# The status of the artisanal fishery of Lake Victoria, Kenya, with notes on improvements to the catch data collection system

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**Abstract:** Catch and effort assessment surveys have been used to assess trends in fish landings in Kenyan waters of Lake Victoria since 1976. Landings reached a maximum of 200 000 t annually in 1989-1991 as Nile perch, *Lates niloticus* (L.), catches increased due to an expansion in stock size and increased fishing effort. CPUE peaked at 180 kg boat day-1 in 1989 and decreased thereafter with increasing effort. By 1998 total Nile perch catches were half those at the beginning of the decade despite increased effort. Catches of *Rastrineobola argentea* (Pellegrin) have levelled off despite increased effort.

## Introduction

Management of fisheries relies on an underlying knowledge of stock abundance and population parameters (Cowx 1996), for which a well-organised catch data collection system is required. This needs knowledge of the structure of the fishery, proper design of the survey, auditing checks and accurate reporting of results. Catch assessment surveys to determine trends in the landings, species composition, methods of fishing and demand for fish and their products are vital for management of fisheries.

Lake Victoria, shared by Tanzania, Uganda and Kenya, lies between longitudes 0° 30' N and 2° 20' S, and latitudes 31° 40' and 34° 50' E. The lake has a surface area of 68 680 $km^2$, with a catchment area of about 200 000 $km^2$. In the early 1980s, changes in the Lake Victoria fishery occurred (Okemwa 1981; Ssentongo & Welcomme 1985). The lake's fisheries have subsequently become dominated by catches of *Lates niloticus* (L.) and *Rastrineobola argentea* (Pellegrin) (Rabuor 1989, 1991; Othina & Osewe 1995, 1996).

To assess the dynamics of the fishery for management purposes, a catch assessment survey was established by KMFRI, Kisumu in the mid-1970s. This has provided catch data since 1976 but these are considered biased because of a number of problems with the system put into place. The present study reviews catch trends since 1976, examines trends found for future management of the fishery, and assesses sources of bias in the catch statistics. Changes in the sampling programme to correct for potential sources of bias in future recording are examined.

## Methods

On each day of sampling, the catches of from five to 15 boats selected randomly from the targeted landing site were recorded. Twenty three of the 256 Kenyan landing sites (Fig. 1) were covered by the survey. Selection of the landing sites was influenced by factors such as presence of infrastructure and accommodation for enumerators, and thus was not random. Parameters recorded for each sampled fishing boat were the number of crew, gear type, and size, time and duration of fishing. Catches were sorted into species and weighed (nearest kg).

After data auditing in the KMFRI office, annual catches were estimated as follows:

$$AC = CPBD \times FD \times B / 1000$$

where $AC$ is the annual catch (t), $CPBD$ is the mean catch per boat-day (kg), $FD$ is the number of fishing days in the year (i.e. 365 or 366), and $B$ is the mean number of boats fishing daily (i.e. mean ratio of number of boats landing on beach divided by number of boats recorded on beach in the previous frame survey, multiplied by total number of fishing craft recorded on the Kenyan coastline in the frame survey).

Effort in boat days by the different fishing gears was calculated by raising sampled boat days to total annual figure as above, and CPUE, as mean catch per boat per day, was estimated as the arithmetic mean of sample CPUEs. Raw data prior to 1989 were no longer available and thus effort and CPUE, which were not separately calculated at the time of collection and reporting, could not be estimated retrospectively.

## Results

Total landings in the last two decades changed markedly, reaching a maximum of 200 000 t annually between 1989 and 1991 (Fig. 2). This was followed by a downward trend in *L. niloticus* catches, while those of *R. argentea* levelled off. Other species, including tilapiines and haplochromines have shown small increases in recent years (Fig. 2, Table 1).

Effort, expressed in boat days, increased for all gears (Fig. 3, Table 2), but CPUE showed consistent declines (Fig. 4, Table 3).

CPUE increased to 180 kg boat day$^{-1}$ in 1989, but in recent years has dropped to a mean of about 80 kg boat day$^{-1}$. Mosquito seine landings increased from 25% of the total catch in 1987 to 50-60% since 1994, while the gillnet contribution declined from over 50% to 20% in the same period (Fig. 5). The long line contribution halved, while the contribution of beach seines continued to be high despite a ban on their use.

There were marked declines in CPUE in the gillnet and mosquito seine fisheries with increasing effort (Fig. 6A, B). In the mosquito seine fishery, which targets *R. argentea*, the catch and effort trends were investigated using the biomass dynamic model (Punt & Hilborn 1996) to fit the Schaefer model, using the catch and effort data from 1989 to 1998. The model suggests the MSY for Kenyan waters is 86 000 t with a corresponding effort of 445 000 boat days. The gillnet data were more difficult to evaluate using the biomass dynamic model but suggested an MSY of 48 000 t at an effort of 580 000 boat days.

