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Overview of Catch, Size, and Catch Rate Data for Shortfin Mako Shark *Isurus oxyrinchus* from the Hawaii-based Pelagic Longline Fishery: 1995-2012

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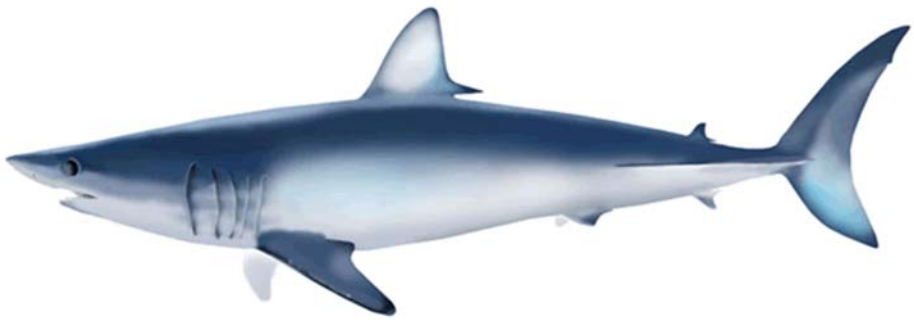

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Abstract

This working paper (WP) presents preliminary statistical information about catch, size, and catch per unit of effort (CPUE) for shortfin mako shark caught by the Hawaii-based pelagic longline fishery in 1995-2012. The data come from the records of the Pacific Islands Regional Observer Program (PIROP) submitted to the Pacific Islands Fisheries Science Center (PIFSC). This WP informs the Shark Working Group of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) about the data available at the PIFSC. Results included a description of spatial and temporal distribution of fishing effort, catch, size frequency, and annual mean nominal CPUE. Overall, shortfin mako size frequency data showed no significant temporal trends in both the deep-set and shallow-set sector. The deep-set sector annual mean nominal CPUE between 1995 and 2012 showed some variability along the years, but the values remained relatively stable in general. For the same period, the mean nominal CPUE for the shallow-set sector showed a much higher variability than the deep-set sector; it increased substantially after the re-opening of the sector in 2004, and then decreased continuously over the past decade.

Introduction

The shortfin mako *(Isurus oxyrinchus*) shark is a widespread, prominent pelagic shark species found in all oceans (Campana et al., 2004). There are no directed commercial fisheries for shortfin mako shark in Hawaii, however, it is often caught as a bycatch in the Hawaii-based pelagic longline fishery. Shortfin mako shark comprised 2.8% of all captured sharks reported by fishery observers in 1995–2006 (Walsh et al., 2009). The population status of shortfin mako shark in waters fished by the Hawaii-based pelagic longline fleet is presently unclear. Walsh et al. (2009) conducted the first overview of shortfin mako shark caught in this fishery, and concluded that catch rates for this species were stable for the deep-set sector, and increased 389% between 1995-2000 and 2004-2006 in the shallow-set sector of this fishery. At present, it is unknown if this increase reflected a change in abundance or rather the influence of one or more operational factors. In contrast with these findings, Clarke et al. (2012) reported that standardized mako shark (*I. oxyrinchus* or *Isurus paucus*) CPUE from observed longline fishing in the northern hemisphere in regions overseen by the Western and Central Pacific Fisheries Commission (WCPFC) declined significantly between 1996 and 2010.

The objective of this working paper (WP) is to inform the Shark Working Group of the ISC (SHARK WG) about catch, size frequency, and catch per unit of effort (CPUE) for shortfin mako shark from the Hawaii-based pelagic longline fishery in 1995-2012. The main source of data is observer reports from the Pacific Islands Regional Observer Program (PIROP) submitted to the Pacific Islands Fisheries Science Center (PIFSC).

