most chosen cause of YFP decline (Figure 5.3 A), no stakeholders were carrying out any mitigation relating to reducing boat traffic or reducing the likelihood of propeller collision (Figure 5.3 D, denoted with *).

When questioned about current YFP conservation activities, a total of 92.6% of stakeholders were carrying out public awareness training, and the remaining 7.4% were not, indicating that this activity is a key form of current conservation efforts.

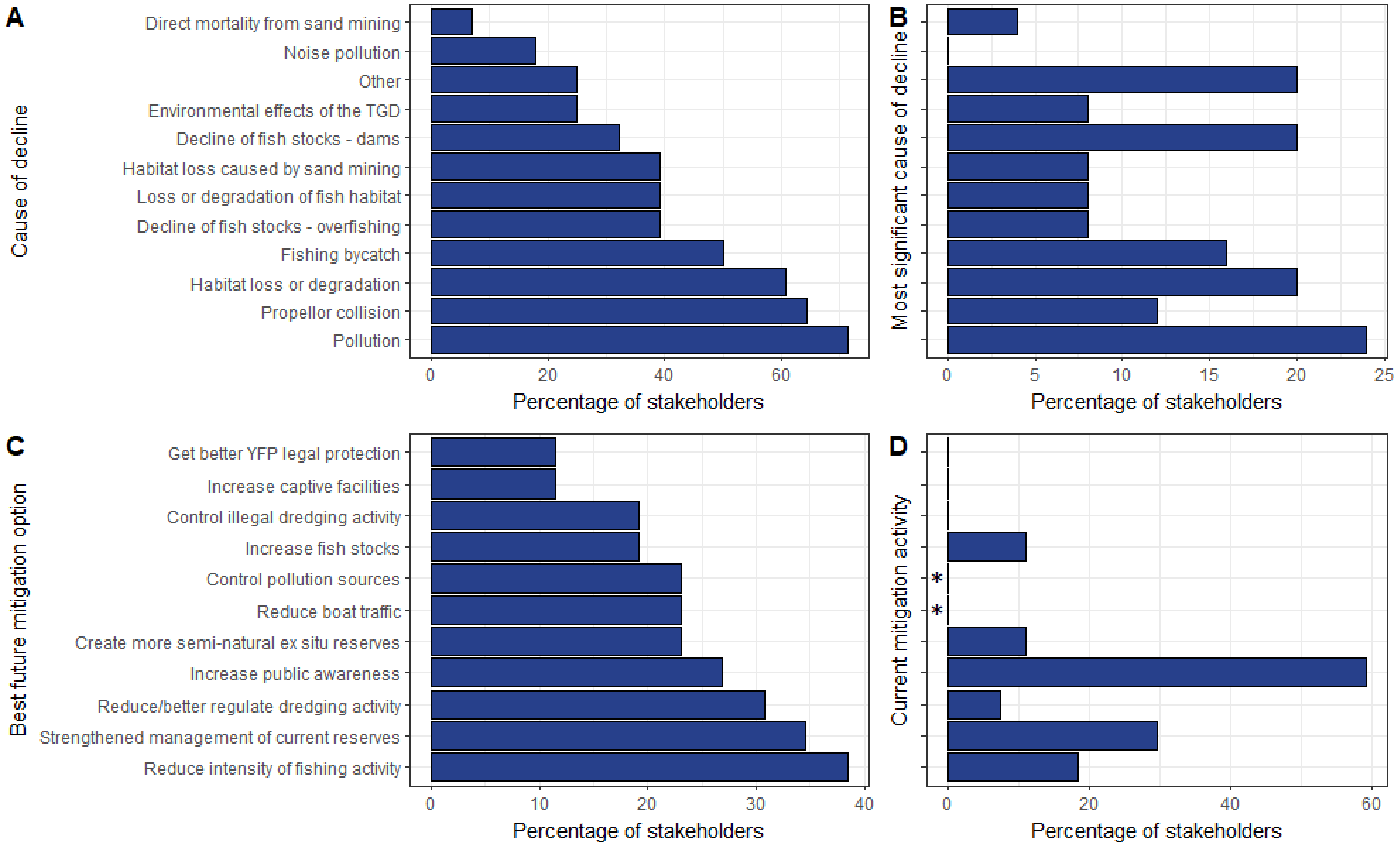


Figure 5.3: Noted causes of YFP decline (**A**, n=28) and the primary cause of decline (**B,** n=25, 3 answered with “Don’t know”, not shown) from all stakeholders interviewed. Stakeholder opinion on the best future mitigation option for YFP conservation (**C,** n = 26), compared to mitigation currently being conducted (**D**, n = 28). On (**D**), * denotes the top 2 noted causes of decline in (**A**). Values for all figures sum to more than 100% as many stakeholders noted >1 option and all options were included separately.

5.4.2.2 Perceived levels of success of current YFP conservation

Stakeholder opinion on the success of in-situ and ex-situ conservation activities is shown in Figure 5.4. Perceived success of YFP conservation was similar for ex-situ (including semi-natural reserves) and in-situ mitigation efforts, with both receiving 72% positive responses (Figure 5.4). In-situ efforts were mostly assigned as 'somewhat successful' on the Likert scale (53.6%), but ex-situ efforts were mostly assigned as 'very successful' (42.9%). However, there was no significant difference between stakeholder scores on the success of in-situ and ex-situ mitigation efforts by stakeholders (Wilcoxon signed-rank test, Z = 110.5, p = 0.1402).

In-situ YFP conservation was noted to be more useful for future YFP conservation than ex-situ conservation (39.3% for in-situ, 28.6% ex-situ) but 14.3% stakeholders considered that both methods should be used (Figure 5.4).

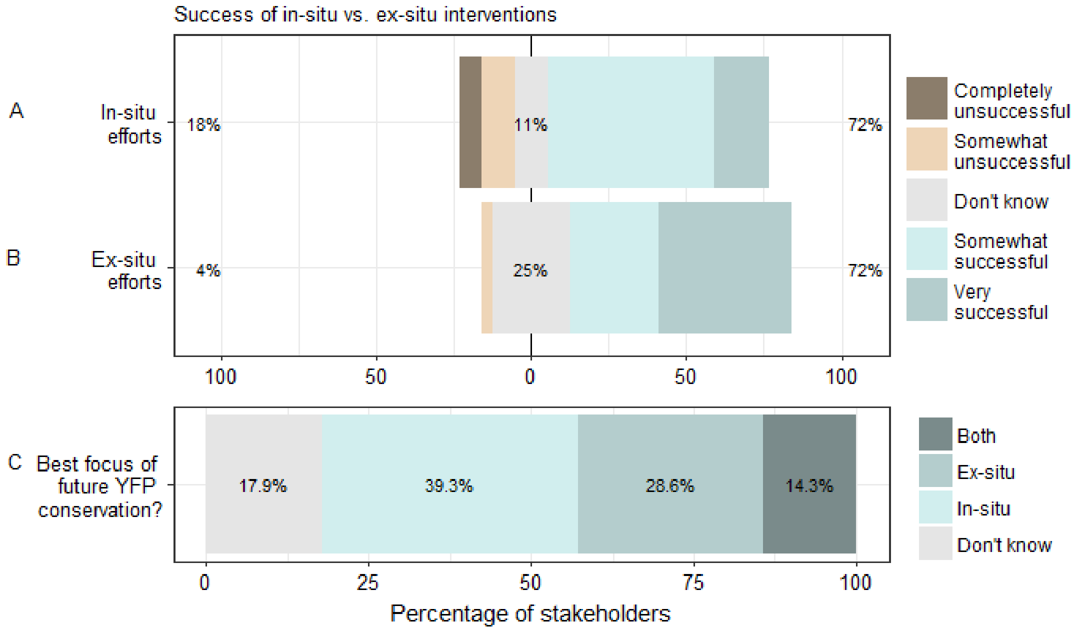


Figure 5.4: Stakeholder perception of the success of both in-situ and ex-situ (including semi-natural) reserves (N=28). A and B are both Likert scale data and C are categorical data. The percentage values shown in A and B are negative (left value, "completely unsuccessful" and "somewhat unsuccessful"), neutral (central value, "don't know"), and positive (right value, "somewhat successful" and "very successful") responses. Percentages and A and B are rounded up.

Although more stakeholders reported that their personal conservation efforts had been successful (64%) than the overall conservation efforts (46%, Figure 5.5, A, B), there was no significant difference between scores assessing personal success and overall success (Wilcoxon signed-rank test, Z = 58, p = 0.1092, Figure 5.5 A and B). Only 17.9% of stakeholders reported that their organisation is currently doing enough to conserve the YFP. A total of 60.7% of stakeholders did not think they are currently doing enough to conserve the YFP (Figure 5.5, C). Equal numbers of stakeholders reported that the YFP population was either increasing or decreasing in their area (28.6%, Figure 5.5 D), and 21.4% responded that the YFP population was stable. Stakeholders that did not know or did not express and opinion on the local YFP population trend comprised 21.4% of respondents (Figure 5.5 D).

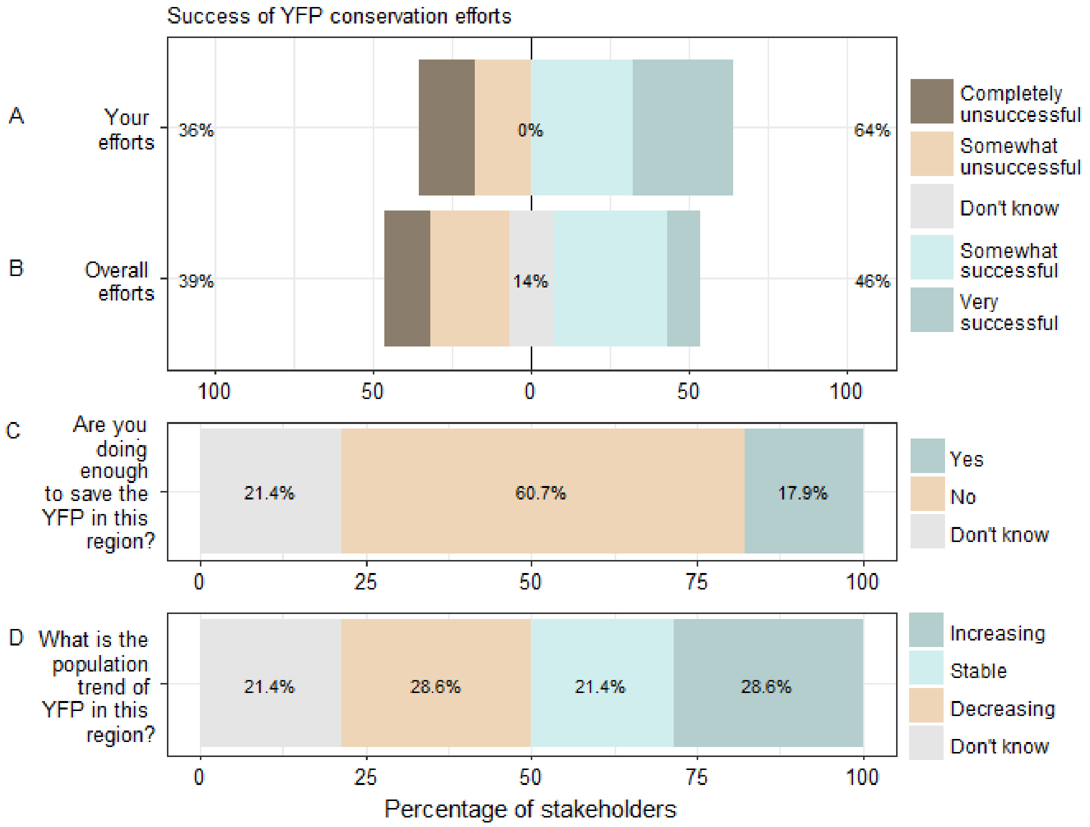


Figure 5.5: Perceived level of success of personal (**A**, n= 28) and overall (**B**, n= 28) YFP conservation efforts, perceptions of the sufficiency of local YFP efforts (**C**, n= 28), and perceived local YFP population trend (**D**, n= 28). The percentage values shown in A and B are negative (left value, “completely unsuccessful” and “somewhat unsuccessful”), neutral (central value, “don’t know”), and positive (right value, “somewhat successful” and “very successful”) responses. In A and B, percentages are rounded up.

5.4.2.3 Communication and sources of YFP based information

When stakeholders were asked about the level of YFP population decline, the predominant source of information for their answer was personal experience (42.9%) or observations, followed by non-academic surveys or patrols (38.1%, Figure 5.6). A total of 19% of respondents did not give any source of information for their opinion. The Institute of Hydrobiology (IHB) or other academic bodies that conduct YFP-based research were the source of information for only 14.3% of stakeholders (Figure 5.6). 85.7% of stakeholders reported that they communicate with IHB in some form, whether giving or receiving information about YFP. Other organisations that stakeholders reported communicating with were NGOs (35.7%) and other fisheries bureaus (35.7%) and YFP reserves (14.3%).

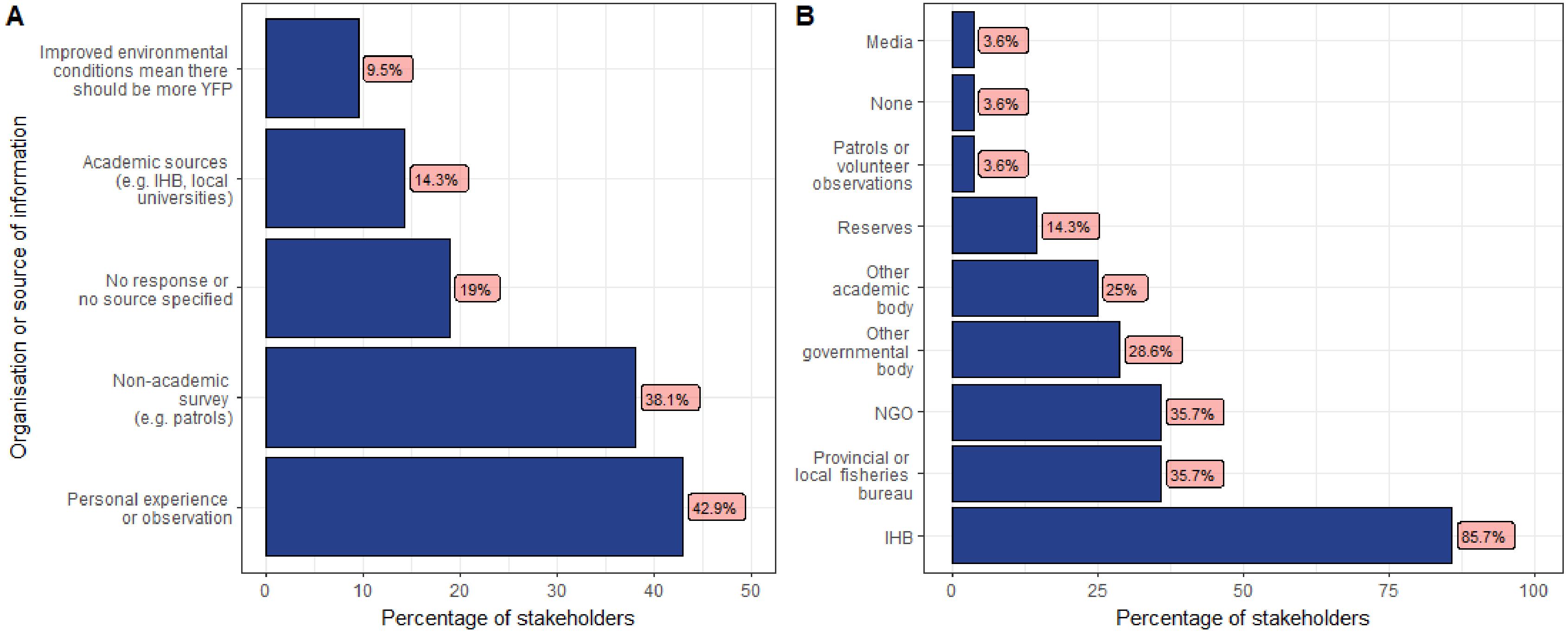


Figure 5.6: (A) Sources of information for stakeholders perceptions of YFP population status (n = 26) and (B) Independent bodies that stakeholders communicate with about YFP (both giving and receiving information) (n = 28)

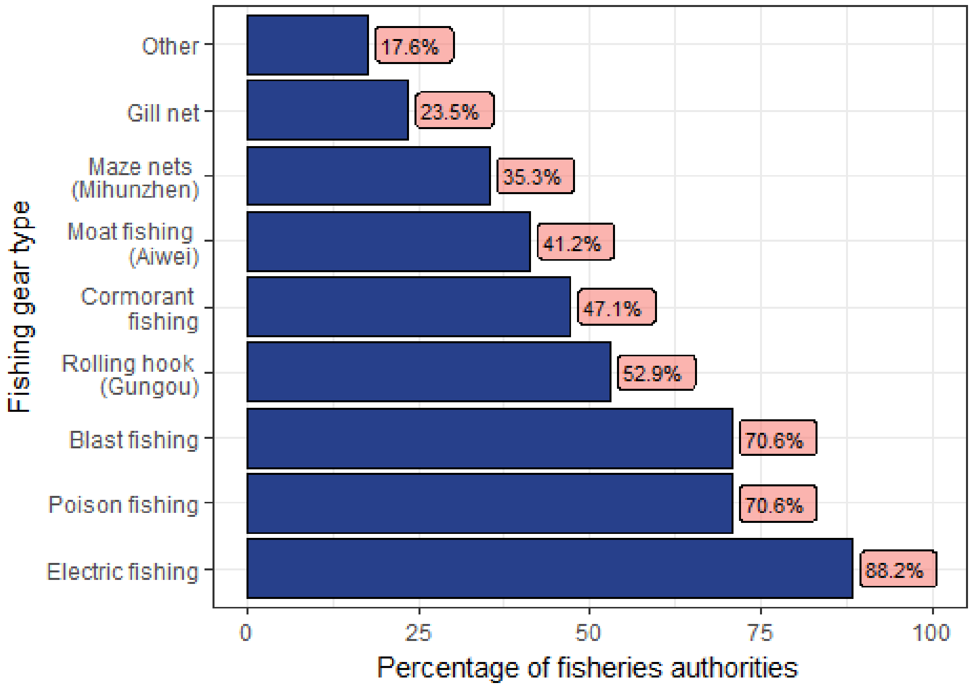


Figure 5.7: Types of illegal fishing gear noted by fisheries bureaus (n=17)

When fisheries bureaus (n=17) were asked which types of fishing gear are illegal in their region of jurisdiction, the gear types varied between location (Figure 5.7). The fishing gear most commonly noted as illegal was electric fishing, followed by poison fishing and blast fishing (Figure 5.7). Rolling hook (gungou) was noted as illegal by 52.9% of fisheries bureaus. In addition, 59% of bureaus stated fishing was illegal at night, with 35% saying it was not illegal and one bureau (6%) stating they did not know.

Electric fishing is illegal at a national level, but the other fishing gear types included here are only illegal at local provincial levels (Turvey, Hao & Ding, 2012). For example, some fixed nets are illegal in the middle to lower Yangtze drainage and rolling hook fishing is only illegal in Hubei and Anhui province but not in Hunan or Jiangxi provinces, meaning hook fishing is not illegal in both Dongting and Poyang Lakes (Turvey, Hao & Ding, 2012).

When questioned about illegal sand mining, 53% of fisheries bureaus reported that they were aware of it occurring in the Yangtze system, however 6% stated that illegal sand mining did not occur and 41% answered ‘do not know’. A total of 47% of fisheries bureaus were not aware of how sand mining was regulated. When asked to specify the proportion of sand mining that is illegal, the proportion of illegal sand mining varied from “a few” to 100%, with one answer stating that all sand mining in Poyang Lake is illegal.