**Table 1.** Annual catches (t) from the Kenyan Lake Victoria fisheries.

| *Year* | *L. niloticus* | *R. argentea* | Tilapia | Haplo-chromines | Other species | Total |
|---|---|---|---|---|---|---|
| 1976 | 94 | 5 652 | 1 007 | 6 370 | 5 557 | 18 680 |
| 1977 | 203 | 6 704 | 1 435 | 6 264 | 4 726 | 19 332 |
| 1978 | 1 066 | 8 710 | 2 606 | 6 632 | 4 842 | 23 856 |
| 1979 | 4 286 | 9 321 | 2 739 | 6 601 | 7 645 | 30 592 |
| 1980 | 4 310 | 9 443 | 5 013 | 3 633 | 4 515 | 26 914 |
| 1981 | 22 834 | 7 635 | 3 897 | 800 | 2 925 | 38 091 |
| 1982 | 33 134 | 10 419 | 4 475 | 2 561 | 10 369 | 60 958 |
| 1983 | 52 337 | 16 444 | 4 322 | 619 | 3 605 | 77 327 |
| 1984 | 41 319 | 19 437 | 7 478 | 70 | 3 550 | 71 854 |
| 1985 | 50 029 | 25 866 | 9 442 | 90 | 3 162 | 88 589 |
| 1986 | 64 929 | 31 084 | 2 764 | 613 | 2 860 | 102 250 |
| 1987 | 86 832 | 30 803 | 3 519 | 377 | 4 094 | 125 625 |
| 1988 | 82 019 | 50 484 | 3 434 | 415 | 1 960 | 138 312 |
| 1989 | 119 276 | 82 764 | 5 777 | 2 246 | 5 904 | 215 967 |
| 1990 | 118.503 | 82 764 | 4 494 | 2 299 | 3 239 | 211 299 |
| 1991 | 122 780 | 84 663 | 5 212 | 1 073 | 2 445 | 216 173 |
| 1992 | 105 979 | 98 232 | 7 035 | 3 669 | 4 554 | 219 469 |
| 1993 | 109 195 | 80 501 | 12 768 | 5 223 | 6 251 | 213 938 |
| 1994 | 60 830 | 98 745 | 10 301 | 1 810 | 2 314 | 174 000 |
| 1995 | 81 721 | 76 564 | 9 111 | 978 | 4 546 | 172 920 |
| 1996 | 48 700 | 73 200 | 7 100 | 1 500 | 23 900 | 154 400 |
| 1997 | 53 400 | 86 300 | 6 400 | 1 100 | 39 100 | 186 300 |
| 1998 | 61 416 | 98 304 | 11 235 | 0 | 16 290 | 187 245 |

**Table 2.** Annual effort (boat days x 1000) for the main gears used in the Kenyan Lake Victoria fisheries.

| Year | Gillnet | Long line | *Beach* Seine | Mosquito seine | *Total* |
|---|---|---|---|---|---|
| 1989 | 650 | 73 | 155 | 323 | 1202 |
| 1990 | 742 | 102 | 194 | 349 | 1387 |
| 1991 | 670 | 217 | 243 | 366 | 1496 |
| 1992 | 743 | 232 | 206 | 425 | 1606 |
| 1993 | 901 | 256 | 223 | 482 | 1862 |
| 1994 | 1022 | 197 | 160 | 482 | 1862 |
| 1995 | 795 | 362 | 226 | 625 | 2007 |
| 1996 | 833 | 207 | 432 | 499 | 1971 |
| 1997 | 781 | 337 | 242 | 647 | 2008 |
| 1998 | 828 | 338 | 368 | 657 | 2190 |

**Table 3.** Annual CPUE (kg boat day$^{-1}$) of the main fishing gears used in the Kenyan Lake Victoria fisheries.

| Year | Gillnet | Long line | *Beach* seine | Mosquito seine |
|---|---|---|---|---|
| 1989 | 145.2 | 64.7 | 387.8 | 256.6 |
| 1990 | 92.3 | 63.9 | 449.8 | 240.8 |
| 1991 | 66.9 | 59.8 | 339.2 | 221.4 |
| 1992 | 64.6 | 44.3 | 301.7 | 220.2 |
| 1993 | 45.5 | 43.1 | 222.3 | 203.8 |
| 1994 | 36.4 | 43.3 | 52.3 | 210.0 |
| 1995 | 41.0 | 30.9 | 118.7 | 147.4 |
| 1996 | 67.3 | 42.5 | 108.7 | 113.8 |
| 1997 | 58.9 | 45.5 | 120.6 | 133.7 |
| 1998 | 47.3 | 53.8 | 164.7 | 164.4 |