Materials and methods

Results for the spatial distribution of fishing effort, size frequency, catch, and shortfin mako shark annual nominal CPUE from observer records were presented separately for shallow-set (target: swordfish) and deep-set (target: bigeye tuna) sectors. Data from the shallow-set sector were tabulated from 1995–2000 and 2004–2012. The latter years represent the period after the reopening of this sector, and had mandatory 100% observer coverage (i.e., an observer was aboard all shallow-set trips). For the former period annual observer coverage was generally below 5%. There are no 2001-2003 shallow-set data because the fishery was closed. In the latter part of 2000 observer coverage in the deep-set sector was increased and subsequently maintained at about 20% annually from 2001 to present. Prior to that observer coverage in the deep-set sector was generally below 5%. Observer data presented here thus represent a subsample of the fishery, and are only complete for the shallow-set sector from 2004 to present. Thus, relative values of catch and effort for the deep and shallow sectors do not represent the real proportions of catch and effort between these sectors.

A total of 12,354 observed shallow-sets and 43,081 observed deep-sets were analyzed. The longline sets were distributed throughout a wide area in the North Central Pacific Ocean around the Hawaiian Islands, ranging from 50^0 N and 0^0 latitude and 180^0 W and 135^0 W longitude. This total fishing ground was divided into eight regions, based on Walsh and Teo (2012). Along with the increase in observer coverage in 2000, the observer sampling design was improved with the intent to provide a more unbiased and representative sample of the deep-set fishery, so that seasonality and geographic distribution of the observed data should reflect similar patterns as the entire sector. Logbook data are available for virtually 100% of both sectors of the fishery but these do not accurately reveal the species of sharks in the catch.

Caught shortfin mako sharks were measured by onboard observers from 1995 to 2012. During this time period, 2,422 individuals (1,130 females, 1,270 males, and 22 unknown) were sexed and measured to the nearest cm fork length (FL). Observers also recorded the disposition of sharks, here aggregated into five categories: finned, kept, released alive, released dead, and unknown.

In addition to total observed catch for both sectors of the fishery, this working paper provides estimates of the total catch for the deep-set sector using the generalized ratio estimator (for details see McCracken, 2012).

Results

Spatial and temporal distribution of observed fishing effort

Fishing effort was highly variable between sectors. It also varied strongly as a function of region, season (i.e., quarter of the year), and period (i.e., 1995-2000 and 2004-2012). Fishing effort by the deep-set sector was intense (90%) on regions 3, 4, 5, and 6, though between 2001 and 2012, effort from this sector was most aggregated in regions 4 and 5 (Figure 1). Shallow-set effort occurred in all regions except 1 and 2, however most of the effort (98%) was located in regions 5, 6, 7, and 8 (Figure 2). A shift in effort occurred in the shallow-set sector between 1995 and 2012. In 1995-2000, 33% of the sets were deployed in region 5 and 25% in region 7. After the re-opening of the shallow-set sector, 45% of these sets were deployed in region 7 and 14% in region 5. Due to low effort, data from regions 1, 2, 3, and 4 were not included in further analyses for the shallow-set sector.

The season analyses revealed that the effort varied by quarter of the year. For the deep-set sector, all eight regions combined, effort was slightly higher in the fourth quarter than in the other quarters. In regions 5 and 6 effort was also greater during the fourth quarter, while for regions 7 and 8 most of the effort occurred during the third quarter (Figure 3). There was a clear pattern of aggregated within-season effort for the shallow-set sector; for regions 5 and 6, effort was highly

concentrated in the second quarter, while for regions 7 and 8, and all four regions combined, most effort took place in the first quarter (Figure 4).

Observed catch

Nominal observed catch of shortfin mako shark peaked in 2008 and 2010 for the deep-set and shallow-set sector, respectively (Figure 5). However the observed catches for each sector prior to 2000 are not even relatively comparable to observed catch after observer coverage was increased in 2000. To make this comparison over time the observed sample would need to be extrapolated to the entire fleet. Shallow-set nominal observed catches were substantially larger after the reopening of this sector, averaging 782 individuals per year since 2004, and this increase in observed catch was likely due to increased observer coverage. An increase in nominal observed catch was observed in the deep-set sector from 2000 through 2008 remaining fairly stable after that, while observer coverage remained around 20% though out this period.

Estimated total catch (deep-set sector)

The estimated total catch using the generalized ratio estimator showed very similar annual trends to those from the observed catch. However, the values for the estimated total catch were, in average, 5 times greater than the observed catch (Figure 5).