5.4.2.4 Barriers to YFP conservation (all stakeholders)

[Please note that where quotes are given, they have been subject to translation and will be as close as possible to the given meaning]

The most common reported barrier to YFP conservation was financial limitations (42.9%), followed by "other" barriers (39.3%) and legal barriers (32.1%, Figure 5.8 A). Those that reported "other barriers" stated issues with the following:

- "*False reporting by the public [of stranded YFP]*",
- "*Conflicts with fishers that want to kill YFP for oil*",
- "*Management chaos"*, referring to the overlap of reserve management between different counties,
- "*Subsidies [for fishers] do not match or follow regulations*",
- "*Violence against fisheries officials"*.

One stakeholder (a fishery bureau) that reported an ecological barrier noted that it was difficult to assign a river section to protect as they did not know the best place to do so. The one stakeholder that noted an ecological barrier did not elaborate on their choice of this category. One stakeholder stated that environmental impact assessments are not carried out for dam projects, and that the law does not state they are required to. Another stated that it is difficult to control advanced, modern fishing equipment, and another stakeholder believed that the fishing ban should be extended (bureaus themselves do not have the power to extend fishing bans; this is under the control of higher government).

Fishers in the Yangtze often fish at night and fisheries bureau patrols predominantly occur in the daytime, meaning there is a disconnect in the timing of effective enforcement. There was one specified logistical barrier report of importance; "*Equipment for night patrols (need more speed and light on ships, destroying of nets has to be done using knives and by hand) and low manpower (workers are older than 35)*". This fishery bureau indicated they were willing to conduct night patrols to address this problem, but they are limited by logistical restrictions. One respondent noted "it's less safe" and another that "all illegal fishing happens at night". Of those that answered, 64% believe night patrols would be effective at reducing illegal fishing, with the remaining 36% believing they would not be (n=11 this question was fisheries bureaus only). One bureau noted that there is no overtime fee for bureau staff conducting such night patrols.

In contrast, when all stakeholders were asked about factors that have led to successful YFP conservation, national (57.1%) and local government support (50%) were the most frequent responses (Figure 5.8 B). Contrasting to the information given about barriers to conservation, financial support was only noted as a factor of success by 21.4% of stakeholders interviewed (Figure 5.8 B).

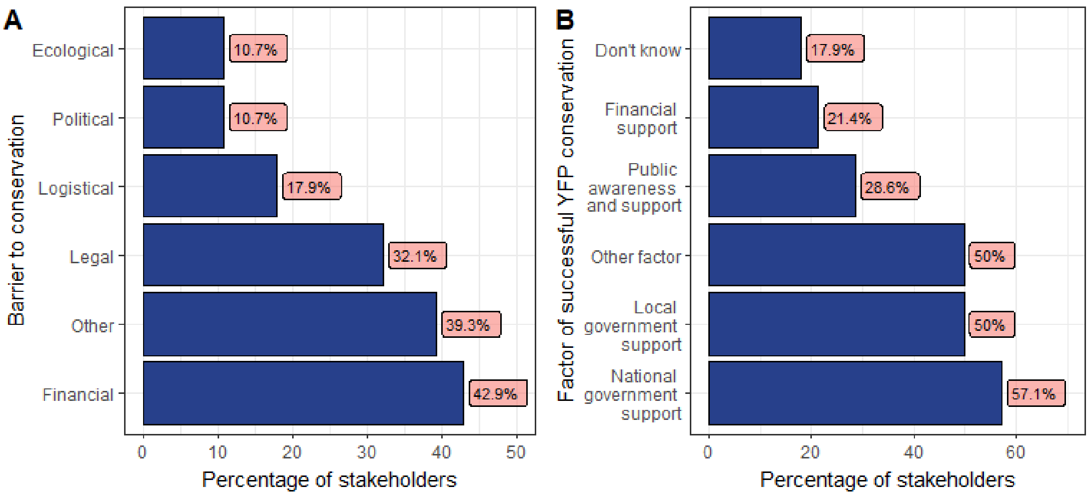


Figure 5.8: Reported barriers to conservation (A) and key factors for successful conservation (B) reported by all stakeholders (n=28).

A total of 48.1% of stakeholders were aware of conflicts that have arisen between reserve staff and local communities. Examples given were:

- *"Encountered violence when apprehending fishers with illegal electric nets"*, and
- *"Fishers threatening to commit suicide when informed to confiscate gears"*.

5.4.3 Fish stock management and enforcement of mitigation in the Yangtze River (fisheries bureaus only)

Out of seventeen interviewed fisheries bureaus (one did not answer), 75% believed fish stock management in the Yangtze was effective. All interviewed bureaus (100%) believed that fish fry addition programme and the seasonal fishing ban has increased fish stocks in the Yangtze River. However, when questioned about the population trend nine fish species stocks, the predominant answer for 6 of the 10 species was "decreasing" (Figure 5.9). The 9 species used are the same YFP prey species used when questioning fishers in chapter 4 of this thesis. The same figure from fisher interviews is shown for comparison (Figure 5.10).

As a proportion of responses from all fish species, 7.8% of responses were "increasing", 55.6% of responses were "decreasing", 10.5% of responses were "stable", and 26.1% of responses were "don't know". In comparison, fishers answered 8.0%, 68.9%, 19.6% and 3.6%, respectively. The proportion of responses given in each of the status categories for all the fish species combined was different between fisheries bureaus and fishers (X^2= 230.29, df = 3, p<0.001). Residuals indicated that fisheries bureaus answered "decreasing" (z = -3.553, p <0.05) and "stable" (z = -2.852, p<0.05) less often than fishers. In addition, fisheries bureaus more often answered "don't know" when asked about fish stock status (z= 15.097, p<0.05). Fishers were therefore less optimistic about the status of fish stocks than fisheries bureaus, and fishers were more confident in giving a definitive answer than fisheries bureaus.

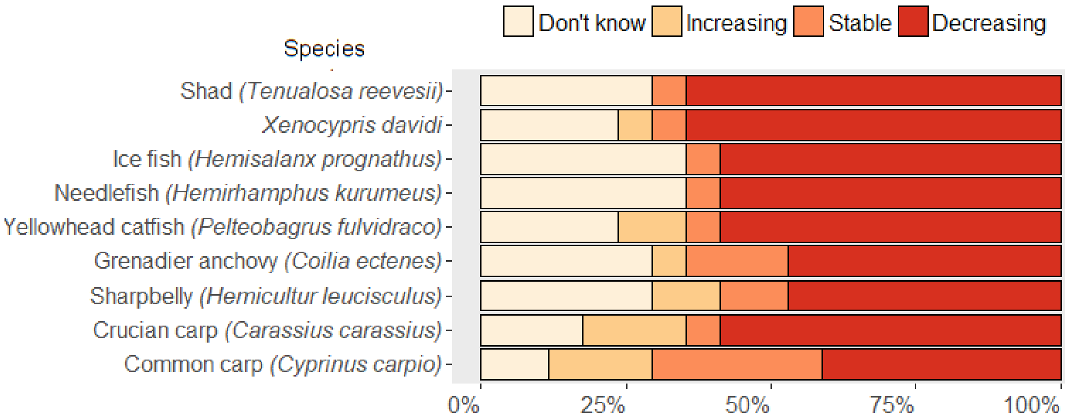


Figure 5.9: Status of nine YFP prey-specific fish stocks in the Yangtze River according to fisheries bureaus (n=17). These species are in the same order as the same figure from the same question asked to fishers (bottom – decreasing the least according to fishers, top – decreasing the most).

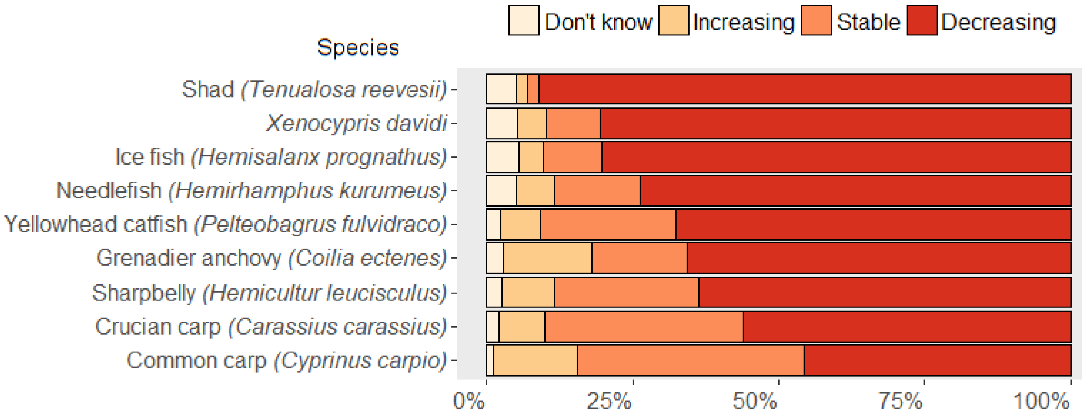


Figure 5.10: Status of nine YFP prey-specific fish stocks in the Yangtze River according to fishers (in order from top to bottom, n=212, n=227, n=218, n=216, n=238, n=238, n=231, n=232, n=243). From fisher interview data as shown in chapter 4 of this thesis.

All fisheries bureaus conduct enforcement patrols of some kind in their respective area of jurisdiction, but the types, regularity and duration of patrols was highly varied. Twelve of the seventeen bureaus interviewed stated they did night patrols. Of those that answered, 63.6% thought that patrols at night would be useful and the remaining 36.4% did not (n = 11).

Five of the bureaus provided further details on regularity; responses given were:

› *"once per year",*
› *"during the fishing ban",*
› *"throughout the year",* and
› *"twice to thrice per month".*

Enforcement of illegal fishing laws was also highly varied; the number of convictions or punishments for illegal behaviour averaged at 42.3 per year but varied from 1 to 406 (n = 16). Fisheries bureaus noted that the most successful form of prosecuting for illegal fishing was arresting the fishers (58.8%), followed by confiscating the illegal gear (41.2%) and fining the offender (35.3%, n = 17).

A total of 65% of fisheries bureaus interviewed had alternative livelihood schemes for fishers, with some still currently active and some instigated in the past (2006 onwards). Alternative livelihoods mentioned include; building and construction; aquaculture; labourer; farmer; and factory work. Of thirteen bureaus that answered, 76% believed the schemes had been at least somewhat successful, and only 8% believed they had been somewhat unsuccessful (Figure 5.11). One notable comment from a bureau was “Management policies need to catch up with the pace of the schemes as some fishers may accept the payment yet return to illegal fishing”.

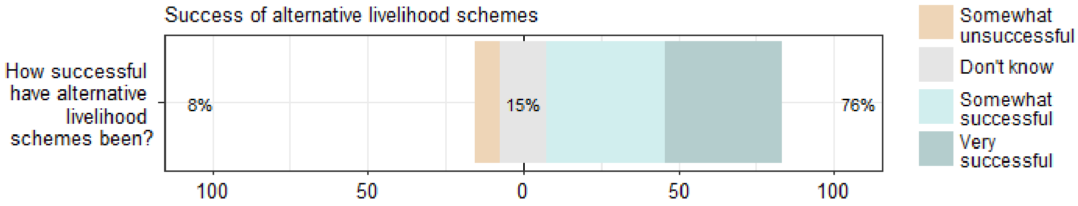


Figure 5.11: Perceived success of alternative livelihood schemes by fisheries bureaus (n=13). The percentage values are negative (left value, “completely unsuccessful” and “somewhat unsuccessful”), neutral (central value, “don’t know”), and positive (right value, “somewhat successful” and “very successful”). The percentages are rounded to the nearest integer.

5.5 Discussion

5.5.1 Are current YFP research goals appropriate?

Given that there are no long-term post-mortem data and only limited quantification of the primary causes of mortality, YFP conservation has been limited by a severe deficiency in data to inform effective intervention choices (Turvey, Hao & Ding, 2012; Turvey *et al.*, 2013). This issue, in addition to the YFP's rapid population decline and risk of extinction (Zhao *et al.*, 2008; Mei *et al.*, 2012; Huang *et al.*, 2017), means that investigating how to improve conservation outcomes should arguably be the predominant focus of YFP-based research. However, the bibliographic assessment shown here demonstrates that there is very little appropriate research focussed specifically on assessing threats to YFP, and there has been no research specifically aiming to improve conservation decisions or outcomes. Within published studies from the last 10 years, there has also been no reporting of any monitoring of the success (or otherwise) of any in-situ interventions, aside from continued reporting of population decline.

Based on insights from other species recovery programmes and current conservation practice, significant gaps in conservation-based research are restricting conservationist's ability to improve the success of YFP interventions. Identifying and removing threats is a key driver in successful species recovery programmes (Crees *et al.*, 2016), which was addressed specifically in only two YFP studies in the last 10 years (Turvey, Hao & Ding, 2012; Turvey *et al.*, 2013). Poor stakeholder coordination and management is a key weakness in species recovery programmes. Stakeholders have been included in one YFP-based study as a key source of LEK (Turvey *et al.*, 2013), but they have never been specifically included in any published management plan or addressed as part of ongoing interventions.

Although some of the studies outside of the specific 'conservation' bracket shown here may still be generally relevant for conservation by providing background information on the ecology or biology of the species, none of the studies over the last 10 years have specifically gone on to apply that knowledge within a conservation framework. For example, analysis in Mei *et al.* (2017) determined habitat preferences of YFP. However, the study was completed and published but then no practical input has been subsequently conducted to analyse in-situ habitat to identify optimal conservation areas. This problem is evident in the placement of Longkou and Laoyemiao YFP reserves in Poyang Lake (chapter 3, this thesis); despite continued research into YFP habitat preference, these reserves have not been placed in seasonally appropriate areas. Practical application of relevant studies to in-situ conservation is therefore a key gap in the mitigation process for YFP conservation.

This problem is a common theme amongst YFP research overall; there is an underlying pattern in research focus that shows an emphasis on data over action. This knowledge-action boundary is a common barrier to implementing practical conservation solutions within conservation research; the science community rewards and promotes publication rather than engagement with conservation practitioners (Cook *et al.*, 2013). Producing real-world relevant studies that can improve the outcome of conservation may therefore not be a key driver of

YFP research, rather, research itself of any kind is the goal (e.g. Gibbons *et al.*, 2008; Arlettaz *et al.*, 2010). Practical conservation relevant studies may also be limited by barriers to multidisciplinary research that may develop more holistic solutions to conservation problems (Ludwig, Ray Hilborn & Walters, 1993; Knight *et al.*, 2008), and also by funding restraints that limit the coverage of large spatial and temporal scales (Fausch *et al.*, 2002; Kettenring & Adams, 2011). This could explain the deficit in conservation relevant YFP research; despite the urgency for active intervention there is little academic benefit of producing practical conservation-based studies or actively working with on-the-ground conservationists to implement in-situ interventions.

In general, conservation research is poorly transferred into on-the-ground conservation (Milner-Gulland *et al.*, 2010), partly because two-thirds of literature contain no action recommendations (Knight *et al.*, 2008). In addition, conservation science is often not made policy relevant and so it does not leave the academic realm (Rose, 2015). Finding the balance of robust conservation science and management-relevant science that can inform policy and practice is therefore an ongoing challenge (Linklater, 2003). However, there is still “evidence-complacency” when it comes to applying evidence to conservation decisions (Sutherland & Wordley, 2017). This issue was noted as a significant barrier to effective conservation that contributed to the extinction of the baiji (Turvey, 2008) and this has also been an ongoing issue with Vaquita conservation (Jaramillo-Legorreta *et al.*, 2007). Given the common patterns in research for both the Baiji and YFP shown here, the research community has not changed course even after the failure to save the baiji. To address the ongoing issue, we recommend that individuals and organisations studying this highly at-risk species re-evaluate their research focus and consider including more conservation relevant research to address the significant knowledge gaps that surround the conservation of this species. Without a better understanding of the causes of decline or a strategic assessment of mitigation options, conservationists will be limited in their ability to reverse the declining population trend and prevent extinction of another Yangtze cetacean.

5.5.2 Are conservation decisions for the YFP based on evidence?

The results shown in this interview survey demonstrate that stakeholders in YFP conservation are very limited in their use of evidence-based conservation. Although in Chapter 2 of this thesis it is argued that pollution may be a significant factor in YFP decline, there has been very little published data surrounding pollution related YFP deaths and very few studies implicating pollution as a key cause as yet, however, it was most often cited as a cause of YFP decline by stakeholders and was also selected most often as the primary cause of decline. As there has so far been very little empirical evidence to implicate pollution as an overall key cause of decline, these opinions cannot be evidence-based. Furthermore, despite this belief, no stakeholders were conducting any interventions to tackle pollution as part of their YFP conservation work. In addition, propeller collisions were the second most common noted cause of decline, yet no stakeholders are conducting any work to reduce this as an impact. Current understanding of causes of YFP decline (whether evidence-based or not) is therefore not feeding into mitigation choices presently being used and there is a mis-match between published evidence about causes of decline and perceived causes of decline amongst stakeholders. Evidence-based conservation is the most effective method of implementing mitigation efforts (Sutherland *et al.*, 2004; Pullin & Knight, 2009); if evidence isn't used in the decision making process, conservation outcomes may be significantly compromised (Cook, Hockings & Carter, 2010).

When stakeholders were asked for their personal sources of YFP-based information the most common source of information was "personal experience or observation" and primary scientific literature was not mentioned by any of the interviewees. This pattern of relying on personal experience or traditional methods to inform conservation decisions is common in conservation in other systems. A study by Sutherland *et al.* (2004) investigated sources of information by practitioners in the United Kingdom. The most cited source of information for making conservation decisions was "common sense" followed by "personal experience" and "speaking to other managers in the region". Another study by Pullin *et al.* (2004) showed that primary scientific literature and secondary reviews of literature accounted for only 11% and 16% of information sources for conservation management plans, respectively. It is widely recognised that traditional practices were commonly not designed to fulfil conservation goals but were more intended meet agricultural, forestry or game management, and so relying on personal experience or simply continuing methods that are already is use may not be effective at meeting conservation goals (Pullin & Knight, 2003). A similar pattern of poor understanding of the available evidence has been observed here in these data, further indicating that stakeholders are not using evidence-based conservation for the YFP. This pattern of relying on personal observation or opinion may explain the discrepancy between current understanding of YFP decline and stakeholder opinion on causes of decline, as well as the mis-match between perceptions of causes of decline and on-the-ground mitigation choices.

It was noted by Pullin *et al.* (2004) that the accessibility of resources and time to assess resources are the key barriers to using primary scientific data, not the willingness to use these data. This was empirically assessed by Walsh, Dicks & Sutherland (2015), whereby it was shown that, when directly given the appropriate relevant information, decision makers were more likely to implement effective interventions and less likely to choose ineffective actions. Access to relevant scientific material is therefore the key barrier, not willingness to accept the new information. The accessibility of primary scientific material was not assessed in this study but the internet access restrictions in China in addition to the expense of a non-academic body accessing scientific reports could easily restrict access to published YFP related research. Most of the published reports relating to YFP (shown in Table 5.1) are also in English and so they are not easily accessible to native Chinese speakers. This could be a key barrier to the flow of information from primary scientific literature to decision makers involved in YFP conservation in China. A system whereby all research material is available through a database or repository could improve access.

In addition to removing accessibility barriers, improving relationships between researchers and policy makers and increasing the clarity of research improves the uptake of information by policy makers (Oliver *et al.*, 2014). One-on-one interactions between policy makers and scientific researchers is the most useful method to facilitate information flow, but these interactions very rarely occur (Seavy & Howell, 2010).