## Discussion

### *The status of the Kenyan Lake Victoria fisheries*

The catches in the Kenyan waters of Lake Victoria have changed since the Nile perch population explosion in the early 1980s. The increase in Nile perch catches has been well documented (e.g. Okemwa 1981; Ssentongo & Welcomme 1985; Rabuor 1989, 1991). Rabuor & Polovina (1995) also showed the increase in landings up to 1991 which they attributed entirely to increasing effort, and they expressed concern about the expanding fishery. They stated that the fishery and stock were not in equilibrium and suggested that a substantial decline in catches could be expected. The scenario of increasing effort leading to increased catches did indeed take place but the direct link to fishing effort is an over-simplification. Whilst effort did increase (detailed effort and CPUE data prior to 1989 have been lost but records show that CPUE increased annually from 82 kg boat day$^{-1}$ in 1986 to 180 kg boat day$^{-1}$ by 1989), it was stimulated by the expanding Nile perch stock at that time.

Irrespective, the trends found (Fig. 2) show that the concerns of Rabuor and Polovina (1995) were well founded. Catches declined despite a continued increase in effort and by 1998 were half those of the beginning of the decade.

The situation in the gillnet fishery is worse than the data suggest. Effort is expressed in boat days and does not consider the amount of gear per boat. Rabuor and Polovina (1995) noted that mesh sizes were getting smaller, nets were getting longer and soak times were increasing. These changes in fishing strategies are responses to declining catch rates and the trends have continued although evidence to support this is anecdotal. In addition, gillnets are now actively fished by drifting. Increased overall effort and decreased mesh sizes tend to lead to increased fishing mortality and reduce the size and age at recruitment, but it is not possible to show this in the effort and CPUE data collected up to the present.

The extent to which the various factors have contributed to the decline in Nile perch catches is difficult to assess. There has been a measurable decline in CPUE in terms of catch per boat coupled with the increase in effort. Unfortunately, detailed information on number and type of gears in use is poor, although this is being addressed under the Lake Victoria Fisheries Research Project (see below). The stock expansion of Nile perch in the 1980s resulted in very high, but unsustainable catches by the end of the decade, and it is not yet known whether the ecology of the lake and the fish population structure are approaching relative stability or are still in a state of flux after the radical and rapid changes in the ecology of the lake in the 1980s. Evidence on niche changes of the fish species in the lake (Agullo 1999; Njiru 1999) suggests that stability has not yet been realised. Further empirical evidence is being gathered under the LVFRP to investigate the trophic status of the lake.

The extent of fish migration between Kenya and the other two riparian countries, and hence the impact of fishing effort in those countries on the stocks in Kenya, is unknown. An additional factor in the assessment of the Kenyan fishery is the unknown extent of cross-border fish trade with Uganda and Tanzania. Some fish caught in Ugandan and Tanzanian waters may be recorded landing on Kenyan beaches because of differences in pricing policies and market demand between the countries.

Because of these uncertainties, which are currently under investigation, only tentative conclusions can be drawn. There is, however, no doubt that the Nile perch fishery is overfished. The tentative estimate of effort to produce MSY, 580 000 boat days, was exceeded by an average of 50% annually since 1993. As an initial step in controlling the gillnet fishery, the number of gillnet-carrying boats needs to be reduced by about 30% and a minimum mesh size of 127 mm (5") must be enforced (Schindler *et al.* 1998).

A common trend in heavily exploited fisheries is a decline in use of large meshed gears used to catch adult, larger, high valued species and an increase in small-meshed gears for smaller, less valuable species. The fisheries of Lakes Malombe and Malawi are examples from African lakes which show similar fishery changes (Tweddle *et al.* 1994, 1995; Turner 1995), and Welcomme (1999) reviewed trends in multi-species fisheries in general which illustrate this issue. The Kenyan Lake Victoria fishery exhibits these classical changes associated with overfishing (Fig. 3). The contribution of the two gears targeting large fish, gillnets and long lines has declined, while the small-meshed beach seine and mosquito seine fisheries have increased in importance. The beach seines catch large quantities of juveniles of the larger commercial species. They are also used in important inshore breeding and nursery areas and are thus particularly destructive. Despite a lake-wide ban on beach seines, their use continues to increase in Kenya.