Size frequency distribution

There was not a clear annual trend in shortfin mako size observed in both fishery sectors, however, fork length (FL) varied significantly between set types (Figure 6). Shortfin makos from the deep–set sector were significantly ($P<0.001$) larger than those caught on shallow-sets. Males were significantly larger ($P<0.001$) than females in the shallow-set sector, while there was no statistically significant difference in FLs between genders in the deep-set sector.

Catch disposition

The observed disposition of the shortfin mako shark varied between fishery sectors and period. In both fishery sectors a much greater percentage of shortfin mako sharks were released alive after the fishery was reopened; the percentage of individuals kept showed a decrease in both sectors, though the percentage of shortfin mako sharks kept in the deep-set sector was higher than in the shallow-set sector (Figure 7).

Nominal catch rate

Of the 55,435 pelagic longline sets that were monitored and used in this study, positive shortfin mako shark catches occurred in 37% of shallow-sets and 14% of deep-sets. However, there was an abrupt increase in percentage of shortfin mako shark positive catches between 1995-2000 (17%) and 2004-2012 (59%) in the shallow-set sector.

Shortfin mako shark annual mean nominal CPUE as reported by PIROP observers is presented in Figure 8. Annual mean nominal CPUE in the shallow-set sector was greater than that of the deep-set sector in 1995-2000 and 2004-2012. Mean nominal CPUE for the deep-set sector fluctuated between 0.04 and 0.14 during 1995-2012, showing a relatively stable trend. In contrast, for the shallow-set sector, the shortfin mako shark annual mean nominal CPUE more than doubled after the fishery reopened. The annual mean nominal CPUE in shallow-set sector showed a continuous decrease over the past decade.

Discussion

As required for stock assessment purposes, in 2014, the ISC SHARK WG will conduct a detailed review of all available biological information, catch, and catch rate data for shortfin mako shark in the North Pacific Ocean.

The results presented here showed very interesting spatial and temporal distribution patterns of shortfin mako shark size frequency data, catch, and nominal CPUEs. Three distinct yet related findings deserve to be particularly highlighted: I) the significant increase of shortfin mako shark annual mean nominal CPUE for the shallow-set sector between 1995-2000 and 2004-2012; II) the continuous decrease of shortfin mako shark annual mean nominal CPUE in the past decade; and III) the increase in the proportion of shortfin mako sharks released alive throughout the years in both fishery sectors.

Consideration must be given to the changes in observer coverage and fishery practices in 2000 (deep-set) and in 2004 (shallow-set). Increases in nominal observed catch that occurred coincident with increases in observer coverage are not representative of the real change in catch.

The large increase in annual mean nominal CPUE in the shallow-set sector may have been related to the switch from squid to fish bait (Walsh et al., 2009) required by new regulations in 2004. The use of squid as bait decreased from 94% in 1995-1999 to 0% in 2004-2011, while fish bait was used in 94% of the shallow-sets after the re-opening of this sector. In addition, the bait change occurred while the geographic expanse of the waters exploited by the fishery was also increasing. Simultaneously there was a regulatory formalization and enforcement of the difference between deep-set and shallow-set fishing that eliminated a certain amount of

intermediate style fishing behavior that had previously existed, especially in the shallow-set sector. Thus, the regional effects and the influence of changes in fishing practice (e.g. bait type) on shortfin mako shark CPUE estimates must be examined in detail.

One possible explanation for the steep decrease in shortfin mako shark annual mean nominal CPUE in the shallow-set sector during 2004-2012 is that there was a decline in the population. However, such a conclusion needs to be further investigated, as the Hawaii longline CPUE may not accurately reflect changes in population size. Consequently, for calculating a CPUE time series for shortfin mako shark useful for stock assessment, it will be necessary to adjust the data for the impacts of factors other than the changing abundances of the species over time. In order to achieve this, CPUE standardization methods must be used.

The increase in the proportion of shortfin mako sharks released alive in both fishery sectors might reflect a substantive switch from the traditional J-hooks to circle hooks after the fishery closure. This switch in hook type was a requirement for the reopening of the shallow-set sector in 2004, and a more gradual, voluntary, and incomplete shift in the deep-set sector. Another important factor in shark disposition was the US nationwide ban on finning sharks without landing the respective shark carcass which became law at the end of 2000.