Further to the lack of evidence-based conservation, there is a mismatch between perceptions of effective YFP conservation methods and interventions currently being implemented. The predominant focus of YFP conservation is public awareness, which, although has its value, is not directly mitigating the causes of decline. Given the rapid rate of decline (Zhao *et al.*, 2008; Mei *et al.*, 2012) and risk of extinction (Huang *et al.*, 2017), focussing on direct mitigation to reduce the impact of key causes of mortality should be the predominant focus of conservation (as per Crees *et al.*, 2016). Fisheries bureaus, for example, have the power to enforce illegal fishing regulation, better regulate sand mining (and remove illegal sand mining), and implement shipping rules to reduce the likelihood of propeller impacts yet this is not being done effectively.

The social context plays an important part in the extent to which conservation science is implemented into action (Ntshotsho *et al.*, 2015) and there are cultural differences in thought patterns between western and Chinese cultures (Nisbett, 2004; Chan & Yan, 2009). Traditionally, Chinese culture has viewed wildlife as a resource to be exploited, not as a resource to be protected for its intrinsic worth (Zhang, Hua & Sun, 2008). The focus of conservation has so far been heavily based around creating reserves rather than mitigating for probable causes of decline in-situ. Instead, economic development has taken precedence over direct mitigation to reduce or remove threats to YFP. This aspect of YFP conservation is difficult to change but should be considered when designing and implementing further conservation efforts.

5.5.3 Perceived YFP conservation successes and shortfalls

Salafsky *et al.* (2002) identified three fundamental questions required for outlining effective conservation; (1) What should our goals be and how do we measure progress in reaching them? (2) How can we most effectively take action to achieve conservation? (3) How can we learn to do conservation better? Success in conservation is therefore defined by our ability to outline the goal required and subsequently target the threats to achieving that goal. By outlining clear definitions and measures of success, conservation can be made more effective by a process of measuring and then adapting management to realign interventions towards goals (Salafsky *et al.*, 2002). However, this process requires a metric of success (Salafsky *et al.*, 2002; Saterson *et al.*, 2004), which is difficult to quantify as interventions are often in a range of forms (e.g. public awareness to direct species interventions) and stakeholders may differ in their priorities of conservation (Brooks *et al.*, 2006). The overarching goal and indicator of successful YFP conservation would be a measurable reduction or pause in the rate of population decline or, optimally, an increase in the population size, none of which has occurred (Mei *et al.*, 2012).

Ex-situ conservation (including semi-natural reserves) has arguably been more successful than in-situ conservation, as demonstrated by the growth of the semi-natural reserve YFP populations and the severe continuing decline of the in-situ YFP population, respectively. Yet the perceived success by stakeholders of both interventions did not differ. Stakeholder opinions also conflicted the current YFP population trend; 50% of stakeholders believed the YFP population in their area was stable or increasing despite evidence of ongoing decline across their range (Mei *et al.*, 2014; Huang *et al.*, 2017). In addition, 64% of stakeholders rated their YFP conservation efforts as somewhat successful or very successful, but only 17.9% believe that enough is being done to conserve YFP in their region. There is therefore a mismatch in the ability of involved stakeholders to successfully appraise current YFP conservation efforts.

Accurate self-evaluation of performance is subject to bias from illusory superiority, also known as unrealistic optimism (Weinstein, 1980; Alicke, 1985; Buunk & Van Yperen, 1991). The disparity between perceived and actual success of YFP conservation efforts may also be evidence of such a cognitive bias, which would explain why stakeholders have over-stated their personal success relative to reality. There may also be a personal investment in over-stating the success of their organisation in an interview scenario where they feel the interviewee perceives that they are being directly appraised. Another possible reason for this disparity in perceived success is that these organisations have not set specific goals or metrics by which success may be measured, for example as per Salafsky *et al.* (2002) and Saterson *et al.* (2004). The predominant intervention type used by interviewed stakeholders was public awareness programmes, the success and effectiveness of which is difficult to empirically assess. An example of a metric of success in YFP conservation could be an increase in the YFP population, for example, which is difficult to directly attribute to an activity like awareness programmes. If conservation goals were to be more well defined, it would be easier to quantify and measure success relative to those specific goals.

A falsely inflated assessment of conservation success can lead to misleading confidence in current interventions and therefore complacency towards implementing further mitigation or improving current interventions. This is a common problem with “paper park” protected areas, for example (Rife *et al.*, 2013; Minin & Toivonen, 2015), whereby the presence of the protected area gives a assumed and misguided sense of conservation success based upon the presence of the park rather than empirical measures of achievement. To what degree this cognitive bias affects the success of conservation generally has never been well studied or quantified. However, complacency towards YFP conservation could be contributing to continuing YFP population decline by increasing perceived levels of conservation success, which in turn removes the impetus of stakeholders to instigate further conservation efforts. It may be difficult to counter this phenomenon as there is little literature available specifically addressing it. However, quantitatively assessing success in YFP conservation will give a more empirical measure of outcomes, whether this be by assigned metrics (Howe & Milner-Gulland, 2012)or frameworks of systematic measurement of success (Kapos *et al.*, 2008). If such a framework were implemented to measure outcomes across key habitats or the range of the YFP, success of interventions could be directly measured and improved where necessary, improving the outcome and therefore prospects for the remaining YFP population.

In addition to this misinformed assessment of YFP conservation success, the mismatch between identified barriers to success and factors of successful conservation shown here indicates that stakeholders have a poor grasp of what factors are required to implement successful YFP conservation. Combined, these results indicate that stakeholders have an overinflated sense of personal success (whether they believe it is true or they are over-stating it purposefully), a misinformed assessment of what is required for successful YFP conservation, and that more appropriate metrics of success are required to more effectively understand successes and shortfalls in YFP conservation.

Finally, the YFP-prey fish stock based results shown here from fisheries bureaus conflict with the results of fisher interviews presented in chapter four. The conflicting results from these fish stock questions mean that it is difficult to assess (1) the current fish stock status and (2) the success of fish stock based interventions. It is also not clear what (if any) data the responses were based on, as many bureaus were asked to share fish data but either claimed there is no data or that they are not willing to share that data. Considering the over-stated success of YFP conservation efforts demonstrated here, it may be argued that the higher number of positive responses to fish-stock questions given by fisheries bureaus is further evidence that the bureaus are over-stating the success of their personal interventions, or that they have very little understanding of species-specific fish stock status in the Yangtze River. The fishers, however, observe relative changes in fish catches directly and are arguably more likely to be more reflective of reality. It is difficult to interpret these data so to better understand the possible presence of prey-limitation on YFP as well as the effectiveness of current fish-based interventions, empirical assessment of fish stocks through direct quantification is required.

5.6 Conclusions

The results presented here demonstrate that evidence-based conservation is not being applied to YFP conservation efforts, and that key stakeholders involved in YFP conservation are misguided in their conservation efforts and over-stating their personal conservation success. This problem is apparent throughout the life cycle of conservation, with poor evidence use to inform interventions and no system of assessment or feedback for the success or failure of current interventions. A key issue that may be contributing to this problem is that current YFP-based research is not sufficient to inform effective conservation, and that there are key data gaps with respect to identifying appropriate mitigation. Additionally, this issue could be due to a lack of clarity and communication between stakeholders and research bodies, and barriers affecting the flow of primary scientific material to stakeholders involved in YFP conservation. A more centralised and open system of publication and data sharing is recommended to ensure all of those involved in YFP conservation are well-informed with current research. The significant data gaps highlighted here should be the predominant focus of YFP based research to ensure that mitigation can be well-informed and designed as effectively as possible. To address the issues identified here, we also recommend that highly informative techniques such as quantitative decision making (e.g. structured decision making, Gregory *et al.*, 2011) and continued intervention monitoring and adaptation (e.g. adaptive management, McCarthy & Possingham, 2007; Kingsford, Biggs & Pollard, 2011) be applied here to improve the effectiveness of interventions throughout the YFP conservation process. If current conservation efforts for the YFP are not improved, there is a danger of this species succumbing to conservation complacency and there is a high-risk of extinction.

6 Discussion

This study has used a wide range of survey and analysis techniques and multiple existing and novel data sets to improve the current evidence-base surrounding causes of YFP mortality and population decline. In addition, current conservation practices have been critically appraised and areas for improvement identified. These findings and recommendations must be integrated into or directly used to inform current and future interventions if the conservation community is to successfully reverse population decline in the YFP and avoid extinction of another Yangtze River cetacean.

This research has addressed a number of the data gaps relating to potential threats to the YFP noted in Table 1.3 from the introduction. New data or information is now available on fishing bycatch (Chapter 2, Chapter 3, Chapter 4), vessel collision (Chapter 3), sand mining (Chapter 3), pollution (indirectly though Chapter 2, calf analysis), loss of prey (Chapter 4 and Chapter 5) and the possibility of a genetic bottleneck (also indirectly through Chapter 2, calf analysis). This research has improved understanding of the spatio-temporal patterns in YFP seasonal movement as seasonal overlap with key potential threats. In addition, this research has highlighted that current YFP conservation efforts are being undermined by complacency and poor enforcement from managers, lack of appropriate conservation research, and inappropriate mitigation design (Chapter 5).

Although current understanding of the threats to YFP has improved, there are urgent improvements to be made in mitigation efforts and there are still significant data gaps. These points have been noted in Table 6.1. Below, the main conclusions of this research and a number of the points made in this table are summarised and discussed collectively.

In addition to this discussion, this is followed by a critical appraisal of the effectiveness of the present YFP reserve network, which includes recommendations for improvement of reserve design and placement based on some of the research completed in this study (section 6.4 onwards). This section is a unique summary of the collective knowledge (from publications, personal communications and in-field observations) surrounding the YFP reserve network, which has had very little publication attention.

Table 6.1: Summary of potential threats to YFP in the same order as presented in chapter 1, listing the current understanding of each threat as a potential cause of YFP decline, whether each threat is being addressed in current mitigation efforts, and whether more information is needed.

Threat	*Addressed in current YFP mitigation?*	*What further mitigation could be applied?*	*Do we need further information?*
Fishing	Some fishing types banned. Seasonal fishing restrictions.	Banning further high-risk fishing types identified in this study. Improving enforcement of fishing bans and fishing gear restrictions using spatio-temporal data presented here.	Identification of fishing gears that do not cause YFP bycatch that can be used in this system. Spatio-temporal use of maze nets in key habitat.
Vessel collision	Not directly for YFP conservation.	Implementing vessel speed restrictions to reduce the likelihood of YFP collisions. Restricting the quantity of vessels allowed in the Yangtze River and appended lakes.	Assessment of current vessel speeds in the Yangtze River. Assessment of vessel noise levels and potential impact.
Sand-mining	Not directly for YFP conservation.	Improved regulation of sand-mining (for habitat management). Restriction to localised areas with very low YFP density. Deterrent devices such as bubble nets and pingers.	Assessment of the potential for noise pollution and potential impact on YFP behaviour, hearing and health.
Pollution	Not directly for YFP conservation.	Removal of industrial activities from the Yangtze River. Implementing legally binding world-class environmental impact assessments for all industrial activities and chemical production. Implementing clean-up projects to targeted areas.	A comprehensive study of pollution levels in the Yangtze River and in further YFP samples is needed to better understand this as a potential threat to YFP.
Loss of prey resources	Fish fry supplementation in some areas, but not with the specific intention of increasing YFP-specific prey stocks.	Improved enforcement of current fishing bans and fishing gear restrictions. Reduction in the number of fishing licences. Expanding alternative livelihood and aquaculture schemes.	A detailed survey directly assessing the fish stocks of YFP-specific prey species in key areas is required to better understand this potential threat.
Habitat alteration, degradation and loss	Not directly for YFP conservation.	Removal of artificial concrete banks. Ceasing all sand-mining activity. Removal of dams to restore natural water and sediment regime.	This is challenging to investigate as a direct threat, but research could identify spatial areas of key habitat for restoration.
Genetic bottleneck	*In-situ:* no. *Semi-natural reserves*: supplemented with wild individuals and individuals moved between reserves.	Identification of genetically diverse YFP populations for specific conservation attention.	YFP genetics are relatively well studied, but gaps remain about whether there are localised genetic bottleneck patterns.
Cumulative or synergistic effects	Not directly for YFP conservation.	Unknown with current information.	An in-depth study of potential threats is required to understand the direct and indirect impact of combined threats.

6.1 Bycatch and fishing-based mitigation options for the Yangtze finless porpoise

The results presented in Chapters 2 and 3 of this thesis demonstrated weak correlation of fishing activity with YFP mortality and minimal overlap of fishing activity with YFP distribution in key habitats. As noted in the relevant chapters, this contradicts previous reports that bycatch is the main driver of YFP decline. However, the results presented in Chapter 3 demonstrated that bycatch of YFP is still occurring but is dominated by a few key fishing types, namely maze nets (MiHunZhen), rolling hook, and electric fishing. These fishing types are commonly used across the range of the study and therefore significant changes are needed in legislation, enforcement and mitigation efforts to combat YFP bycatch. As electric fishing is becoming more common and hook-based fishing declining (Chapter 4) and it is commonly used across key habitat studied here, electric fishing should be a key target of legislation and enforcement. Maze nets have not been studied well and this remains a key data gap (discussed further in 6.1.1 below).

Lack of funding was noted as a key limitation to YFP conservation by fisheries bureaus in Chapter 5, a common problem in conservation in China (Xu & Melick, 2007). This funding shortfall needs to be addressed so that fisheries bureaus have the resources to conduct appropriate, effective mitigation targeted to threats such as vessel collision and bycatch. In lieu of an increase in funding, prioritising current resources towards focussed high-risk areas could improve the effectiveness of current efforts. The results presented in chapter 3 demonstrate seasonal areas of both high YFP density and of higher fishing activity. These data and maps can be used to target patrols and enforcement to temporal and spatial high-priority areas, improving the effectiveness in reducing illegal activity (e.g. illegal fishing gear use, fishing in protected areas). Fishing patrols should be focussed in the summer months, when overlap of fishing and YFP distribution is at its highest (Chapter 3). Central regions of Poyang Lake identified as having very high YFP density in summer should additionally be redesignated as protected areas instead of the current regions (Chapter 3). As overlap of fishing activity and YFP is predominantly at distances between 150 and 300m from the river bank, this can also help target patrols and illegal fishing enforcement.

In addition to spatial and temporal factors, targeting illegal fishing should explicitly consider demographics (Chapter 5), especially when considering hook-based and electric fishing types. The demographic information presented in chapter 4 could also be used to target alternative livelihood schemes to those most likely to be using illegal or bycatch-causing fishing types such as hook-based or electric fishing. Alternative livelihood schemes (detailed in Chapter 5) have only been used in the jurisdiction of 65% of the fisheries bureaus interviewed (section 5.4.3). This should be expanded to include all fisheries bureaus, reducing both the likelihood of YFP bycatch but also attempting to address and reduce the issue of severe over-fishing and alarming trends of fish stock decline demonstrated in both the fisher and fishery bureau interviews. Improving legislation and targeting the minimal resources available for enforcement to key areas such as this is essential if we are to reduce bycatch-caused YFP mortality and increase the YFP prey base to sustain the remaining population.

6.1.1 Quantifying maze net (MiHunZhen) use in Poyang Lake

In Chapter 4, maze nets (MiHunZhen) were identified as having caused a large proportion of YFP mortalities observed and reported by fishers from three separate interview surveys. This type of fishing is illegal in a number of regions but is still permitted in many jurisdictions (Chapter 5). Although these data were not to be taken as absolutes, the number of mortalities observed was very high in each survey year. Given the very low PBR and sustainable removal calculations made in Chapter 2, it is recommended that the precautionary principle is applied and that this fishing method be made illegal across the range of the YFP to reduce bycatch caused mortality. Priority should be given to Poyang Lake, where a large proportion of the YFP population remains.

Although this fishing gear has been identified as a cause of YFP mortality through bycatch (Chapter 4) and it has been demonstrated that this fishing type is still used (Chapter 4), a problematic data gap is quantifying maze net use in key YFP habitat. From the authors personal observations, this fishing type is commonly used in shallower waters (<5m) outside of the typical survey routes in Poyang Lake, which were not accessible during the boat-based surveys in Chapter 2. High-quality satellite imagery would provide a means of accurately quantifying the use of this fishing type, as well as precisely assessing spatial distribution and seasonality (low-resolution examples shown in Figure 6.1). Unfortunately satellite imagery cannot simultaneously be used to assess YFP overlap as they are not visible at this scale (as is possible with other, larger cetaceans e.g. Fretwell, Staniland & Forcada, 2014). However, this information is vital to targeting key high-density maze net areas for patrols and enforcement, an area needing urgent improvement as demonstrated in chapter 4 (illegal fishing activity still continuing) and 5 (poor enforcement by fisheries).

Figure 6.1: Google Earth imagery showing maze nets (MiHunZhen) in Poyang Lake.
Left: Poyang Lake, 29 09’43”.68 N, 116 05’54.77” E, 12/05/2011. Right: Poyang Lake, 28 46’43”.17 N, 116 18’30.28” E.

6.2 Vessel strike mitigation options for the Yangtze finless porpoise

The previous analysis by Turvey *et al.* (2013), combined with the new analysis presented in chapter 2 of this thesis, strongly suggest that actions to reduce vessel strikes should be a key target to mitigate anthropogenically caused YFP mortality.

In other cetacean species, mitigation for vessel strikes predominantly focusses on restricting speed of the vessels or rerouting shipping lanes to avoid key habitat and minimise the likelihood of impact. Rerouting is usually the preferred first option, as it counters the overlap of threat and the target species. However, often this is not possible (e.g. Firestone, 2009), and vessel speed restrictions are used instead.

In marine environments, shipping routes can sometime be diverted around key areas (e.g. North Atlantic right whale (NARW), *Eubalaena glacialis*, Nichols *et al.*, 2005). Currently, the shipping channels in the Yangtze are predominantly within the central, deepest parts of the river that have a deep enough draft for vessels to safely travel in. The relatively narrow dimensions of the Yangtze River mean that changing the route of vessels in the Yangtze River is not a viable option. Indeed, many parts of the main river are very narrow (e.g. a narrow strait at Pengze, ~0.6km wide), making avoidance manoeuvres by both vessels and YFP more difficult. The only viable mitigation option is therefore restricting vessel speed.

Reducing vessel speed has been the predominant intervention to mitigate vessel strikes in the remaining populations of the endangered NARW, the success of which has been well studied and monitored (Lagueux *et al.*, 2011; Asaro, 2012; Silber, Adams & Fonnesbeck, 2014; Silber *et al.*, 2015). Here, the speed of vessels over 65ft. in length has been mandatorily restricted to <10 knots or 18km/hr^{-1}, which significantly reduces the likelihood of NARW mortality (Conn & Silber, 2013). An important part of the success of this restriction was compliance; only after continued notification and enforcement programmes did awareness of the law and compliance increase (Silber, Adams & Fonnesbeck, 2014). Voluntary vessel speed restrictions can also be effective (Vanderlaan & Taggart, 2009), and this has been successfully implemented to reduce collisions of vessels with endangered Bryde’s whales (*Balaenoptera edeni*) in New Zealand waters (Constantine *et al.*, 2015). However, mandatory speed regulations are more likely to result in compliance (Wiley *et al.*, 2011).