The mosquito seine targets the small pelagic cyprinid *R. argentea.* Mosquito seine fishery effort continues to increase but catches have stabilised and, thus, CPUE has declined. The biomass dynamic model suggests that effort is now about 40% higher than the 445 000 boat days which produces MSY. A spread in the use of mosquito seines to previously unfished grounds has been observed since 1994. This may affect assessments of yield if fish migrations are limited in this species, thus caution is needed in interpretation of the results. No further development of this fishery should be considered in those areas already exploited, while expansion to unfished areas should be carefully monitored.

The catch data (Fig. 2) for 'other species' suggests a marked rise in 1996/97 and a decline in 1998. The 1998 decline may be partially attributed to the revised system for subsampling mixed juvenile catches and attributing the catches to the correct species. Also included in 'other species' are the lungfish, *Protopterus aethiopicus* Heckel, and the air-breathing catfish, *Clarias gariepinus* (Burchell). It is believed that these species have benefited through being able to take refuge under the large mats of water hyacinth, *Eichhornia crassipes* (Mart.) Sohms, as a result of their tolerance of low oxygen levels under the mats. This hypothesis is under investigation.

*Modifications to catch assessment survey to correct for sources of bias*

In the course of analysis of the existing data, investigation was made into real and potential sources of bias so that modifications to counteract bias could be made to the sampling system under the LVFRP. In the course of the analysis, the following sources of bias in data collection were identified.

1. The calculations for the catches were based on the data for the entire length of the Kenyan coastline. The fishery was not divided into areas, either ecologically or geographically. This approach therefore assumed, inappropriately, that the fishery was uniform throughout.

2. For logistical reasons, sampling was originally concentrated in the Nyanza Gulf, which has different characteristics to the open lake; extrapolation from the Gulf fishery to that in open water is not valid.

3. The beaches were selected on the basis on accessibility and accommodation for enumerators. The characteristics of these beaches are likely to lead to greater commercialisation of the fishery in such areas as the ease of access and the better infrastructure means that catches landed at these beaches are more easily marketed. Thus large fishing boats carrying more gear and landing larger catches are attracted to such beaches, whereas smaller beaches with very poor access to outside markets are more likely to host subsistence fishermen or fishermen landing small quantities of fish for sale and consumption in the immediate vicinity of the landing. Data from the sampled beaches are therefore biased towards boats carrying more gear and landing larger catches than would be found on beaches where access is more difficult and the market more localised.

4. During sampling, the number of boats which landed on the beach was recorded, of which a proportion was sampled. The raising factor for catches was based on the ratio of the number of fishing craft that went out fishing and the number recorded on the beach during the previous frame survey. The number of craft on the beach at the time of sampling was not recorded. While the number of boats along an entire coastline is likely to show only minor changes over a short time span, the number on a single beach may shift over time as fishermen target different fish concentrations and move from beach to beach. By ignoring such local changes, large biases may be introduced.

Over a longer stretch of coastline, however, local movements are less likely to affect the number of craft in that particular area in the same proportion. Although the frame survey counts have to be used as the ultimate raising factors, the calculation process has to cover a much greater length of coastline than an individual beach to reduce the impact of localised movements.

5. Data recorders were inadequately trained in the principles of random sampling. There was a tendency for more cooperative fishermen to be consistently sampled by the beach recorders.

6. Although larger fish species were recorded separately by data recorders, sub-samples were not taken to assess details of catch composition in cases of mixed landings of small species and juveniles of larger species.

7. No recording took place over the weekend. Fishing goes on throughout the week, although effort may be reduced at weekends; thus total catch is over-estimated if based on weekday catches raised to seven days, or under-estimated if raised to five days.

8. The prevalence of particular gears varies from beach to beach. Widespread common fishing gears are sampled regularly using any random sampling system and catch and effort estimates are fairly reliable for such fisheries. Estimates of catches from localised gears will, however, be affected by beach selection. If a beach with a rare gear is selected and catches from the gear are regularly sampled, the raising factors involved in the estimation process will lead to over-estimation of catches in the area as a whole. If beaches where the gear operates are not selected, no records of catches from the gear will be obtained. Tweddle *et al.* (1995) illustrated the weakness of a boat-based system that did not take gear distribution into consideration.

These sources of bias were addressed in the new sampling system implemented under the LVFRP, which incorporates the following modifications.

1. The Kenyan coastline was stratified according to geography and prevalence of different fisheries.

2. Recording effort is distributed proportionally along the shoreline

3. Beaches were selected randomly. Although the enumerators are still based at accessible beaches, bicycles bought by the LVFRP enable all selected beaches to be sampled.

4. Beaches were divided into three sub-strata, i.e. small, medium and large-sized beaches, to ensure that both commercial and subsistence fishermen are included.