Literature cited

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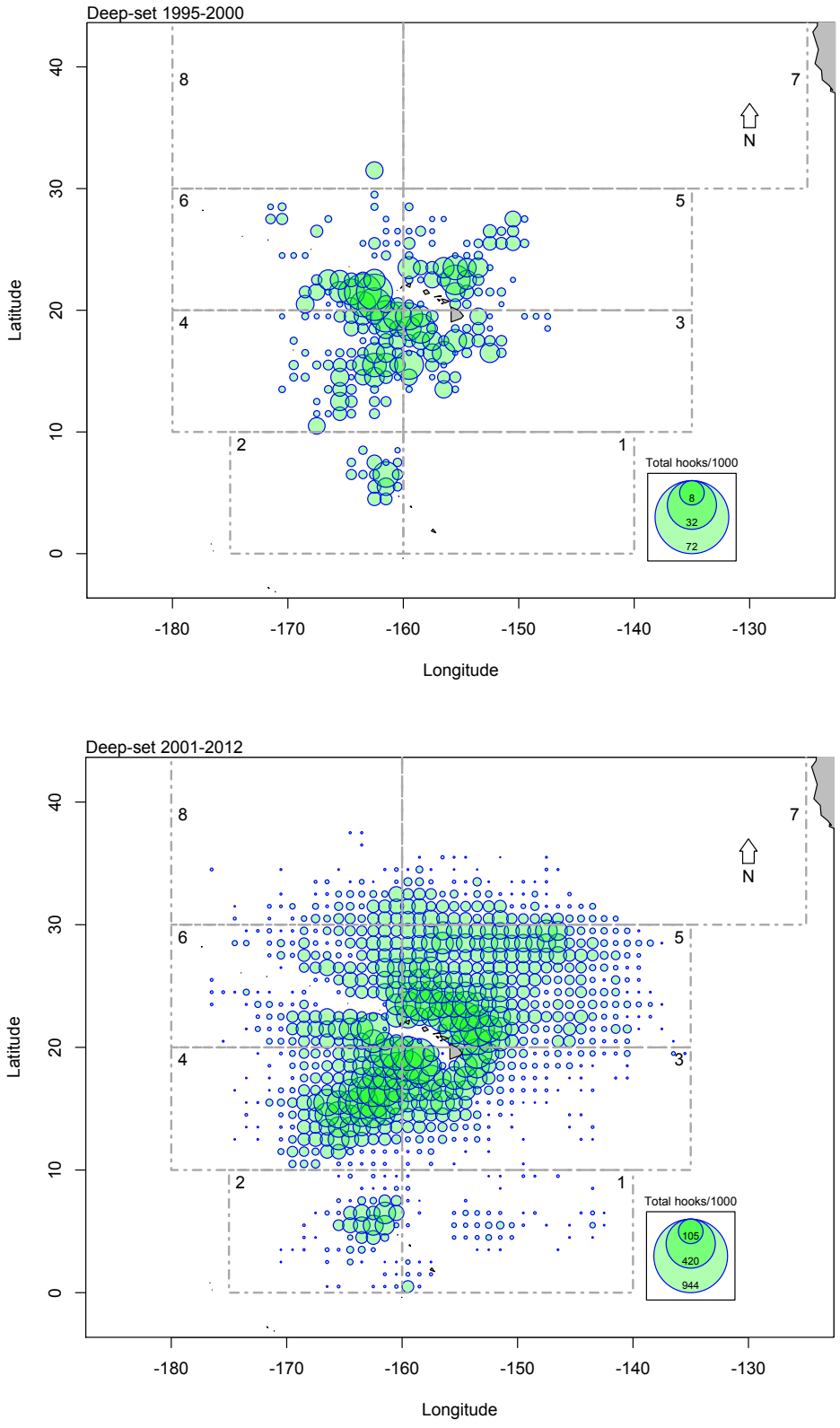

Figure 1. Distribution of fishing effort by the deep-set sector of the Hawaii-based pelagic longline fishery in number of hooks in 1995-2000 and 2001-2012.