Reducing vessel speed has previously been recommended as a key conservation priority for YFP (Akamatsu, 2002), but no legal speed restriction has ever been implemented in the Yangtze River. The speed of large vessels in the Yangtze River has never been quantified, but the association of cargo vessels with YFP mortality shown here suggests that they travel too fast to allow for effective avoidance manoeuvres by YFP. To implement appropriate speed restriction measures specific to this species and system, a rapid assessment of current shipping lanes, vessel activity and vessel speeds should be conducted. This process would inform what speed restrictions should be in place to mitigate for vessel strikes. In lieu of such an assessment, the evidence presented here supports an immediate vessel speed restriction to counter further losses by vessel strikes. A speed restriction of 10 knots has been implemented in key finless porpoise (*Neophocaena phocaenoides*) areas around Hong Kong (Jefferson, Hung & Würsig, 2009) and the same speed restriction is in place in key areas for the NARW (Conn & Silber, 2013). Based on other studies, there should be a maximum of 10 knots or 18km/hr^{-1} in the Yangtze River to reduce the likelihood of vessel collision.

As evidenced by the results in Chapters 3, 4 and 5, uniform enforcement does not occur with fishing restrictions and there is spatial variation in compliance. It is vital that enforcement of speed restrictions is uniform or even enhanced in high-density YFP areas noted in this study such as Poyang Lake and the HA mainstem section. The seasonal movements of YFP shown in Chapter 3 demonstrate that seasonal distribution of YFP should also be taken into account when considering speed-based restrictions; enforcement needs to be targeted to key areas and seasons. These measures would be the beginning of mitigation for vessel-based impacts, but much more research and monitoring is needed to ensure that mitigation is and continues to be effective at reducing vessel impact based YFP mortality. In addition, there is a significant data gap relating to how YFP respond to vessel noise and the impact of vessel noise on YFP distribution and health, which is a noted issue with other cetaceans (Allen *et al.*, 2012; Rolland *et al.*, 2012; Dyndo *et al.*, 2015). The very high levels of industrial and vessel noise in the Yangtze River could be pushing YFP into marginal habitat that is reducing ecological fitness and that is less optimal for recovery (Shreeve, Dennis & Pullin, 1996; Chilvers *et al.*, 2006). A rigorous investigation of the effect of noise on YFP is needed, and appropriate mitigation applied with a priority to high-density YFP habitat identified in chapter 3.

6.3 Other recommendations for improving YFP conservation efforts

Significant improvement must also be made in measures to improve the use of evidence-based conservation by key YFP stakeholders. To improve evidence-based conservation, improved communication between relevant parties and non-academic stakeholders is necessary, for which we recommend the formation of a Yangtze finless porpoise Recovery Group. This group should comprise government representatives involved in Yangtze River management, relevant NGOs, the IHB, academic bodies, and local representatives of key areas (for example, representatives of fishing communities around Poyang Lake). This group should also contain representatives from industry such as sand mining and riverside factories or industrial complexes to facilitate dialogue, understanding and communication between the conservation and industrial sectors. A similar system of recovery groups has been effective in improving communication between academics and other parties involved in New Zealand bird species (Ewen, Adams & Renwick, 2013). This group would bridge the knowledge transfer gap between scientific research and on-the-ground decision makers and managers.

Overarching all recommendations made in this study is the much-recommended but as yet unheeded requirement for a systematic post-mortem scheme across the range of the YFP. Although the proxy methods used here have been very informative and useful, post-mortems are the typical way of gathering reliable information on causes of mortality in cetaceans. This is exampled by successful programmes such as the Cetacean Strandings and Investigations Programme (CSIP), which has produced many informative and robust studies into causes of decline, strandings and health issues in cetacean populations based in UK waters (e.g. Barnett, Davison & Jepson, 2009; Law *et al.*, 2012; Jepson *et al.*, 2013, 2015).

6.4 Are current reserves and interventions sufficient to protect YFP in-situ?

The YFP protected area network was highlighted as inadequate by the mapping studies in Chapter 3. As very little has been published about the protected areas, a critical review of currently available information has been shown here for further information and to identify specific areas requiring urgent attention or improvement.

Protected areas (PAs) are a common conservation tool used to protect systems and species, with the total number reaching over 161,000 in terrestrial habitats (Soutullo, 2010) and an additional 5,878 in the marine environment (1.17% of global oceans as of 2010, Toropova *et al.*, 2010). Freshwater Protected Areas (FPAs) are thought to hold significant conservation potential (Abell, Allan & Lehner, 2007) and they are gaining traction as a method of protecting freshwater resources from the significant pressures they face (Suski & Cooke, 2007). However, freshwater protected areas are generally understudied as a potential conservation tool and bridging the gap between freshwater ecology and conservation biology is still ongoing (Strayer & Dudgeon, 2010). Current understanding of how to make freshwater protected areas effective is therefore minimal (Hermoso *et al.*, 2016). Although there is a wealth of knowledge relating to marine mammals and protected areas (e.g. Gormley *et al.*, 2012; Edgar *et al.*, 2014; Roberts, Valkan & Cook, 2018), there have been no specific studies investigating how to effectively implement FPAs to specifically conserve freshwater cetaceans.

Protected areas have been a key part of YFP conservation efforts so far, and, as such, a critical review of these interventions is presented here. both in-situ and in the form of the semi-natural oxbow lakes (full details are shown in Table 1.4 of the introduction chapter and Figure 5.2 of chapter 5). There are currently eight in-situ and four semi-natural YFP reserves across the Yangzte River and the appended lakes of Poyang and Dongting (Figure 5.2). The semi-natural breeding reseves are all in oxbow lakes, which can be isolated from human activity. How the other reserves have been assigned to their locations varies, and the design of the reserves is not clear in published literature. There has been no published monitoring of the success of these reserves, indeed, it is not even well understood how the reserves are managed to reach conservation goals.

As a well-studied parallel, Marine Protected Areas (MPAs) can provide some guidance as to how to establish and manage FPAs. MPAs are only effective when they fulfil all of the five 'NEOLI' categories: no take, enforced, old, large and isolated (Edgar *et al.*, 2014). Evidence in Chapter 3 of this thesis shows the two Poyang Lake reserves are not no-take as extractive activity is still occurring in them, and evidence shown here indicates that reserves and illegal behaviour restrictions are not well enforced. The reserves are also relatively new (Table 1.4, Chapter 1). Their relative size can be argued as representative of a small overal species range, but isolation is difficult to assess within a densly populated and indutrialised river. The older reserves that are National level reserves (and so are better protected) such as Tian'e-Zhou may fulfill these requirements, but even with the information shown here it is difficult to fullly assess whether these reserves are well enforced as access to the reserves and the managers is restricted. There have been no publications detailing any information relating to these reserves ans so access to information is a barrier to assessing their effectiveness and adaptive management is not possible.

6.4.1 Is zoning within YFP reserves appropriate for cetacean conservation?

Balancing conservation and development in China is an ongoing challenge (Zhang, 2015). Many Chinese national parks use zoning systems that are designed to promote economic activities and development in and around them (Miller-Rushing *et al.*, 2017). Zoning of terrestrial reserves in China is often by a central “core zone”, surrounded by a “buffer zone” and “experimental” or “transition” zone (Ma *et al.*, 2009; Xu *et al.*, 2016). Often, human activities and development are permitted in all three zones (e.g. Ma *et al.*, 2009; Xu *et al.*, 2016). Many of these types of reserves have allowed continued human disturbance in all three zones over long time periods, with some even showing an increase in disturbance in the core zone (Xu *et al.*, 2016). This emphasis by Chinese government on the economic development of national parks risks undermining the environmental protection of these areas (Miller-Rushing *et al.*, 2017). Further to this issue, control of national parks is being passed down from national government to local government, who generally prioritise economic goals over conservation (e.g. tourism and resource extraction) (Xu & Melick, 2007; Urgenson *et al.*, 2014; Miller-Rushing *et al.*, 2017). The predominant aim of reserves is to remove known threats to a species or system and allow an area devoid of or with significantly reduced human impact. The effiicacy of the zoning system in Chinese reserves is therefore inappropriate for conservation, as often the permitted uses mean that threats or degrading processes continue (Ma *et al.*, 2009).

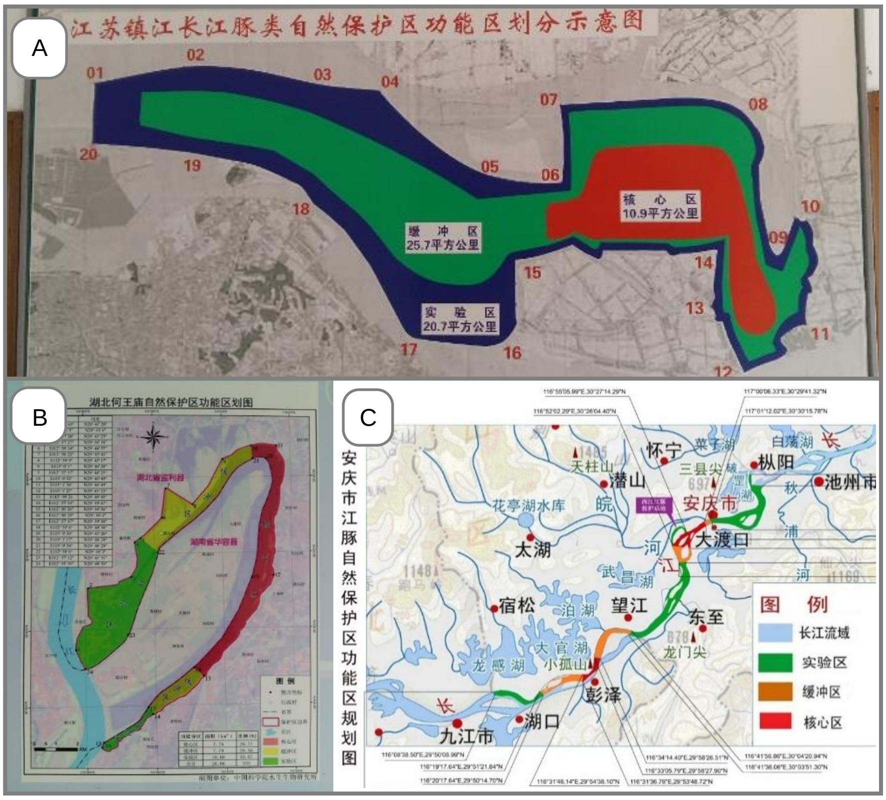


Figure 6.2: Design of (A) Zhenjiang in-situ YFP reserve, (B) Hewangmiao reserve and (C) mainstem Hukou – Anqing reserve. Each shows the core zone (red), buffer zone (green) and experimental zone (blue). All photos taken from publicly available maps in-country.

This zoning approach has been adopted in both Zhenjiang and Hewangmiao semi-natural YFP reserves, and also in a large Yangtze mainstem reserve area betweek Hukou and Anqing (Figure 6.2). Given that there are no published studies documenting cases of successful freshwater cetacean protected areas, the effectiveness of this zoning system cannot have been legitimately justified. Given the stark differences in habitat and target species, it seems implausible that directly applying a terrestrial zoning system to freshwater conservation areas would be the most effective approach. A targeted assessment of potential protected area management techniques is therefore needed to ensure these YFP reserves are appropriately and effectively designed. If these reserves are ineffective, another concern is that the placement of ineffective "paper-parks" can incite complacency within managers (Rife *et al.*, 2013; Minin & Toivonen, 2015).

As there are no documented cases of successful freshwater cetacean reserves, it is difficult to recommend improvements upon this model. However, the design of these reserves should explicitly consider and be designed using all information available, including the data shown in this study. The mapping studies shown in chapter 3 demonstrate that YFP are have seasonal changes in their distribution that should be explicitly included in reserve placement. In Poyang Lake, reserves should be moved to the high YFP density areas shown, and threats such as fishing activity removed. As vessel strikes were demonstrated to be a significant cause of YFP mortality in chapter 2 all shipping vessels should, in so far as is possible, be restricted from entering any YFP reserve to reduce the likelihood of propeller impacts. Where this is not possible (winter low-water, for example, where the channels become very narrow) vessel speed in the reserves should be restricted to well below YFP swimming speed of 4.3 km/hr (Akamatsu *et al.*, 2002). Improving the spatial, temporal, threat-based and ecological basis of reserve placement and design should improve the effectiveness of this intervention, and could, if successful, act as an unprecedented template for freshwater cetacean reserve design and management

6.4.2 Is enforcement sufficient in YFP reserves?

Enforcement is also necessary to ensure the effectiveness of protected areas (Guidetti *et al.*, 2008). Recovery of marine animal populations specifically (e.g. whales, sharks, seabass) requires that awareness, legal protection and enforcement of management plans are ensured (Lotze *et al.*, 2011). Enforcement by fisheries bureaus interviewed in the chapter 5 was highly varied between areas, with no centralised system of reporting, punishment, or patrols. The system of punishment is also vague and confusing (Figure 6.3). Illegal fishing types also varied between areas. Illegal night fishing is prevalent in the Yangtze River system (chapter 4), and the lack of regular enforcement may be allowing this to continue unregulated. It was noted by one fisheries bureau in the interviews in chapter 5 that they would find it useful to have a "*formal legitimate document which specifically points out the position of core YFP protected area*". As the fisheries bureau is responsible for enforcing illegal fishing restrictions that may cause YFP mortality in the reserve areas, poor understanding of the boundaries makes the reserve more likely to be ineffective. Retro-fitting this terrestrial design system to a freshwater reserve, as well as the poor management and enforcement could therefore be contributing to conservation complacency.

禁渔

鄱阳湖（全湖及五河干流入湖口以内水域）；
长江江西段（瑞昌市马头镇至彭泽县马垱镇水域）。
保护鱼类繁殖生长。

从事任何形式的捕捞作业
（包括捕捞鱼、虾、螺、蚌等水产品）；
销售禁渔区的任何渔获物。

违反禁渔规定非法捕捞水产品在150公斤以下或价值1500元以下的，处1500元以下罚款；在150公斤以上500公斤以下或价值1500元以上的，处5000元以下罚款并分别没收渔获物。

一年内两次及以上违反禁渔期规定作业的，涉案渔船扣除全年渔业油价补助，情节严重的没收渔具、吊销捕捞证，处5万元以下罚款；情节特别严重的没收渔船。

禁渔区内使用禁渔工具或禁用的方法捕捞的，非法捕捞水产品在500公斤以上或价值5000元以上的，暴力抗法的等构成犯罪的行为，均依法追究刑事责任。

Figure 6.3: Poster detailing the fishing ban from Taojiakancun village, Wucheng Township, Yongxiu County (永修县吴城镇陶家坎村)

Penalty: *Defendant is subject to a fine of not more than RMB1500 if the illegal fish catch is below 150kg or cost less than RMB1500. For fish catch between 150kg and 500kg or cost more than RMB1500, the fine may not exceed RMB5000. If defendant get caught twice or more for illegal fishing in a single year, he will not receive the annual fuel subsidy. In serious cases, fishing gear will be confiscated or/and fishing license will be cancelled or/and subject to a fine of not more than RMB50,000. Defendant may also result in confiscation of boats in more serious case. If the fish catch is more than 500kg or cost more than RMB5000; or/and defendant violently resisted an arrest, he shall be investigated for the criminal responsibility according to law.*

It has been recommended that Strategic Adaptive Management (SAM) is applied to freshwater protected areas (Kingsford, Biggs & Pollard, 2011). This process involves identification of a specific goal with corresponding management objectives, and subsequently using ongoing reflection, learning and adaptation to ensure the goal is still attainable given ongoing change in the reserve. This process is not occurring in these reserves, as evidenced by the lack of data available about the reserves themselves, and absence of any ongoing monitoring or adaptation of current interventions.

6.4.3 Conflict within YFP reserves

Another potential issue that requires more attention within these reserves is conflict management. As shown in chapter five, conflict with local communities has occurred at YFP reserves and between fishers and fisheries bureaus. The design and allocation of reserves in China have often not taken into account the local populations affected, meaning interests of local stakeholders are not incorporated into management (Xu *et al.*, 2012a). Local communities in China are more likely to be in conflict with reserve managers if park management is centralised and non participatory (Nepal, 2002). As management of reserves in China is usually centralised, conflicts between reserves and local communities often occur (Foggin, 2014). Conflict has the potential to undermine conservation interventions, and can also destabilise economic development, resource sustainability, and social equality (Woodroffe, 2005; Dickman, 2010). Effective conflict management requires integration of social context into the management of alternative management approaches (Raymond *et al.*, 2010). Zhang *et al.* (2017b) recommend increased engagement of protected area managers with local communities to reduce conflicts and imrove success of reserves in China. Understanding and managing conflicts resulting from YFP conservation efforts is therefore vital to minimise negative impacts on YFP-based interventions (Redpath *et al.*, 2013). The

IUCN CSG has previously recommended that fishers be brought on board with the YFP conservation and planning process, and has recognised that to be successful this requires government intervention (Kreb *et al.*, 2010).

6.4.4 Genetic and inbreeding issues within YFP reserves

Within the semi-natural protected areas, there is evidence of some inbreeding; within the semi-captive YFP population in Tian'e-Zhou reserve, inbreeding has resulted in individuals being removed and other "wild" individuals introduced (Chen *et al.* 2014). Continually taking individuals from the wild is unsustainable as decline of the wild population is likely to continue. It is recommended that a genetic management plan is intriduced, as simply introducing new individuals can lead to unsustinable captive populations removed from their natural slection pressures (Lynch & O'Hely, 2001). As these semi-natural reserves have been the predominant intervention used here, improvement of the genetic management of the reserve populations is vital to ensure longeivity of these populations if the wild population continues to significantly decline.

6.4.5 Are current YFP reserves appropriate for cetacean conservation?

A study by Ross *et al.* (2011) assigned ten guiding principles for priority habitat delineation for small cetaceans. A comparison of these standards to the two in-situ Poyang Lake reserves is shown in Table 6.2. Although semi-natural reserves have arguably been successful, in-situ reserves are poorly designed and reinforced (chapter 3, 4, 5, and 6 of this thesis) and the current reserve set-up does not explictly consider many of the crucial points noted as essential to effective reserve design in this study. This is partly due to a severe lack of data on both the species and also the methodology behind the current reserve set up. These data gaps are currently restricting application of these guiding principles; further detailed investigations are required into the bathymetry and habitat type of Poyang Lake, aswell as fish resources and behavioural studies of YFP in-situ, and other key information relating to YFP biology and ecology (points 1, 2, 3, 5 and 10, Table 6.2). However, given the new data presented in this thesis (predominantly chapters 3, 4, and 5) and the overall review of the current reserves presented above, the in-situ YFP reserve network needs urgent reassessment.

The information presented from this study should be used to reallocate current reserve placement and spatial coverage in Poyang Lake by explicitly considering spatial and seasonal movements of YFP and accounting for seasonal overlap of YFP and threats (chapter 3 of this thesis, point 4, 6 and 7 in Table 6.2). Areas where YFP density is high in a single or for both seasons should be covered to ensure that there are no temporal gaps in protection from threats. In addition, areas where there is higher overlap with fishing and vessel traffic should be targeted to try and reduce the pressure of these key threats in high-overlap sections in both summer and winter seasons. Enforcement of the reserves is also crucial. It is recommended that standardised, regular and targeted boat-based patrols are carried out by all relevant fisheries bureaus in Poyang Lake to ensure that threats are removed from the reserves effectively (as noted in chapter 5).

The reserve network is also in urgent need of a centralised monitoring and assessment system that allows feedback and adaptation to newly available information (point 9, Table 6.2) whilst also accounting for local communities through sustained, appropriate and well managed compensation systems. Any new reserve design should explicitly account for the guiding principles shown in Table 6.2, and should take into account all presently available data and information. The design of any planned reserves should also explicitly account for connectivity between reserves and ecological requirements of YFP (points 2 and 5, Table 6.2, e.g. physical and biological habitat requirements, calving seasonality). For example, the reserve design should explicitly take into account slope, depth and fish resources, as YFP show preferential use of habitats with flat benthic slopes and moderate depths (7-12m) (Mei *et al.*, 2017).