5. Data recorded daily now include the number of fishing craft on the beach as well as the number fishing on that day. The raising factor is thus the number of boats fishing over the number on the beach at the time. Frame survey data on the

amount of craft overall are then taken into account at the next level of calculation, minimising errors caused by local fishing craft movements within the stratum.

6. Recording now takes place over weekends as well as on weekdays, thus differences in daily fishing intensity are taken into account when using raising factors.

7. Boats to be sampled at each selected landing site were selected randomly.

8. The number of boats to be sampled in each stratum was selected using the Neyman optimum allocation.

9. Sub-samples of catches of mixed small fishes are taken once from each boat during the sampling week to assess CPUE by gears and species.

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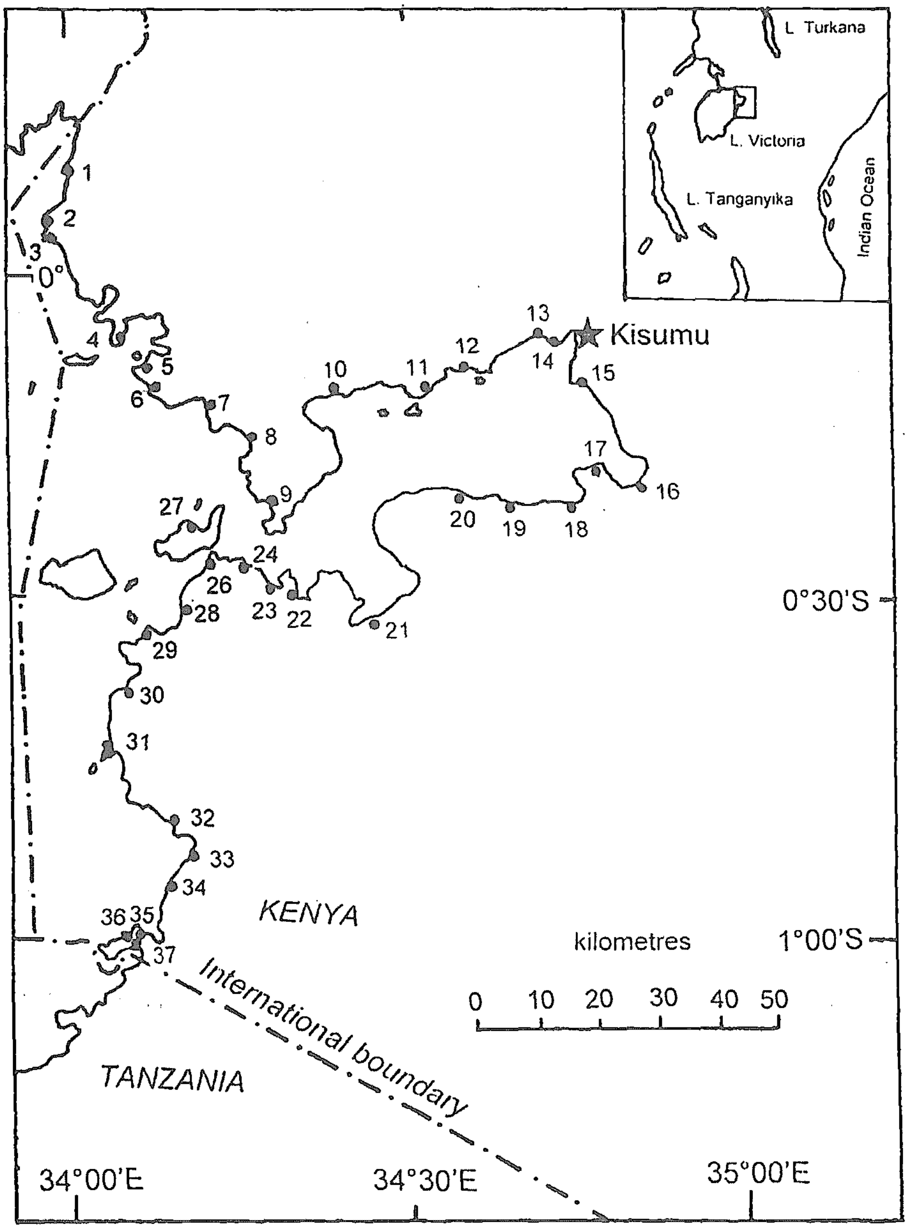


**Figure 1.** The Kenyan waters of LakeVictoria, showing the sampled landing sites.

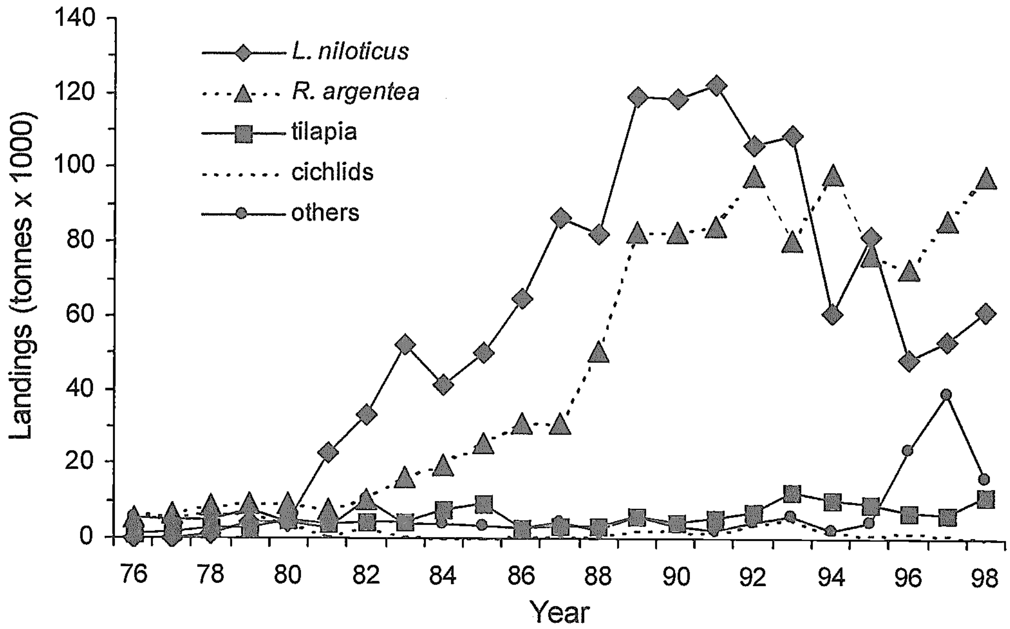


Figure 2. Annual catches from the Kenyan waters of Lake Victoria 1976 - 1998

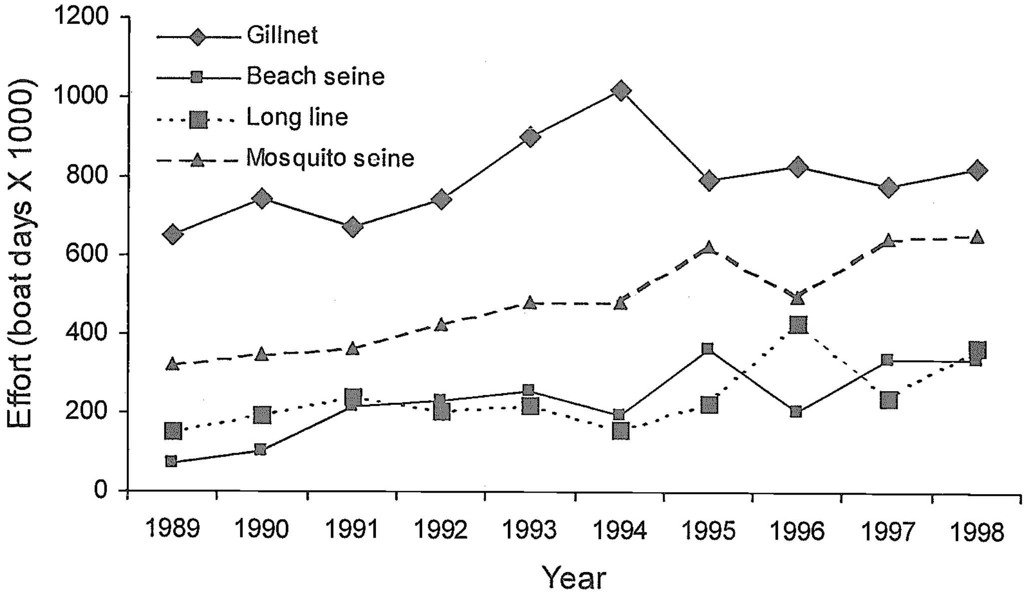


Figure 3. Trends in effort for the four major fishing gears.