If appropriately reassessed, reallocated and well enforced, a redesigned and well-managed YFP reserve network could not only contribute to reversing population decline in a Critically Endangered species but would also act as an unprecedented template for in-situ freshwater cetacean conservation.

Table 6.2: Appraisal of the current reserves within Poyang Lake based on cetacean reserve recommendations by Ross *et al.* (2011)

Category	Details	Adequately considered with Poyang Lake reserve design?	Further recommendations
1. Food	Priority habitat shoud contain sufficient food to sustain the population.	No available information on prey distribution in Poyang Lake.	Further study needed.
2. Habitat features	Priority habitat must include the full range of physical, chemical and biological features required for population persistence.	No available information on features of Poyang Lake or the reserves.	Further study needed.
3. Habitat size	Priority habitat should be sufficient to allow long-term persistence.	Reserve areas are arguably relatively small to maintain a large YFP population.	Further study needed.
4. External connections	Priority habitat should explicitly consider surrounding habitat necessary to maintain the integrity of priority habitat.	The two reserve areas do not have zoning systems or buffer zones around the main area.	Reassessment of the zoning system in the reserves is needed.
5. Nurseries	Priority habitat should provide adequate protection for reproduction.	No assessment has been done to cover reproduction in this habitat.	Further study needed.
6. Temporal patterns	Include areas occupied at all relevant temporal periods	Reserve design not appropriate to cover all highest density areas of any season (chapter 4).	Reassessment of the reserve placement is needed.
7. Threat description	Designation should be informed by consideration of the anthropogenic threats and the geographic distribution of those threats.	Reserve design not appropriate to cover high human activity areas. Reserves are ineffective in removing threats (chapter 4).	Reassessment of the reserve placement and design is needed.
8. Precaution	In the face of scientific uncertainty, a precautionary approach can help ensure that priority habitat delineation gives the best chance of recovery of the species.	Given the lack of available data, a precautionary approach would require larger, connected areas of protection with no permissible human activity or extraction.	Further study needed and reassessment of the reserve size and connectivity.
9. Adaptive management	Priority habitat designations need to be reconsidered as new information becomes available.	There has been no change in design or management of the reserves, and no reassessment as far as is known despite ongoing research into the species.	Regular ongoing assessment required.
10. Social and behavioural considerations	Include areas for specialized behaviours.	No known specialised YFP behaviours.	Further study needed.

6.5 Overall conclusion

Failure to act quickly on rapid population decline leads to species extinctions (Turvey *et al.*, 2007; Martin *et al.*, 2012; Avila-Forcada, Martínez-Cruz & Muñoz-Piña, 2012), highlighting the need for urgent conservation intervention when at-risk biodiversity is identified. Contradictory to this idea is the increasing call for evidence-based conservation, whereby any intervention is only made once there is appropriate robust data to inform it (Pullin & Knight, 2001; Sutherland *et al.*, 2004; Pullin *et al.*, 2004). This study has used a multi-disciplinary approach to improve understanding of causes of decline and potential threats to the Critically Endangered Yangtze finless porpoise, in order to improve the evidence-base so that conservation can be better informed and targeted to key causes of decline.

This study has demonstrated longitudinal, spatial and seasonal patterns in fishing activity that relate to Yangtze finless porpoise mortality and also shown that fishing bycatch is less likely to be as much of a driver of population decline than previously asserted. These analyses have also demonstrated empirically for the first time the importance of vessel strikes as an as-yet understudied and poorly-mitigated for cause of Yangtze finless porpoise mortality. Further to these conclusions, it has been demonstrated that evidence-based conservation is not being applied to conservation of this species, meaning that interventions are currently ineffective at targeting key causes of population decline. Additionally, it has been demonstrated that local fishing communities in the Yangtze River are being impacted by depleted fish stocks and local conservation interventions.

The results presented here have further supported the call for urgent conservation intervention for this at-risk species, and also demonstrated that current mitigation needs to be better designed based on the available evidence, as well as better enforced, monitored and managed. In addition, attention must also be given to the social and economic context of the system in which the species exists to ensure successful, integrated conservation interventions. Whilst ensuring the well-being of local communities and livelihoods. These key gaps in current conservation efforts as well as other remaining knowledge gaps relating to threats (**Error! Reference source not found.**) risks extinction of this unique species, meaning the Yangtze River would lose a second cetacean species to preventable, anthropogenic causes of extinction. The results presented here have improved understanding of causes of decline, and the information presented can be directly applied to progress current conservation efforts in-country and counter the existing risk of extinction for this species, whilst also ensuring the future of local livelihoods and maintaining community support. The relatively rapid assessment methods used in this study could be applied to many other at-risk species, enabling conservationists to better conserve biodiversity and fight against the current alarming trends of global species extinction.

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8 Appendices

8.1 Appendix A – chapter 2

2008 interview survey structure

DATE: LOCATION: INTERVIEWER:

A: FISHERIES QUESTIONS

1) Are you a professional fisherman?

a) Are you retired?

2) How old are you?

3) How many years have you been fishing?

4) What kind of fishing gear do you use today? (list all if more than one type)

☐ Free-floating gill nets
☐ Drag nets (feng wang)
☐ Drag nets (wei wang)
☐ Gill net / drag net (tuo wang)
☐ Gill net (san ceng wang)
☐ Other type of fishing gear (describe)

☐ Hao wang
☐ Si wang
☐ Shrimp traps
☐ Crab net (xie wang)
☐ Rolling hooks

5) Size dimensions of gill / drag net:

a) Mesh size

b) Net length

c) Net width

6) Have you always used this kind of fishing gear? (Y/N)

a) When and why did you change your fishing gear?

7) What is the commonest type of fishing gear used in your village?

8) Have you ever used rolling hooks in the past? (Y/N)

a) When did you stop using them?

9) Do you know how many people still use rolling hooks in this section of the river? (Y/N)

a) How many?

10) Do you ever lose/have to replace your fishing gear? (Y/N)

a) How often?

11) Do you ever see ‘ghost’ fishing gear in the river? (Y/N)

a) What kind?

b) How many times in the past year?

12) Is there a problem with electro-fishing around here? (Y/N)

a) Do you know how many electro-fishermen there are in this river section?

b) How many years ago did electro-fishing start in this river section?

13) What species of fish do you catch?

a) Japanese eel *Anguilla japonica* (manli)
b) Crucian carp *Carassius carassius* (jiyu)
c) Predatory carp *Chanodichthys erythropterus* (boyu)
d) Grenadier anchovy *Coilia nasus* (fengweiyu)
e) Grass carp *Ctenopharyngodon idella* (caoyu)
f) Common carp *Cyprinus carpio* (liyu)
g) Sharpbelly *Hemiculter leucisculus* (cantiaoyu)
h) Silver carp *Hypophthalmichthys molitrix* (lianyu)
i) Bighead carp *Hypophthalmichthys nobilis* (yongyu)
j) Chinese longsnout catfish *Leiocassis longirostris* (huiyu)
k) Wuchang bream *Megalobrama amblycephala* (fangyu)
l) Black carp *Mylopharyngodon piceus* (qingyu)
m) Yellowhead catfish *Pelteobagrus fulvidraco* (huangsangyu)
n) Southern catfish *Silurus meridionalis* (nianyu)
o) Chinese perch *Siniperca chuatsi* (guiyu)
p) Other species (list/describe)

14) Have you ever seen or caught Reeves' shad (shiyu)? (Y/N)

a) When did you last see this fish?

b) When is the last time that anybody saw this fish?

15) How many hours do you spend on the river each day?

16) How many days a week do you go fishing?

17) What time of day or night do you go fishing?

18) How much time is your fishing gear in the water for each week?

19) What job do you do during the fishing ban?

20) Apart from the fishing ban, do you do different amounts of fishing at different times of year? (Y/N)

a) Which months do you do the most fishing?

b) Which months do you do the least fishing?

21) Where do you fish?

Main channel (mid)	**OFTEN**	**SOMETIMES**	**RARELY**
Main channel (near bank)	**OFTEN**	**SOMETIMES**	**RARELY**
Behind sandbars/islands	**OFTEN**	**SOMETIMES**	**RARELY**
In tributaries	**OFTEN**	**SOMETIMES**	**RARELY**

22) What are the upstream and downstream boundaries of where you go fishing?

23) Have you always fished in this region? (Y/N)

a) Where did you used to fish?

b) When did you change your fishing range?

24) What kinds of changes have you noticed over time?

a) Amount of fish caught:
BETTER / SAME / WORSE THAN BEFORE

b) Declines of particular species (name any species that have declined)

c) Number of fishing boats on the river:
MORE / SAME / FEWER THAN BEFORE

25) Do you want your children to be fishermen? Is it a good job for the next generation? (Y/N)

SPACE FOR ADDITIONAL COMMENTS:

B: FINLESS PORPOISE QUESTIONS

[Informant is asked to identify a finless porpoise from a series of photographs without being prompted. If he/she is able to do this, the following questions are asked.]

26) How often do you see porpoises when you are on the river?

27) Do you see more porpoises at a particular time of year? (Y/N)

a) When?

28) How many porpoises do you normally see at a time?

29) Do you think that there are as many porpoises today as there used to be in the past? (Y/N)

30) Do porpoises ever take fish out of your nets? (Y/N)

31) Have you ever seen dead porpoises, or heard about porpoises getting killed? (Y/N)

a) When did you last see a dead porpoise? (month, year)

b) Where was this animal seen?

c) Do you know what killed the porpoise?

d) Do you have any information on any other dead porpoises?

32) Do you know if there are any dead porpoises around here anywhere? (Y/N)

33) Do porpoises ever get killed by ships?

a) When was the last time this happened?

b) How often does this happen?

c) How many times has this happened in the last five years?

d) Where in the river do ships kill porpoises?

i. Distance from bank:

ii. Geographical location:

e) How do you know it that the porpoise was killed by a ship?

34) Do porpoises ever get killed by electro-fishing? (Y/N)
a) When was the last time this happened?

b) How often does this happen?

c) How many times has this happened in the last five years?

35) Do porpoises ever get killed in fishing gear? (Y/N)

a) What kind of fishing gear? (describe mesh size)

b) When was the last time this happened?

c) How often does this happen?

d) How many times has this happened in the last five years?

e) Where in the river does fishing gear kill porpoises?

i. Main channel, side-channel or tributaries:

ii. Distance from bank:

iii. Geographical location:

36) If porpoises get caught in fishing gear, what do people do with them?

37) In what months/seasons do porpoises most commonly get caught/killed?

SPACE FOR ADDITIONAL COMMENTS:

C: BAIJI QUESTIONS

[Informant is asked to identify a baiji from a series of photographs without being prompted. If he/she is able to do this, the following questions are asked.]

38) Do you know what a baiji is? (Y/N)

39) Have you ever seen a baiji in your lifetime? (Y/N)

a) How many times have you ever seen baiji?

b) When was the last time you saw a baiji?

c) Where was the last place you saw a baiji?

d) Do you remember what you were fishing for when you saw baiji?

i. What species were you fishing for?

40) Have you ever seen more than one baiji at a time?

a) What is the largest group of baiji you have seen?

b) Where did you see this group?

c) When did you see this group?

d) Do you remember what you were fishing for when you saw baiji?

i. What species were you fishing for?

41) Describe your baiji sightings (e.g. duration, habitat, behaviour, time of year, distance from boat).

42) If you have never seen a baiji, how have you heard about the species?

43) Do you know of anyone else that has ever seen a baiji? (Y/N)

a) Describe their baiji sightings (e.g. location, date, duration, habitat, behaviour, time of year, distance from boat).

44) Do you know of anyone specific who we might want to talk to, who might know more about baiji? (Y/N)

45) Have you ever seen a dead baiji? (Y/N)

a) How many dead baiji have you seen?

b) Describe any dead baiji that were seen (location, date, other details).

46) Have you ever heard of anyone catching a baiji? (Y/N)

a) If so, what kind of fishing gear it was caught in?

47) Have you ever heard of baiji being killed in any other way? (Y/N) (e.g. strandings, boat collisions)

a) Describe:

48) If baiji ever got caught in fishing gear, what happened to them?

49) Did you notice any particular period in time when baiji became much rarer? (Y/N)

a) When?

50) When do you think baiji disappeared?

51) What do you think caused the baiji to disappear?

52) Why do you think that the porpoise has survived but the baiji has disappeared?

53) Do you know about any stories, myths or legends about the baiji?
SPACE FOR ADDITIONAL COMMENTS:

D: PADDLEFISH QUESTIONS

[Informant is asked to identify a paddlefish from a series of photographs without being prompted. If he/she is able to do this, the following questions are asked.]

54) Do you know what a paddlefish is? (Y/N)

55) Have you ever caught a paddlefish in your lifetime? (Y/N)

  a) How many paddlefish have you ever caught?

  b) When was the last time you caught a paddlefish?

  c) When is the last time that anybody you know caught a paddlefish?

  d) Where was the last place you caught a paddlefish?

  e) What kind of fishing gear were you using, and where in the river?

56) If you have never caught a paddlefish, how do you know about the species?

57) Do you know anyone else that has ever seen or caught a paddlefish? (Y/N)

  a) Describe the sighting (date, location, other details):

58) Do you know of anyone specific who we might want to talk to, who might know more about paddlefish? (Y/N)

59) Have you ever heard of paddlefish being killed in any other way? (Y/N) (e.g. strandings, boat collisions)

  a) Describe:

SPACE FOR ADDITIONAL COMMENTS:

2011/12 interview survey structure

Province: ___________________________________

City: ___________________________________

Town: ___________________________________

Village: ___________________________________

A. LIVELIHOOD QUESTIONS

1. Age ____

2. Are you still working or retired? ___________________________________

3. a) How many years have you been fishing? _________________________

b) Describe the geographical area where you go fishing? ______________

4. Annual income over the past 12 months? __________________________

5. Has your income been relatively stable over the past 5 years? __________

If no, describe the variation in your income? ________________________

6. Does your income vary monthly or seasonally? ______________________

If YES, describe how much? ____________________________________

7. Is fishing your main source of income? ____________________________

8. Do you have any other source of income? ___________________________

a) Describe ____

b) Proportion if income from fishing? ________________________

c) Different jobs at different times of year? ___________________

9. How much do you spend per year on gear, boat upkeep, fuel, licenses before you make profit? ____

10. How much more do you spend on fuel today compared to 5 years ago?

____

a) Are increasing fuel costs a problem? ___________________________________

11. Do you receive money from the government as a reimbursement?

a) How much per year

b) What is the reimbursement for?

B. FISHING GEAR QUESTIONS

12. How many types of fishing gear do you use?

13. List all gear types

Gill net: Mesh size / dimensions _____________________

Local name______________________________

Drag net: Mesh size / dimensions _____________________

Local name_______________________________

Fixed net: Mesh size / dimensions ______________________

Local name________________________________

Rolling hook: ____

Ai wei (moat): ____

Trap: ____

Other: ____

14. Jan fish species: ____

Gear: ____

Feb fish species: ____

Gear: ____

Mar fish species: ____

Gear: ____

Apr fish species: ____

Gear: ____

May fish species: ____

Gear: ____

Jun fish species: ____

Gear: ____

Jul fish species: ____

Gear: ____

Aug fish species: ____

Gear: ____

Sept fish species: ____

Gear: ____

Oct fish species: ____

Gear: ____

Nov fish species: ____

Gear: ____

Dec fish species: ____

Gear: ____

15. Gear type 1

a) Name: ____________________________

b) Where do you use this gear?

Main channel Side channel tributary

c) Distance from shore: ____

d) Water depth: ____

e) Geographical features:

sandbar/island Confluence Other

f) Main geographical locations: ____

g) Hours/ day: ____

h) Days/ week: ____

i) Numbers of hours gear left in water: ___________________________________

j) Gear attended or unattended: ____

k) Time of day or night: ____

l) Use more at certain times of year?

If yes, when? ____

m) Main target fish species: ____

n) Other fish species caught? ____

o) Why do you use this more than others? _________________________________

p) Proportion of income from this gear type: _____________________________

Gear type 2

a) Name: ____________________________

b) Where do you use this gear?

Main channel Side channel tributary

c) Distance from shore: ____

d) Water depth: ____

e) Geographical features:

sandbar/island Confluence Other

f) Main geographical locations: ____

g) Hours/ day: ____

h) Days/ week: ____

i) Numbers of hours gear left in water: ___________________________________

j) Gear attended or unattended: ____

k) Time of day or night: ____

l) Use more at certain times of year?

If yes, when? ____

m) Main target fish species: ____

n) Other fish species caught? ____

o) Why do you use this more than others? ______________________________

p) Proportion of income from this gear type: _____________________________

Gear type 3

a) Name: ___________________________

b) Where do you use this gear?

Main channel Side channel tributary

c) Distance from shore: ____

d) Water depth: ____

e) Geographical features:

sandbar/island Confluence Other

f) Main geographical locations: ____

g) Hours/ day: ____

h) Days/ week: ____

i) Numbers of hours gear left in water: __________________________________

j) Gear attended or unattended: ____

k) Time of day or night: ____

l) Use more at certain times of year?

If yes, when? ____

m) Main target fish species: ____

n) Other fish species caught? ____

o) Why do you use this more than others? ______________________________

p) Proportion of income from this gear type: ____________________________

18. Do you know what a Yangtze finless porpoise is?

19. When did you last see a dead YFP?

20. How many dead porpoises have you seen in the past 12 months?

Date:

Location:

Cause of death:

21. What do you so with porpoises that get accidentally entangled?

22. Have you caught porpoises in gill nets in past 12 months?
    - How many?
    - Alive or dead?
    - When?
    - Where?
        - Distance from bank?
        - Main channel/side cahnnel or tributary?
        - Sandbar/island, confluence or other feature?
        - Exact geographical location?
        - Water depth?

23. Have you caught porpoises in drag nets in the past 12 months?
    - How many:
    - Alive or dead?
    - When?
    - Where?
        - Distance from bank?
        - Main channel/side cahnnel or tributary?
        - Sandbar/island, confluence or other feature?
        - Exact geographical location?
        - Water depth?

24. Have you caught porpoises in fixed nets in the past 12 months?
    - How many:
    - Alive or dead?
    - When?
    - Where?
        - Distance from bank?
        - Main channel/side cahnnel or tributary?
        - Sandbar/island, confluence or other feature?
        - Exact geographical location?
        - Water depth?

25. Have you caught porpoises in rolling hooks in the past 12 months?

How many:

Alive or dead?

When?

Where?

Distance from bank?

Main channel/side cahnnel or tributary?

Sandbar/island, confluence or other feature?

Exact geographical location?

Water depth?

26. Have you caught porpoises in other gear in the past 12 months?

How many:

Alive or dead?

When?

Where?

Distance from bank?

Main channel/side cahnnel or tributary?

Sandbar/island, confluence or other feature?

Exact geographical location?

Water depth?

26. b) Have you heard of anyone else catching porpoises in fishing gear?

If YES, describe when, where, type of gear, and how often:

27. Any seasonal variation when porpoises get killed in gear?

What time of year do they get killed the most?

28. Do different numbers of porpoises get killed in gear today compared to the past?

____

Do more porpoises get killed in gear today? ________________________

29. Caught different numbers of porpoises during drought years? _____________

If YES, describe the difference: __________________________________

30. Do you ever find half eaten fish in nets that may have been eaten by porpoises?

____

31. Are you aware of any dead porpoises around here?

____

32. Describe the difference between a baiji and a porpoise?

____

33. Are you able to accurately identify baiji? __________________________________

Ever seen a baiji? ____

If YES, when did you last see a baiji? ________________________________

33. b) Have you ever seen a type of fish called “hetun” (pufferfish)?