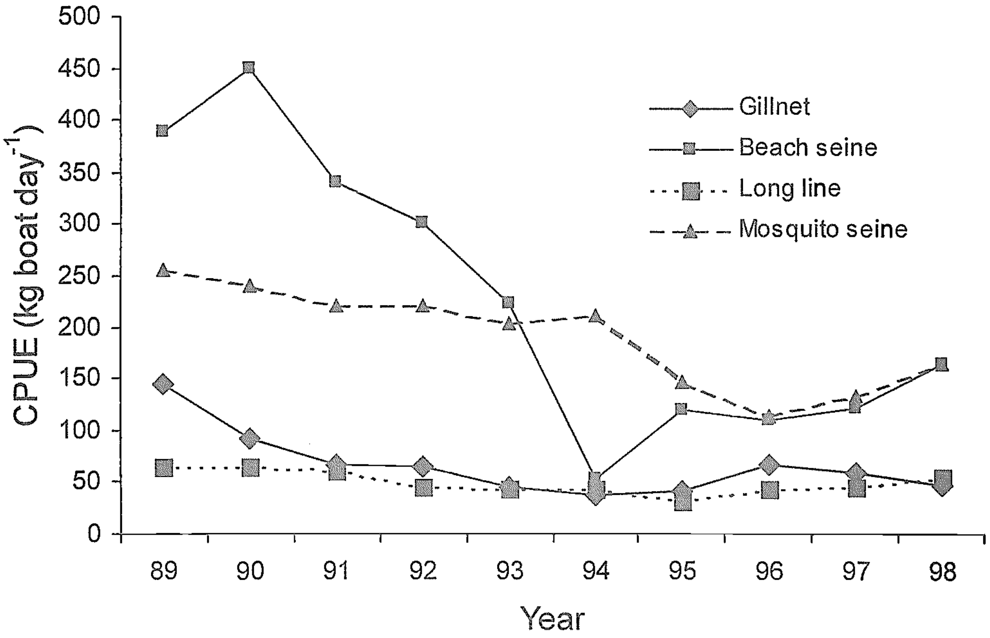


Figure 4. Trends in CPUE of the four major fishing gears.

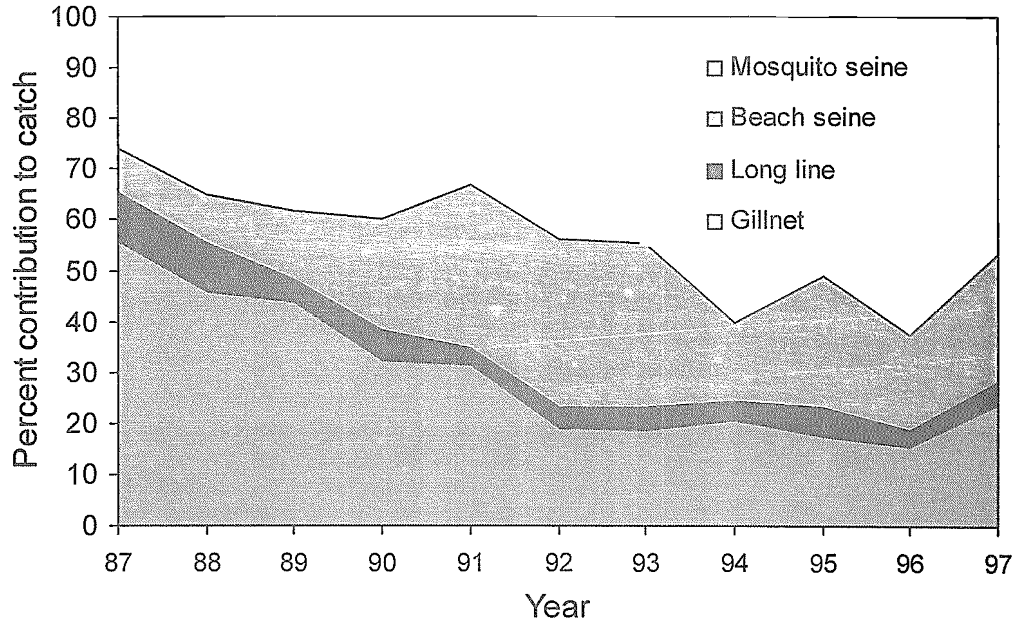


Figure 5. The percentage contribution of the major fishing gears to the catches.

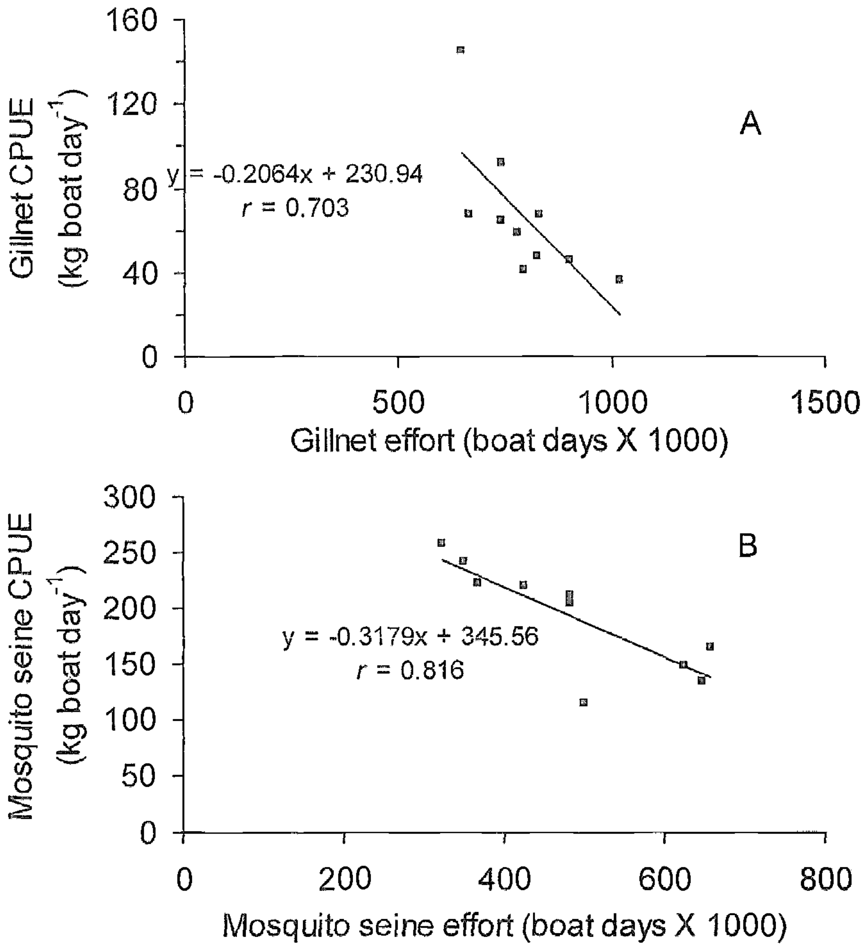


Figure 6. The relationship between CPUE and effort for (A) the gillnet fishery and (B) the mosquito seine fishery. The equation show the linear relationship between CPUE and effort

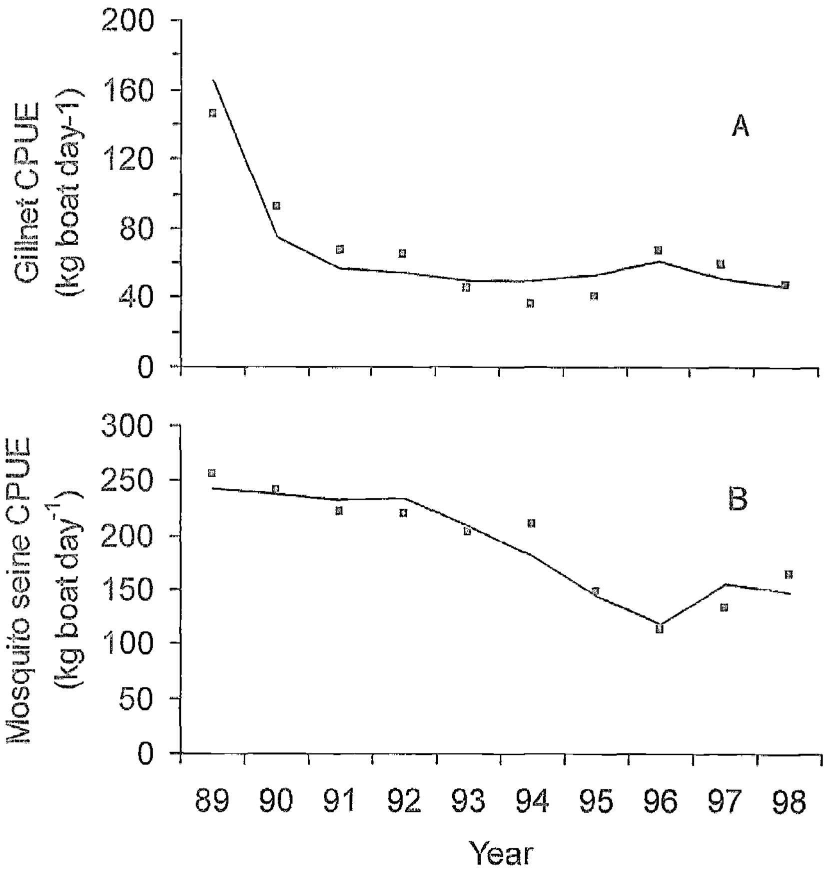


Figure 7. The output of the biomass dynamic models showing the relationship between observed and predicted CPUE for (A) the gillnet fishery and (B) the mosquito seine fishery.