If YES, how long ago? ____

ATTITUDES AND AWARENESS

34. Want to continue being a fisherman in the future? _______________________

a) What other jobs would you want to do instead? ____________________________

b) What would you need to change jobs? ____________________________________

i) New skills/ training

ii) Start-up funds

iii) relocating

iv) other factors

35. What do you do during the fishing ban? ________________________________

36. During the fishing ban, do you earn a different amount? ____________________

37. Describe what the fishing ban is for? ___________________________________

38. Do you object tot the fishing ban? ______________________________________

If YES, describe the main objectives? ________________________

39. What proportion of fishers in this community practice electrofishing?

____

40. How much money can people make from electrofishing per month?

____

41. Why do you use electrofishing over other methods?

____

Catch more fish? ____

Catch more specific fish species? (describe) _________________________________

Easier/less effort compared to other methods? ______________________________

Other reasons? (describe) ____

42. Do you think electrofishing is sustainable? ___________________________

43. Do porpoises ever get killed by electrofishing? ________________________

How many killed in the past year? ____________________________

44. Have you ever killed a porpoise with electrofishing?

____

How many times? ____

When? ____

Where? ____

45. Is electrofishing sustainable for the porpoise population? ________________

46. How much of a problem is electrofishing in this region? ________________

47. Do you know if any fishing gear types are illegal? ____________________

48. Last time that fisheries officials discussed illegal fishing laws with you?

____

49. Do you know if there are any laws about finless porpoise?

____

50. Last time that fisheries officials discussed porpoise conservation laws with you?

____

51. How often do you see/meet with fisheries officials each year?

____

Bubble plots from GLM analysis

Figure 1: Bubble plot for residuals before GLS correction

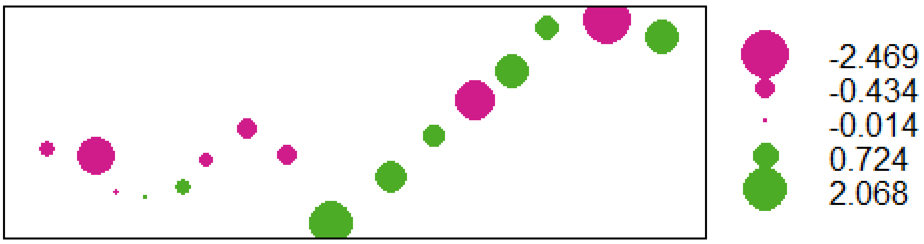


Figure 2: Bubble plot for residuals after GLS correction

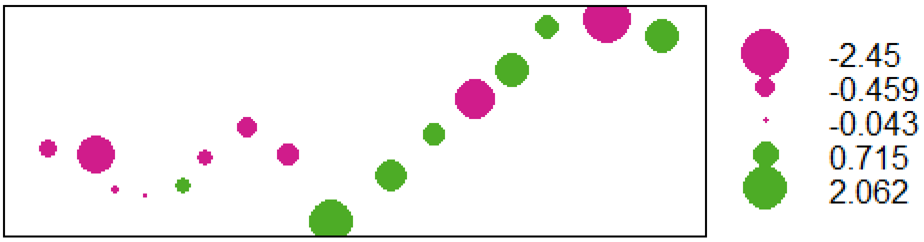
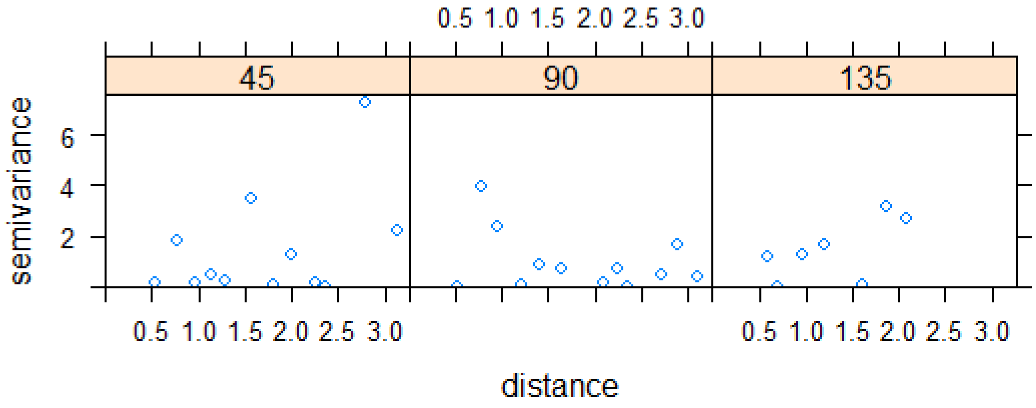


Figure 3: Variogram investigated autocorrelation pattern for GLM data



8.2 Appendix B – chapter 3

Table 1: Summer YFP boat surveys on-effort speed details (km/hr)

Location	Date	Average speed	Maximum speed	Minimum speed	Exact distance travelled
Poyang Lake					
Hukou – Xingzi	12.9.2017	11.30	14.4	8.5	40.58
Xingzi – Duchang	13.9.2017	11.10	13.7	7.3	34.09
Duchang – Ruihong	7.9.2017	10.72	12.3	8.5	66.61
Ruihong – Duchang	8.9.2017	12.63	13.8	5.2	73.75
Duchang – Xingzi	9.9.2017	11.80	13.9	7.6	68.42
Xingzi - Hukou	10.9.2017	11.96	14.9	10.1	40.29
Mainstem					
Anqing – Huayang	3.9.2017	6.09	11.9	2.2	59.56
Huayang – Pengze	4.9.2017	6.04	8.5	3.9	31.14
Pengze – Hukou	5.9.2017	6.07	10.2	4.1	36.89
Hukou – Huayang	1.9.2017	12.38	14.7	4.8	67.06
Huayang - Anqing	2.9.2017	12.89	16.7	7.2	59.90

Table 2: Winter YFP boat surveys on-effort speed details (km/hr)

Location	Date	Average speed	Maximum speed	Minimum speed	Exact distance travelled
Poyang Lake		km/hr	km/hr	km/hr	km
Hukou – Xingzi	1.3.2016	7.60	10.4	4.8	41.87
Xingzi – Duchang	2.3.2016	9.09	16.7	1.9	75.60
Duchang – Ruihong	3.3.2016	9.88	12.5	3.2	74.22
Ruihong – Duchang	4.3.2016	12.91	16.3	1.2	72.82
Duchang – Xingzi	6.3.2016	12.15	16.5	3.0	70.83
Xingzi - Hukou	7.3.2016	12.60	15.3	7.2	41.60
Mainstem					
Anqing – Huayang	11.3.2016	7.43	10.3	5.4	51.83
Huayang – Pengze	12.3.2016	6.36	12.1	2.7	40.49
Pengze – Hukou	13.3.2016	5.70	14.2	3.7	42.90
Hukou – Huayang	22.3.2016	12.40	15.0	4.5	67.68
Huayang - Anqing	15.3.2016	12.46	14.3	7.5	59.72

Table 3: Results of the Mann-Whitney U tests for the individual encounter rate (IER) of YFP observed in summer

Parameter	*Laoyemiao YFP Reserve*	Channel	Laoyemiao Reserve – Longkou Reserve	Longkou Reserve – Ruihong	*Longkou YFP Reserve*
Hukou – Laoyemiao Reserve	W =1451.5, p = 0.001211	W = 1785.5, p = 0.4503	W = 3562.5, p < 0.001	NA (zero obs.)	W = 977.5, p = 0.9582
Laoyemiao YFP Reserve	NA	W = 474.5, p = 0.09435	W = 1367, p = 0.804	NA (zero obs.)	W = 351, p = 0.1124
Channel	NA	NA	W = 1609, p = 0.04221	NA (zero obs.)	W = 314.5, p = 0.739
Laoyemiao Reserve – Longkou Reserve	NA	NA	NA	NA (zero obs.)	W = 869.5, p = 0.07553
Longkou Reserve – Ruihong	NA	NA	NA	NA	NA (zero obs.)

Table 4: Results of the Mann-Whitney U tests for the individual encounter rate (IER) of YFP observed in winter

Parameter	*Laoyemiao YFP Reserve*	Channel	Laoyemiao Reserve – Longkou Reserve	Longkou Reserve – Ruihong	*Longkou YFP Reserve*
Hukou – Laoyemiao Reserve	W =1446.5 p = 0.0246	W = 2194, p = 0.1484	W = 3778.1, p = 0.0072	W = 2265.5, p <0.001	W = 847.5, p = 0.1445
Laoyemiao YFP Reserve	NA	W = 456, p = 0.003282	W = 1477, p = 0.9919	W = 919, p = 0.2087	W = 350.5, p = 0.5627
Channel	NA	NA	W = 2093, p = 0.002334	W = 707, p <0.001	W = 263, p = 0.0126
Laoyemiao Reserve – Longkou Reserve	NA	NA	NA	W = 2380.5, p = 0.123	W = 870, p = 0.6765
Longkou Reserve – Ruihong	NA	NA	NA	NA	W = 736.5, p = 0.09842

8.3 Appendix C – chapter 4

Fishers Questionnaire

Date: D_______/M_______/Y________ Interviewer: ______________________________
Location: ____
Village: ______________ County: _____________ City: _____________ Province: ______________
Interviewee ID: ____
Start Time: _________________ End Time: __________________

Opening statement: This survey is looking into the health of fish stock populations, quality of habitat in the Yangtze, and status of the jiang-tun in the river. This survey is very important to help protect the river and its species. Your participation in this research is voluntary and confidential. We record the name of the village but not of individuals. You do not have to answer any questions if you do not feel comfortable. If you do not know an answer, please say 'I do not know' – it is fine if you do not know the answer. There are lots of questions but each one is very important so please be as accurate as you can.

You should know that you are able to withdraw from the interview at any time without having to give the reason why.

1. Are you willing to participate in this survey? Yes ☐ Unwilling, No ☐

PERSONAL

2. Personal Details
    a. Age
    ____
    b. Are you a fisherman currently? Yes ☐ No, I was but I'm retired now ☐
        i. If RETIRED what year did you retire?
        ____
        ii. If CURRENT fisher, how many years have you been a fisher?
        ____
    c. Have you always been a fisher in **this** region? **YES** ☐ **NO** ☐
        i. If **NO**, where did you fish before? _______________________________
        ii. If **NO**, when did you move to this region? _________________________
    d. Where do you normally go fishing? (give rough location(s) or direction)
    ____
    _
    e. What are the upstream and downstream limits of where you go fishing (approx.)?
    ____
    _
    f. How many fishing boats does your family you own? 1 ☐ 2 ☐ 3 ☐ 4 ☐ or more
    How many do you use for fishing yourself? _____________________________________
    g. Please identify the type of boat(s) you own from the pictures –

	Type 1	Type 2	Type 3	Other
Primary boat	☐	☐	☐	☐
Secondary boat	☐	☐	☐	☐
Tertiary boat	☐	☐	☐	☐

FISHING TYPE QUESTIONS

3. What type of fishing equipment do you use at the moment? **[TICK ALL THAT APPLY]**

Order of use (1st, 2nd, 3rd)

☐ Si Wang		_______________
☐ Xia Long	- shrimp	_______________
☐ Feng wang	- drag net	_______________
☐ Wei Wang	- large circular drift net	_______________
☐ Tuo Wang	- Drag net	_______________
☐ Sancenwang	- 3 layered gill net	_______________
☐ Hao Wang		_______________
☐ Xie Wang	- crab net	_______________
☐ Gungou	- rolling hooks	_______________
☐ Dian Wang	- electric fishing	_______________
☐ Ai Wei	- semi-permanent low wall moat	_______________
☐ Ding Zhe Wang	- set net	_______________
☐ Du Yu	- poison	_______________

☐ Other (specify) ______________________________________

4. **PRIMARY FISHING METHOD:** Most used - equipment type 1 (name): ____________________
   a. Mesh size: ____________(mm)
   b. Size/length of net: _____________(m)
   c. Where used in the channel: Centre ☐ Bank ☐
   d. Water depth: ________(m)
   e. Where it's used (location in lake/river i.e. town/village): ____________________
   f. Time of day/night: ________am/pm to _________ am/pm
   g. Hours per day: ___________/day
   h. Days per week: ____________/week
   i. Number of hours/days equipment is left in the water (soak time): _______hours/days
   j. Is the equipment: Attended ☐ Unattended ☐
   k. Month start – month finish (please circle **ALL** months used):

   Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

   l. Target species: ____
   m. Why do you use this equipment type as opposed to others?

   ____

   n. Proportion of income from this equipment type: ____________(%)

5. **SECONDARY FISHING METHOD**: Fishing equipment type 2: ____________________________
   a. Mesh size: ____________(mm)
   b. Size/length of net: _____________(m)
   c. Where used in the channel: Centre ☐ Bank☐
   d. Water depth: ________(m)
   e. Where it's used (location in lake/river i.e. town/village): ____________________
   f. Time of day/night: ________am/pm to _________ am/pm
   g. Hours per day: ___________/day
   h. Days per week: ____________/week
   i. Number of hours/days equipment is left in the water (soak time): _______hours/days
   j. Is the equipment: Attended ☐ Unattended ☐
   k. Month start – month finish (please circle **ALL** months used):

   Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

   l. Target species: ____
   m. Why do you use this equipment type as opposed to others?

   ____

   n. Proportion of income from this equipment type: ____________(%)

6. **Fishing equipment type 3**: ____________________________
   a. Mesh size: ____________(mm)
   b. Size/length of net: _____________(m)
   c. Where used in the channel: Centre ☐ Bank ☐
   d. Water depth: ________(m)
   e. Where it's used (location in lake/river i.e. town/village): _____________________
   f. Time of day/night: ________am/pm to _________ am/pm
   g. Hours per day: ___________/day
   h. Days per week: ____________/week
   i. Number of hours/days equipment is left in the water (soak time): _______hours/days
   j. Is the equipment: Attended ☐ Unattended ☐
   Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
   k. Month start – month finish (please circle **ALL** months used):
   l. Target species: ____
   m. Why do you use this equipment type as opposed to others?
   ____
   n. Proportion of income from this equipment type: ____________(%)

7. **Fishing equipment type 4**: ____________________________
   a. Mesh size: ____________(mm)
   b. Size/length of net: _____________(m)
   c. Where used in the channel: Centre ☐ Bank ☐
   d. Water depth: ________(m)
   e. Where it's used (location in lake/river i.e. town/village): _____________________
   f. Time of day/night: ________am/pm to _________ am/pm
   g. Hours per day: ___________/day
   h. Days per week: ____________/week
   i. Number of hours/days equipment is left in the water (soak time): _______hours/days
   j. Is the equipment: Attended ☐ Unattended ☐
   k. Month start – month finish (please circle **ALL** months used):
   Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

   l. Target species: ____
   m. Why do you use this equipment type as opposed to others?
   ____
   n. Proportion of income from this equipment type: ____________(%)

8. What type of fishing equipment did you use **5 years ago** (**2010**)?
   a. SAME ☐ DIFFERENT ☐
   b. If DIFFERENT, please specify the type of gear used: _________________________
   c. If DIFFERENT, why did you change the type of fishing gear?
   ____
   d. If DIFFERENT, **what year** did you change to this gear? ________________________
9. What type of fishing equipment did you use **10 years ago** (**2005**)?
   a. SAME ☐ DIFFERENT ☐
   b. If DIFFERENT, please specify the type of gear used: _________________________
   c. If DIFFERENT, why did you change the type of fishing gear?
   ____
   d. If DIFFERENT, **what year** did you change to this gear? ________________________
10. Have you ever changed fishing method over your lifetime? **YES / NO**
   [If they've already said YES to Q 8and 9 above and given details there, ask them if they ever changed fishing type at any other point(s) in their life]
   If **YES**, How (from what method to what method?) __________________________________
   ____

If **YES**, what year? ____
If **YES**, Why? ____
____

11. In the seasons when you are fishing, how many hours a day do you fish now?
    Last year (2015): ____ hours/day
    5 years ago (2010): ____ hours/day
    10 years ago (2005): ____ hours/day

JIANG-TUN QUESTIONS

12. Do you know what a jiang-tun is? **YES / NO**
    THEN SHOW BAIJI AND JIANG-TUN PICTURES PAGE AND ASK THEM TO POINT IT OUT: A, B?
    Correct ☐ Incorrect ☐ If Incorrect, make sure they know you are talking about A

13. Have you seen a jiang-tun this year? **YES / NO**
    If **YES**, give **date** of ***most recent*** sighting: ________________________________

14. **On average, how often** have you seen a jiang–tun when you have been on the river/lake **this year**? (av.)
    ___________________________**day/week/month [don't accept "every day" as an answer]**
    a. Have you seen a jiangtun this week? **YES / NO**
    b. Have you seen a jiangtun this month? **YES / NO**
    c. How often did you see one **5 years ago** (*X/day, X/week)?* __________________d/w/m
    d. How often did you see one **10 years ago** (*X/day, X/week)*? _________________ d/w/m
    e. Do you see more jiang-tun at a particular time of year? **YES / NO**
    If **YES,** when? *(ask for months)* ____________________________________
    If **YES**, ***Why*** do you think you see them more at this time of year? _________________

15. **Where in the river/lake [deleted as necessary]** do you mostly see the jiang – tun? Describe locations:
    ____

16. Where in the channel do you mostly see the jiang-tun?
    Close to the river bank (150m) ☐ Mid-channel ☐ ☐ Other: _________________

17. What water depth? Shallow (0-3m deep) ☐ Middle (5-10m deep) ☐ Deep (>10m) ☐

18. Have you ever heard of **anyone else** (a friend or other fishermen) seeing a **dead** jiang-tun? **Y /N**
    If **YES**, How many times a month, on average? ____________________________**month**
    How many times a year, on average? ______________________________**year**

[FOR BELOW - ASK FOR DETAILS ON THE MOST RECENT DEATHS THEY HAVE HEARD OF]

If **YES** a. Where? ______________________
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you (or they) think made the jiang-tun die? ____________________ **DK**

If **YES** a. Where ______________________
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you (or they) think made the jiang-tun die? ____________________ **DK**

If **YES** a. Where? ______________________
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you (or they) think made the jiang-tun die? ____________________ **DK**

19. Have **you** ever seen a dead jiang-tun? **YES/ NO** [**if there is more than one, take all details**]
If **YES**, How often do you see a dead jiang-tun? ____________________________**d/w/m/y**
How many times a month, on average? _____________________________**month**
How many times a year, on average? _______________________________**year**
If **YES** a. Where? _______________________
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you think made the jiang-tun die? _____________________________
DK
If **YES** a. Where _______________________
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you think made the jiang-tun die? _____________________________
DK
If **YES** a. Where? _______________________
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you think made the jiang-tun die? _____________________________
DK

20. How many **dead** Jiang-tun did you see in 2015? _________________ **DK**
    a. How many **dead** jiang-tun did you see in 2010, five years ago? _______________ **DK**
    b. How many **dead** jiang-tun did you see in 2005, 10 years ago? _______________ **DK**

21. Do you see **dead** jiang – tun more in certain seasons or months? **YES / NO / DON'T KNOW**
If **YES** a. Which months/seasons? ____
b. Why do you think that is? ____

Cause of porpoise decline

22. Have you heard of **anyone else (a friend or other fishermen)** accidentally getting a jiang-tun caught in their fishing equipment in the **last 12 months**? **YES / NO**

[Note: they may have talked about such an event above in 31, if so, write in gap below to reference that answer]

If **YES** a. Which type of fishing equipment? ______________________________________
b. Where in the lake? ____
c. Time of year/month? ____
d. Alive and well, injured or dead? _______________________________________
e. If injured, in what way? ____
f. If dead, cause of death? ____
g. How often does entanglement happen (on average)? _________________**w/m/y**
h. How often have you heard of someone getting a jiang-tun in their fishing equipment?
In the last month? ________________________
In the last year? ________________________
In the last 5 years? ________________________

23. Have **you** caught a jiang-tun in any of your fishing equipment in the **last 12 months? Y / N**
If **YES** a. Which equipment? ____
b. Where in the river/lake? ____
c. Time of year/month? ____
d. Alive and well, injured or dead? ____
e. If injured, in what way? ____
f. If dead, cause of death? ____
g. How often does entanglement happen (on average)? ________________ w/m/y
h. How often have you had a jiang-tun in your fishing equipment

in the last month? ________________________
In the last year? ________________________
In the last 5 years? ________________________

[EXTRA SPACE FOR MULTIPLE ENTANGLEMENT OBSERVATIONS]

YOU / FRIEND OR OTHER FISHER [delete as necessary]

a. Which equipment? ____
b. Where? ____
c. **DATE** & Time of year/month? ____
d. Alive and well, injured or dead? ____
e. If injured, in what way? ____
f. If dead, cause of death? ____

YOU / FRIEND OR OTHER FISHER [delete as necessary]

a. Which equipment? ____
b. Where? ____
c. **DATE** & Time of year/month? ____
d. Alive and well, injured or dead? ____
e. If injured, in what way? ____
f. If dead, cause of death? ____

24. Do the jiang-tun get **caught in fishing equipment** more at a certain times of year? **YES / NO**

If **YES** a. When (give months): ____
b. What type of equipment? ____
c. Why at this time of year? ____

25. What do you do if you ever get a jiang-tun caught in your fishing equipment?

____

26. What do you think is the main cause of porpoise decline?

[**Do not read out answers or show answers to interviewee** – just tick all of those that are mentioned by interviewee]

- ☐ Mortality caused by fishing gear
  - ☐ Electric
  - ☐ Rolling hook
  - ☐ Nets (all)
  - ☐ Other ______________________
- ☐ Decline of fish stocks due to dam projects
- ☐ Decline of fish stocks due to overfishing
- ☐ Loss/degradation of fish spawning habitat
- ☐ Environmental effects caused by TGD
- ☐ Direct mortality caused by dredging activities
- ☐ Habitat degradation caused by dredging
- ☐ Direct mortality caused by ship/propeller collisions
- ☐ Effects of pollution
- ☐ Habitat loss/degradation of porpoise habitat
- ☐ Impacts of noise pollution e.g. can't find food
- ☐ Other (Please state): ____
- ☐ Don't know

INCOME

27. What is your annual income from fishing? (Try to get amount first. If you can't, ask for %)

Last year (2015) __________________¥/year **OR** __________%
5 years ago (2010) __________________¥/year **OR** __________%
10 years ago (2005) __________________¥/year **OR** __________%

28. Is fishing your sole source of income? **YES / NO**

If **NO**, what is your income from other work? (Try to get amount first. If you can't, ask for %)
Last year (2015) __________________¥/year **OR** __________%
5 years ago (2010) __________________¥/year **OR** __________%
10 years ago (2005) __________________¥/year **OR** __________%
If **NO, What** other job(s) do you do? ____
If **NO, When** do you do other work (sometimes evening, or concurrent with fishing work)?
____

If **NO**, Is this in specific months? (give months) _________________________________

29. Has your income been fairly stable over the last 5 years? **YES / NO**
If **NO** Why? ____

30. How much money do you spend every year on the following?
Boat and boat upkeep : ______________________ ¥/yr
Fuel : ______________________ ¥/yr
Fishing equipment (nets etc.) : ______________________ ¥/yr
31. Do you receive money from the government for a reimbursement scheme?
    a. How much/year: ________________ ¥
    b. What for? Fuel ☐ Fishing ban ☐ Other ☐ (state): ________________
    c. How many years have you been receiving this? (get a year): _____________

32. Do you keep any records of your landings and/or earnings? **YES / NO**
If **YES** Can we see the records? **YES / NO**
PLEASE STATE: If you choose to show us your records, they will be kept anonymous.

33. Do you think stocks of the following fish species are:
    a. Stable, Increasing or Decreasing?
    b. Healthy or Depleted?

34. How much of the following species did you catch per day in 2015, 5 years ago (2010), and 10 years ago (2005)?

	34 a			**34 b**		**34 c**			
	Stable	***Incr***	***Decr***	***Healthy***	***Depleted***	***2015***	***5 years ago (2010)***	***10 years ago (2005)***	***DK***
a) Crucian carp *Carassius carassius* (jiyu)	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐
b) Common carp *Cyprinus carpio* (liyu)	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐
c) Yellowhead catfish *Pelteobagrus fulvidraco* (huangsangyu)	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐
d) Xenocypris davidi (huangweigu)	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐
e) Sharpbelly *Hemiculter leucisculus* (cantiaoyu)	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐
f) Grenadier anchovy *Coilia ectenes* (daoyu)	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐
g) Ice fish *Hemisalanx prognathus* (yinyu)	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐
h) Needlefish *Hemirhamphus kurumeus* (zhenyu)	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐
I) Reeve's shad Tenualosa reevsii	☐	☐	☐	☐	☐	_______ kg/g	_______ kg/g	_______ kg/g	☐

FISH STOCKS

35. Have the **species** of fish you catch changed:
    a. In the last 5 years? **YES / NO**
    If **YES** How? ____
    b. In the last 10 years? **YES / NO**
    If **YES** How? ____

36. Are there any factors that you think have negatively affected fish stocks in the Yangtze?

[DO NOT READ OUT OR SHOW ANSWERS, LET THEM ANSWER ONLY]

☐ Pollution
☐ Dams ***(ask ->)*** ☐ Three gorges dam ☐ Other specific dam: ___________
☐ Habitat modification and loss of spawning grounds etc.
☐ Dredging
☐ People now using a certain type of fishing gear. Specify which type(s)
____
☐ Other. Please specify ____

37. How do you think the **seasonal fishing ban** has affected fish stocks in the Yangtze?
____

[IF a change has been noted in Q. 37] When did you notice this change? [give year]
____

38. How do you think the **addition of small fish fry** has affected fish stocks in the Yangtze?
____

[IF a change has been noted in Q. 38] When did you notice this change? [give year]
____

39. What do you think the effect of the dams has been on fish stocks in the Yangtze?
____

    a. Specifically, did you notice any effect on fish stocks from the Three Gorges Dam?
    ____
    b. When did you first notice these effects from the TGD? **[get year]**
    ____
    c. Specifically, did you notice any effect on fish stocks from the Gezhouba dam?
    ____
    d. When did you first notice these effects from the Gezhouba dam? **[get year]**
    ____
    e. What about any other dams? (Effects and what year effects were first noticed)
    ____

40. Rate these items in terms of what you think has caused the reduction in fish stocks in the Yangtze and lakes, 1 being has had most effect, to *n* has had least affect:

[Read or show them all answers]

_______ Pollution
_______ Dams
_______ Habitat modification causing loss of fish spawning grounds etc.
_______ Overfishing
_______ Building concrete riverbank protection
_______ Other. Please specify:
____

41. In the seasons when you're fishing, what is your overall catch of all species in a day?
Last year (2015): ______________________________________ kg/jin/day
5 years ago (2010): ____________________________________ kg/jin/day
10 years ago (2005): ___________________________________ kg/jin/day

ELECTRIC FISHING AND OTHER FISHING TYPES

42. Do you know anyone else that does electric fishing? **YES / NO**
    If **YES** a. **What species of fish** do they catch with it? ______________________
    b. **What time of day** do they do it? ______________________
    c. How **often** do they do it? _________________d/w/m
    d. All year or seasonally? (Write months) ______________________
    e. How much of their income comes from electric fishing? _______________(%)
43. Approximately what proportion of this village does electrofishing?

Now		***Five years ago***		***Ten years ago***	
All	☐	All	☐	All	☐
More than 50%	☐	More than 50%	☐	More than 50%	☐
< or = 50%	☐	< or = 50%	☐	< or = 50%	☐
Less than 25%	☐	Less than 25%	☐	Less than 25%	☐
Very few	☐	Very few	☐	Very few	☐
None	☐	None	☐	None	☐
Don't know	☐	Don't know	☐	Don't know	☐

Why do you think it has changed? **[DO NOT READ OUT ANSWERS OR LET THEM SEE]**
There's fewer fish now so electric fishing gives a better yield ☐
Easier/ less effort ☐
Cheaper ☐
No enforcement ☐
Other (specify) ☐ ____

44. What proportion of your village uses hook and line fishing?

Now		***Five years ago***		***Ten years ago***	
All	☐	All	☐	All	☐
More than 50%	☐	More than 50%	☐	More than 50%	☐
< or = 50%	☐	< or = 50%	☐	< or = 50%	☐
Less than 25%	☐	Less than 25%	☐	Less than 25%	☐
Very few	☐	Very few	☐	Very few	☐
None	☐	None	☐	None	☐
Don't know	☐	Don't know	☐	Don't know	☐

45. Have you ever heard of jiang-tun getting killed by electric fishing? **YES / NO**
    If **YES** a. Where? ____
    b. Day or night time? Day ☐ Night ☐
    c. Any time of year more than another?_________________________________
    d. Where the water is shallow or deep? Shallow ☐ Deep ☐
    e. Are they adult or young porpoises? Adult ☐ Calf ☐

FISHING BAN

46. Do you do other work during the fishing ban? **YES / NO**
    If **YES,** what alternative work do you do during the fishing ban?
    ____

47. Of the fishermen that you know, how many do you think continue fishing during the fishing ban?
    All ☐ More than 50% ☐ Less than or = 50% ☐ Less than 25% ☐ Very few ☐ None ☐

ALTERNATIVE EMPLOYMENT

48. If the government offered you alternative employment, would you take it? **YES / NO**
    If **YES**, what kind of work would you prefer to do? (Give examples)

____

____

If **YES**, would you need additional training to do the work you would like to do? **YES / NO**
If **YES**, specify type of training: ____

49. Would you be willing to relocate to another area to take up alternative employment? **Y / N**

OTHER

50. Do you do any night time fishing? **YES / NO**
If **YES**, What type? ____
If **YES**, How many nights a week? _____ **/7** **[do not accept "everyday" as an answer]**
51. What proportion of your village does night time fishing? ______________________%

52. Do you know anyone that has been prosecuted for **illegal** fishing? **YES / NO**
If **YES** a. When ____
b. What type of fishing? ____
c. How often do you hear of this happening to someone? ____________d/w/m/y
d. What happened?
    - ☐ Confiscated equipment
    - ☐ Confiscated boat
    - ☐ Fine (¥) How much? ______________ ¥
    - ☐ Fishing licence revoked
    - ☐ Other (please describe) ____

53. Do you have any other information on porpoises (any sightings or hearing about dead porpoises etc., any currently around here)?
____

54. When was the last time you saw a live Baiji? ______________________________
55. When was the last time you saw a live Reeves paddlefish? ______________________________
56. When was the last time you saw a live Chinese pufferfish? ______________________________

End Time: __________________

8.4 Appendix D – chapter 4

Stakeholder Questionnaire

Date: D_______/M_______/Y________Interviewer: ______________________________
Organisation: ____
Location: County:__________________City:__________________Province: ________________
Interviewee name: ____
Interviewee role: ____
Contact details: ____
Start Time: _________________ End Time: __________________

This survey is looking into the health of fish stock populations and jiang-tun in the river. This survey is very important to help protect the river and its species. Your participation in this research is voluntary and confidential. We record the name your organisation and your name and contact details, but your name will never be published or disclosed to anyone; it's just to keep track of who we have spoken to. You do not have to answer any questions if you do not want to. If you do not know an answer, please say 'I do not know' – it is fine if you do not know the answer to a question. There are lots of questions but each one is very important so please be as accurate as you can.

You should know that you are able to withdraw from the interview at any time without having to give the reason why.

1. Are you willing to participate in this survey? Yes ☐ No ☐
   If **No,** can you tell us why you are unhappy to participate?
   ____

SECTION A: FOR ALL ORGANISATIONS

2. What is the overall purpose of your organisation? Please give as much detail as possible:
   ____
   ____
   ____

3. How many employees are in your organisation? ____
   - ☐ 0 – 5, very small
   - ☐ 6 – 10, small
   - ☐ 11 – 20, medium
   - ☐ 21 – 50, large
   - ☐ 50 +, very large
   - ☐ Don't know

4. What geographical area(s) do you work in? ____
   - ☐ Main Yangtze section
     - ☐ Hubei
     - ☐ Hunan

- ☐ Jiangxu
  - ☐ Anhui
  - ☐ Jiangxi
- ☐ Poyang Lake
- ☐ Dongting Lake
- ☐ Other: ____

5. Does your organisation organise or participate in activities relating to porpoise conservation?

   Yes ☐ No ☐

   a) **Activity:** ____
   When did you start this activity? ______________________________
   What evidence do you have that this should be a target for porpoise conservation?
   ____

   What is the ultimate goal of this activity? ______________________________

   b) **Activity**: ____
   When did you start this activity? ______________________________
   What evidence do you have that this should be a target for porpoise conservation?
   ____

   What is the ultimate goal of this activity? ______________________________
   c) **Activity**: ____
   When did you start this activity? ______________________________
   What evidence do you have that this should be a target for porpoise conservation?
   ____

   What is the ultimate goal of this activity? ______________________________

6. In relation to porpoise conservation, what has been the most successful part of **your/your organisation's** work so far? **Don't do any** ☐

   ____
   What factors have made this the most successful part? ______________________________
   ____

7. Have you met any barriers or problems when trying to do porpoise conservation work? **YES/NO**
   If **YES**, what were these barriers? **[Read out/show]** **Don't do any** ☐

   - ☐ Legal Describe: ______________________________
   - ☐ Political Describe: ______________________________
   - ☐ Financial Describe: ______________________________
   - ☐ Logistical Describe: ______________________________
   - ☐ Ecological Describe: ______________________________

☐ Other: _______ Describe: ____

8. In general, how successful do you think **YOUR** porpoise conservation efforts have been so far?

Very successful	☐	**[READ OUT]**	**Don’t do any** ☐
Partly successful	☐		
Somewhat unsuccessful	☐		
Completely unsuccessful	☐		
Don’t know	☐		

9. In general, how successful do you think **OVERALL** porpoise conservation efforts have been so far?

Very successful	☐	**[READ OUT]**
Partly successful	☐	
Somewhat unsuccessful	☐	
Completely unsuccessful	☐	
Don’t know	☐	

10. Overall, do you think that the total current conservation efforts are sufficient to conserve:

a. An in-situ porpoise population

Definitely sufficient	☐	**[READ OUT]**
Probably sufficient	☐	
Probably insufficient	☐	
Definitely insufficient	☐	
Don’t know	☐	

Explain your decision: ____

b. Porpoises in ex-situ reserves:

Definitely sufficient	☐	**[READ OUT]**
Probably sufficient	☐	
Probably insufficient	☐	
Definitely insufficient	☐	
Don’t know	☐	

Explain your decision: ____

11. Overall, across the country and all organisations, what specific porpoise conservation activities do you think have been the most successful so far? **[multiple answers ok]** **Don’t know** ☐

(1) ____

Why this? ____

What evidence is there that this has helped porpoise conservation? ____________________

(2) ____

Why this? ____

What evidence is there that this has helped porpoise conservation? ____________________

12. Overall, where porpoise conservation activities **have been successful**, what factors do you think have made them successful? **[Do not show, just let them answer, multiple answers ok]**
    - ☐ Government support – local
    - ☐ Government support – national
    - ☐ Public support and awareness
    - ☐ Sufficient financial resources to conduct the work
    - ☐ Other: ____
    - ☐ Don't know

13. Do you think **you are/your organisation is** doing enough to conserve the porpoise *in this region* **[OR if interviewing reserve staff]** *in this reserve*? **YES/NO**
    If **NO**, what more do you think needs to be done?

    ____

14. Do you think the porpoise population in *this region* **[OR if interviewing reserve staff]** *in your reserve* is:
    Stable ☐ Increasing ☐ Decreasing ☐ Don't know ☐

    [For ALL answers] what **DATA** do you have to suggest this? No data ☐

    ____

Cause of Porpoise Decline

15. What do you think is causing the decline in finless porpoises across the whole Yangtze?
    [**Do not read out answers or show answers to interviewee** – just tick all of those that are mentioned by interviewee] **AND** What makes you think this is causing decline?
    - ☐ Mortality caused by fishing gear ____________________________
      - Electric ☐ ____________________________
      - Rolling hook ☐ ____________________________
      - Nets (all) ☐ ____________________________
      - Other ☐ _____________________ ____________________________
    - ☐ Decline of fish stocks due to dam projects ____________________________
    - ☐ Decline of fish stocks due to overfishing ____________________________
    - ☐ Loss/degradation of fish spawning habitat ____________________________
    - ☐ Environmental effects caused by TGD ____________________________
    - ☐ Direct mortality caused by dredging activities ____________________________
    - ☐ Habitat degradation caused by dredging ____________________________
    - ☐ Direct mortality caused by ship/propeller collisions ____________________________
    - ☐ Effects of pollution ____________________________
    - ☐ Habitat loss/degradation of porpoise habitat ____________________________
    - ☐ Impacts of noise pollution e.g. can't find food ____________________________
    - ☐ Other (Please state): ____
    - ☐ Don't know: If **Don't know**, what extra information is needed to identify the key threats?
      ____

16. **If informant lists more than one cause in 15:** Please rank the answers stated in order of importance:
    (1 as most significant - *n* least significant) **[Do not show answers]**
    ______ Mortality caused by fishing gear

Electric ______ Rolling hook______ Nets (all) ______ Other _________________
______Decline of fish stocks due to dam projects
______Decline of fish stocks due to overfishing
______Loss/degradation of fish spawning habitat
______Environmental effects caused by TGD

______Direct mortality caused by dredging activities
______Habitat degradation caused by dredging

______Direct mortality caused by ship/propeller collisions

______Effects of pollution
______Habitat loss/degradation of porpoise habitat
______Impacts of noise pollution e.g. can't find food
______Other (Please state): ____
☐ Don't know

17. Do you think there are any particular threats that are more locally significant here compared to other areas in the Yangtze? **YES / NO / DK**
If **YES,** What factors? ____

If **YES,** Why do you think that? ____

If **YES,** What evidence do you have of this? ____

18. Has there ever been any dead jiang-tun reported in this area? **YES / NO / DK**
[If there is more than one, take all details]

If **YES** a. Where? ______________________
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you think made the jiang-tun die? ______________________________
e. Why do you think that was the cause of death? ___________________________
If **YES** a. Where ____
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you think made the jiang-tun die? ______________________________
e. Why do you think that was the cause of death? ___________________________

If **YES** a. Where? ______________________
b. When? **M** ________ **D** ________ **Y**________
c. Any visible injuries? ____
d. What do you think made the jiang-tun die? ______________________________
e. Why do you think that was the cause of death? ___________________________

19. How many **dead** Jiang-tun have there been in this area in last year? _______________________
   a. How many **dead** jiang-tun in the last **5** years? **DK** _________________
   b. How many **dead** jiang-tun in the last **10** years? **DK** ________________

20. Are there more **dead** jiang – tun in this area in certain seasons or months? **YES/NO/ DK**
If **YES** a. Which months/seasons? ____
b. Why do you think that is? ____

21. Who do you/ your organisation get information from relating to causes of porpoise decline?
____

22. Do you communicate with any outside organisation that may provide porpoise based information? E.g. porpoise conservation NGOs, research organisations and researchers, fisheries authorities.

YES/NO If **YES:**

Which ones? ____

How often? ____

Do you get information from them or give them information you have? Get ☐ Give ☐

What type of information/data do you get/give? ______________________________________

23. Is there any information/data that is not available that you think would enable you to better help the YFP? **YES/NO**
If **Y**, what information is this? ____

24. Do you collect porpoise mortality data? Or have any information on the causes of mortality in stranded porpoises? **YES/NO** ____
If **YES**, would you be willing to share the data or collaborate using that data? **YES/NO**

    If **YES**, what are the main causes of mortality observed in stranded porpoises? **[IN ORDER]**

    (1) __________________ (2) _______________________ (3) _____________________

Porpoise Conservation

25. What do you think would be the most effective future conservation action(s) to conserve the remaining wild Yangtze finless porpoise population? **[Can have multiple answers]**
[Do not read out answers or let interviewee see – just tick all of those that are mentioned]
    - ☐ Reduction in fishing intensity. **Ask for more detail**:
        - ☐ Reduce the number of registered fishermen/boats
        - ☐ Extend the fishing ban (ask for details): ____________________________________
        - ☐ No-fish zones
        - ☐ Entire fishing ban for a number of years
        - ☐ More patrols to stop illegal fishing types
        - ☐ Provide alternative livelihoods to fishermen
        - ☐ Other: ____
    - ☐ Reduction in dredging activity/ better regulation of legal dredging
    - ☐ Better control and regulation of illegal dredging
    - ☐ Increase public awareness of the YFP and its conservation needs by campaign efforts
    - ☐ More semi natural ex-situ oxbow reserves e.g. Tian-E-Zhou
    - ☐ More in-situ reserves
    - ☐ Strengthened management for existing in-situ reserves
    - ☐ Increase captive facilities/captive breeding, like the dolphinarium in Wuhan
    - ☐ Increase fish stocks by supplementation of fish fry
    - ☐ Reduction in boat traffic
    - ☐ Better legal protection of the YFP Please detail – at what level?: _________________
    ____
    - ☐ Other (please specify):____
    - ☐ Don't know

26. Do you think *in-situ* or *ex-situ* conservation efforts are more important for porpoise conservation?
    - ☐ *Ex situ*. Why? ____
    - ☐ *In-situ*. Why? ____
    - ☐ Don't know

Other

27. Do you or your organisation have any other role in environmental protection or species conservation in the Yangtze? **YES/NO.** If **YES**, provide details (species, funding, time scale, etc.):

    ____

    ____

28. Are you aware of any situations where porpoise conservation activities (either in-situ or ex-situ) have come into direct conflict with local communities? **YES/NO**
    If **YES**, When did this happen? ____

    If **YES**, Where? ____

    If **YES**, please provide details of the conflict: __________________________________

    ____

    If **YES**, In-situ or ex-situ? In-situ ☐ ex-situ ☐

    Was there an attempt at conflict resolution? ________________________________

    Was this successful? ____

29. Does your organisation conduct any public awareness training or similar activities? **YES/NO**
    If **YES**, please detail (regularity, content, target audience): __________________________
    ____

Dredging

30. How is dredging regulated in your area? **Don't know** ☐

    ____

    ____

31. How many legal dredgers are registered to dredge in the area you work in? **Don't know** ☐

    ____

32. Is there any illegal dredging? **YES/NO/DK**
    If **YES**, what proportion of dredgers are illegal in your area of jurisdiction? _____________ **DK** ☐
    If **YES**, how are they controlled? ______________________________________ **DK** ☐
    If **YES**, how could illegal dredging be better controlled? ___________________________ **DK** ☐

    ____

33. From the below list of possible threats to porpoises, which, if any, do you think are ***unlikely to be a major driver*** of porpoise decline in the Yangtze system? Tick as many as you think.
    [Show interviewee the full list and ask them to read]

    ☐ Mortality caused by fishing gear
    Electric ☐ Rolling hook ☐ Nets (all) ☐
    ☐ Decline of fish stocks due to dam projects
    ☐ Decline of fish stocks due to overfishing
    ☐ Loss/degradation of fish spawning habitat
    ☐ Environmental effects caused by TGD
    ☐ Direct mortality caused by dredging activities
    ☐ Habitat degradation caused by dredging
    ☐ Direct mortality caused by ship/propeller collisions
    ☐ Effects of pollution
    ☐ Habitat loss/degradation of porpoise habitat
    ☐ Impacts of noise pollution e.g. can't find food
    ☐ Don't know: If **Don't know**, what extra information is needed to identify the key threats?

____

34. From the below list of possible conservation mitigations, which do think will be the ***least*** useful? Tick as many as you think. **[Show interviewee the full list and ask them to read]**
    - ☐ Reduction in fishing intensity.
        - ☐ Reduce the number of registered fishermen/boats
        - ☐ Extend the fishing ban (ask for details): ___________________________________
        - ☐ No-fish zones
        - ☐ Entire fishing ban for several years
        - ☐ More patrols to stop illegal fishing types
        - ☐ Provide alternative livelihoods to fishermen
        - ☐ Other: ____
    - ☐ Reduction in dredging activity/ better regulation of **legal** dredging
    - ☐ Better control and regulation of **illegal** dredging
    - ☐ Increase public awareness of the YFP and its conservation needs by campaign efforts
    - ☐ More semi natural ex-situ oxbow reserves e.g. Tian-E-Zhou
    - ☐ More in-situ reserves
    - ☐ Strengthened management for existing in-situ reserves
    - ☐ Increase captive facilities/captive breeding, like the dolphinarium in Wuhan
    - ☐ Increase fish stocks by supplementation of fish fry
    - ☐ Reduction in boat traffic
    - ☐ Better legal protection of the YFP Please detail – at what level?: _________________
      ____
    - ☐ Don't know

SECTION B: NON-FISHERIES ORGANISATIONS ONLY – NGOs, research organisations, etc.

General

35. Who is your organisation funded by? ____
36. What are you registered as with the government? _______________________________________
    ☐ Not registered ☐ Don't know

37. What is your approximate yearly budget? ______________________________(¥/$) **DK** ☐
38. How much of that is spent directly on porpoise based work (give units of time)? **DK** ☐
    X_______________(¥/$) Unit of time: ___________/month/year % of T budget ________%
39. Are there any porpoise conservation activities you would like to be doing that you don't have funds for? **YES/ NO**. If **YES**, Describe:
    a) Purpose of required funds: ____
    Amount required (approx. ¥/$): ____ (d/w/m/y)
    b) Purpose of required funds: ____
    Amount required (approx. ¥/$): ____ (d/w/m/y)
    c) Purpose of required funds: ____
    Amount required (approx. ¥/$): ____ (d/w/m/y)
40. Are your porpoise recovery plans or actions ever delayed through lack of funds? **DK** ☐
    ☐ Never ☐ Rarely ☐ Occasionally ☐ Regularly ☐ Always

Patrols and legal power

41. Does your organisation conduct any patrols, surveys or porpoise monitoring? **YES/NO**

If **YES**, Please describe in detail:

Survey/patrol/monitoring type 1: ____

a. What is the purpose of the patrol/survey? ____
b. How often? _______________ d/w/m/y
c. How many people for 1 patrol/survey? ________
d. Is this patrol or survey seasonal? **YES/NO**. If **YES**, What months? _____________________
e. Do you collect porpoise data? **YES/NO** If **YES**, are you interested in sharing data? **YES/NO**
f. How much does one patrol/survey cost? __________________________¥/$

Survey/patrol/monitoring type 2: ____

a. What is the purpose of the patrol/survey? ____
b. How often? _______________ d/w/m/y
c. How many people for 1 patrol/survey? _________
d. Is this patrol or survey seasonal? **YES/NO**. If **YES**, What months? _______________________
e. Do you collect porpoise data? **YES/NO** If **YES**, are you interested in sharing data? **YES/NO**
f. How much does one patrol/survey cost (estimate/average)? _____________________¥/$

42. Do you have any legal power to prosecute illegal activities? **YES/NO**
If **YES**, What geographical area do you have legal jurisdiction over?
____

If **YES**, What for: **[Tick in box]**

	Confiscate equipment	Confiscate boat	Monetary fine (¥)	Prison term	Other (state)
Illegal fishing type			(¥)		
- Electric fishing			(¥)		
- Rolling hook			(¥)		
- Other			(¥)		
Fishing in an illegal area			(¥)		
Not having correct licence			(¥)		
Fishing during a ban			(¥)		
Other (state)			(¥)		

If **YES**, How often, on average, does this happen? _______________________________**W/ M/ Yr**

If **YES**, How many times has your organisation prosecuted someone in the last year? __________

43. In general, what patrolling activity do you think would be most effective in reducing threats to porpoises?
To prosecute for what activity:
☐ Illegal fishing type ☐ Electric ☐ Rolling hook ☐ Other ____
☐ Fishing in illegal areas What kind of areas? _____________________________
☐ Not having a fishing licence (illegal fishers)
☐ Other - Please detail: ____
☐ Don’t know

Legal ability to (what actions):

☐ Confiscate boat
☐ Confiscate fishing equipment
☐ Monetary fine
☐ Revoking fishing licence
☐ Other - Please detail: ____
☐ Don’t know

44. Do you do any policing/patrolling for illegal activity at night? **YES/NO**
If **YES,** please describe: ____
If **NO**, do you think this would be helpful? **YES/ NO**
If **YES**, Describe how and what for: ____

Fish stocks

45. Do you think fish stocks in the Yangtze are: Increasing ☐ Decreasing ☐ Stable ☐ **DK** ☐
Please justify your answer: ____

46. Do you think the seasonal fishing ban has helped fish stocks in the Yangtze? **YES/NO/DK**
Please justify your answer: ____
47. Do you think the addition of small fish fry has helped fish stocks in the Yangtze? **YES/NO/DK**
Please justify your answer:____
48. Do you think fish stocks were affected by dams? **YES/NO/DK**
Please justify your answer:____
49. Do you know of any other organisations or individuals that are involved in porpoise conservation in this area? **YES/ NO**
If **YES**, name(s)? ____
If **YES**, can you provide contact details or put us in touch? **YES/NO** __________________________

End time: _________________

SECTION C: FOR LOCAL FISHERIES AUTHORITIES ONLY

Fisher Details

50. How many fishers are registered within your region?
[Make sure you get numerical information on whichever category the bureau uses to measure fishing activity – may only be only be one unit or two]

Individual fishers: ____#

Families: ____#

Vessels: ____#

51. How many boats does each fishing family typically have? _________________________________
52. How many boats does one family use at any one time?
1 ☐ more than 1 ☐ record how many: ________________

53. Do any fishing boats come into your area of jurisdiction from outside your area? **YES/NO/DK**
If **YES**, How many? **[get number or percentage]** ______________________ #/%
If **YES**, Where from? **[give province, or other geographical info.]** ___________________________
If **YES**, Why do they move into your area? ____
If **YES**, Is this constant year round or is it more in certain months? **Constant** **Seasonal**
If **Seasonal**, Give **ALL** months that it occurs: ____
If **Seasonal**, Why these months? ____

If **YES**, Has this number always been **constant** or has it **changed** over the years?
Constant ☐ Changed ☐
If **Changed,** more or less now than before?
More ☐ **Less** ☐
By how much? ____
Why? ____
Since when? ____

54. Approximately what proportion of the **total amount of fishing** in your area of jurisdiction occurs at night time? _____________________% **[If asked, clarify, "sunset to sunrise"]**

55. On average, how many **nights a week** does one fisherman usually do night fishing?
________________ **/week**

Fish Stocks

56. Do you think fish stocks in the Yangtze are:
Increasing ☐ **Decreasing** ☐ **Stable** ☐ **Don't know** ☐

Do you have data (or know of data) to support your opinion? **YES** ☐ **NO** ☐
If **YES**, What kind of data? i.e. time period, species, from what source?
____
If **YES**, Who has these data? ____

57. Do you think management of fish stocks in the Yangtze is currently effective? **YES/NO/DK**
If **NO**, what more should be done? ____

58. Do you think the seasonal fishing ban has helped fish stocks recover in the Yangtze? **YES/NO/DK**
What evidence do you have to indicate this?:____

59. Do you think the addition of small fish fry has helped fish stocks in the Yangtze? **YES/NO/DK**
Please justify your answer: ____

60. Do you think fish stocks have been affected by the construction and presence of dams? **YES/NO/DK**
Please justify your answer: ____

61. Do you think stocks of the following fish species are:
    a. Stable, Increasing or Decreasing?
    b. Healthy or Depleted?
    i. If depleted, how much has it declined since 5 years ago and since 10 years ago?

	a			**b**		**b(i)**		
	Stable	***Incr***	***Decr***	***Healthy***	***Depleted***	***5 years ago (2011)***	***10 years ago (2006)***	***DK***
a) Crucian carp *Carassius carassius* (jiyu)	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐
b) Common carp *Cyprinus carpio* (liyu)	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐
c) Yellowhead catfish *Pelteobagrus fulvidraco* (huangsangyu)	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐
d) Xenocypris davidi (huangweigu)	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐
e) Sharpbelly *Hemiculter leucisculus* (cantiaoyu)	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐
f) Grenadier anchovy *Coilia ectenes* (daoyu)	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐
g) Ice fish *Hemisalanx prognathus* (yinyu)	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐
h) Needlefish *Hemirhamphus kurumeus* (zhenyu)	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐
I) Reeve's shad *Tenualosa reevsii*	☐	☐	☐	☐	☐	___________%decline	___________%decline	☐

i.e. stock has declined by X% since 5yrs ago

Patrols and monitoring

62. What types of fishing are illegal in your area of jurisdiction? **Don't know** ☐
[Do not read out]

- ☐ Rolling hook
- ☐ Electric
- ☐ Gill netting (some types) Details of type: ____________________________________
- ☐ Ai wei (moat fishing)
- ☐ Poison fishing
- ☐ Blast fishing
- ☐ Cormorant fishing
- ☐ Other type: ____

63. Is it illegal to fish at night? **YES/NO/DK**
64. Do you visit fishing communities to provide information about fisheries regulations?
Yes ☐ No ☐
If **YES**, approximately how often? ____
If **YES**, approximately how many communities in this region? _________________________

65. Do you ever go to fishing villages/communities to confiscate illegal fishing equipment?
Yes ☐ No ☐
If **YES**, approximately how often? ____
If **YES**, approximately how many communities in this region? _________________________

66. What patrols do you conduct for illegal fishing and fishing bans? **No patrols** ☐
[Prompts: Enforcing fishing ban, for electric fishing or other types of illegal fishing, in reserves]

Get details on each type of patrol or monitoring (1), (2), (3):

(1) Aim of patrol: ____

When (seasonal/months): ____
What time of day?: ____
How long does one patrol take (approx.)?: ______________________________ min/hours
How regular are patrols: ____/day/week/month
How often is illegal fishing detected: ___________________________________/hour/day/week
How much does each patrol outing cost? ______________________________ ¥

(2) Aim of patrol: ____

When (seasonal/months): ____
What time of day?: ____
How long does one patrol take (approx.)?: ______________________________ min/hours
How regular are patrols: ____/day/week/month
How often is illegal fishing detected: ___________________________________/hour/day/week
How much does each patrol outing cost? ______________________________ ¥

67. Do you do any policing/patrolling for illegal activities at night? **YES/NO** **Don't know** ☐
If **YES,** please describe: ____
If **YES**, how much does one outing cost? ____¥
If **NO**, do you think this would be helpful? **YES/ NO**
If **YES**, Describe how and what for: ____
If **YES**, how much would it cost per outing? ______________________________________¥

68. In your area, what are the penalties for any of these activities? **None** ☐
[Tick appropriate boxes]

	Confiscate equipment	Confiscate boat	Monetary Fine (¥)	Prison term	Other (state)	**How often prosecution?**
Illegal fishing type			(¥)			
Electric fishing			(¥)			
Long line			(¥)			
Other			(¥)			
Fishing in an illegal area			(¥)			
Not having fishing licence			(¥)			
Fishing during a ban			(¥)			
Other (state)			(¥)			

69. Is there any other enforcement for illegal fishing that has not been discussed so far?
YES/NO **Don't know** ☐

If **YES**, what? ____

70. In general, what penalty is the most effective to deter fishers from doing illegal fishing?
[Do not read out or let them see, just let them answer] **Don't know** ☐

☐ Prison term
☐ Confiscate boat
☐ Confiscate fishing equipment
☐ Monetary fine
☐ Revoking fishing licence
☐ Other - Please detail: ____

71. How many times has there been a prosecution for illegal fishing in your region in the last year?
______________ **Don't know** ☐

Financial

72. What is the average yearly income for a fisherman in this region from fishing alone?
______________________________ ¥ / year **Don't know** ☐

73. What is the net annual income from ***fishing in the main river channel***/***around the lakes*** **[delete as necessary]** in your region? i.e. the value of fishing to the local economy:
______________________________ ¥ / year **Don't know** ☐

[NOT INCLUDING AQUACULTURE]

74. Do any fishermen compensation schemes exist in this region, to reduce or reimburse fishing activities? **YES/NO/DK**
If **YES**, please detail type (i.e. what for):
☐ Fuel reimbursement Amount: ________________¥/________ **DK**
☐ Money to hand over illegal fishing equipment Amount: ________________¥/________ **DK**
☐ Reimbursement for the seasonal fishing ban Amount: ________________¥/________ **DK**
☐ Other _____________________________ Amount: ________________¥/________ **DK**

If **YES**, How many people have been offered the scheme in your area?
[may only give one of these measures, try and get as much information as possible]
Number of people: ________________________#
As a percentage of fishermen registered: ________________________%

How many have accepted: ________________________ (#/%)
How many are currently on the scheme: ________________________# fishermen/families

75. Have alternative employment schemes ever been offered in this region for fishermen to change their livelihoods? **YES/NO/DK**
If **YES,** Current scheme or past scheme? ☐ Current☐Past Give year(s): _____________

[IF PAST SCHEME, ask for details of past scheme same as below, just change tense of Q]
Are they offered a range of work or are people assigned new work without choice?
☐ Offered range of work ☐ Assigned without choice
What kind of work are they offered/given? ____
Do they get equal pay at the new job or is it more/less? Equal ☐ More ☐ Less ☐ **DK** ☐
What proportion of fishers were reluctant or unwilling to take up the scheme? _____________%
How many people have been offered the scheme in your area?
[may only give one of these measures, try and get as much information as possible]
Number: ________________________#
As a percentage of fishermen registered: ________________________%
How many have accepted: ________________________ (#/%)
How many are currently on the scheme: ______________________ # fishermen/families

Is skills training offered as part of the scheme? **YES/NO/DK**
If **YES,** give examples of type(s) of training _______________________________________
Describe the funds/resources required for this training ______________________________
____

76. Approximately what proportion of fishers that have been part of an alternative livelihood scheme have gone back to fishing? ________________%
For what reason(s): ____

77. Do you think the alternative employment schemes have been effective in terms of reducing the impact of overfishing in the **Yangtze River/lake systems [say whichever is relevant]**?
☐ Highly effective
☐ Somewhat effective
☐ Somewhat ineffective
☐ Highly ineffective
☐ Don't know

Read the following paragraph:

To better understand how the availability of porpoise prey may be affecting the porpoise, we are trying to gather some data on fish stocks of particular species. We are particularly interested in how those fish stocks may have changed over time, say, the last ten years.

78. Do you have any quantitative data on current fish stocks **and/or** catches from the past? **YES/NO** Details: ____
If **YES**, Would you be willing to share the data? **YES/NO**

79. Do you know of any other organisations or individuals that are involved in porpoise conservation in this area? **YES/ NO**
If **YES**, name(s)? ____
If **YES**, can you provide contact details or put us in touch? **YES/NO** _________________________

End time: _________________