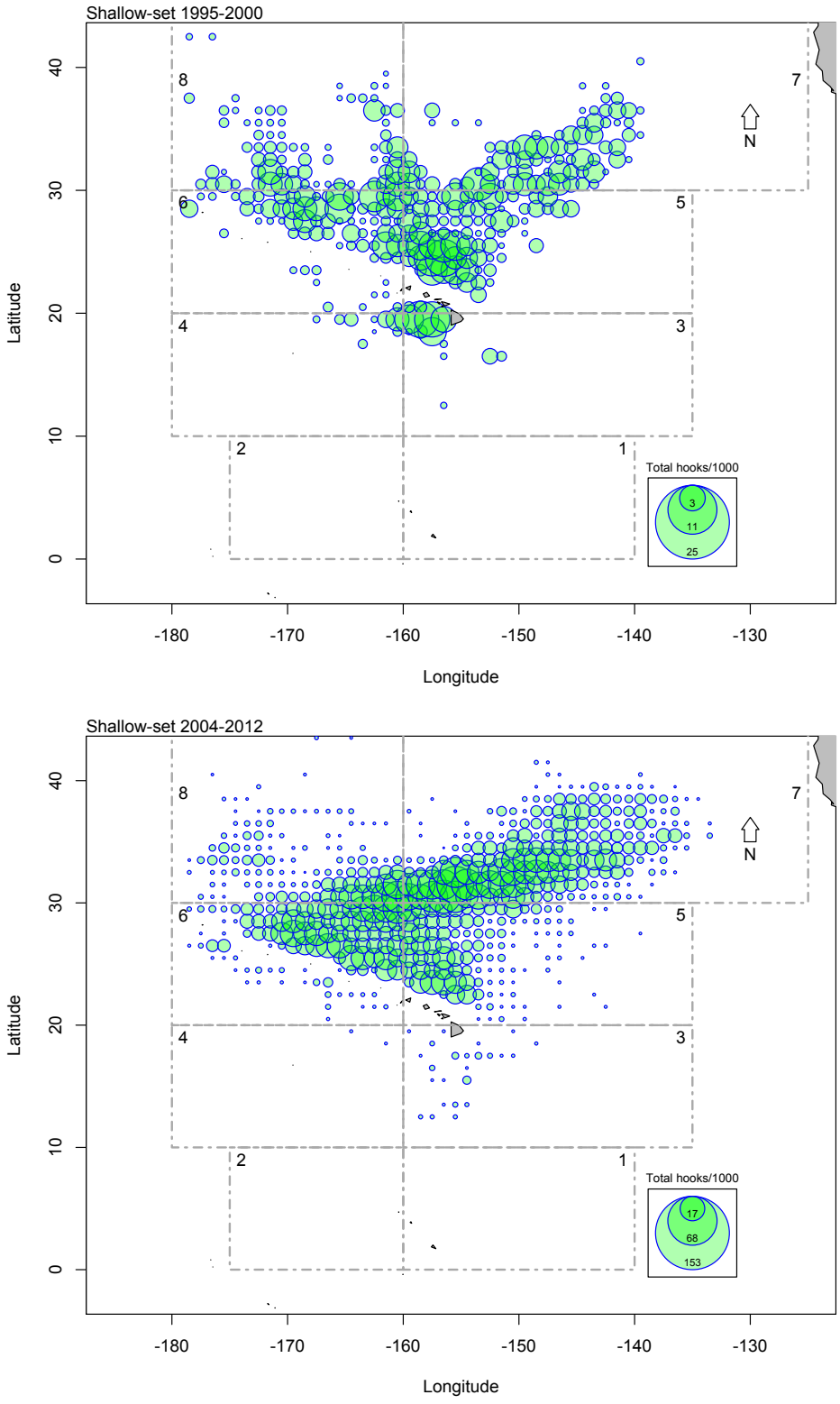

Figure 2. Distribution of fishing effort by the shallow-set sector of the Hawaii-based pelagic longline fishery in number of hooks in 1995-2000 and 2004-2012.

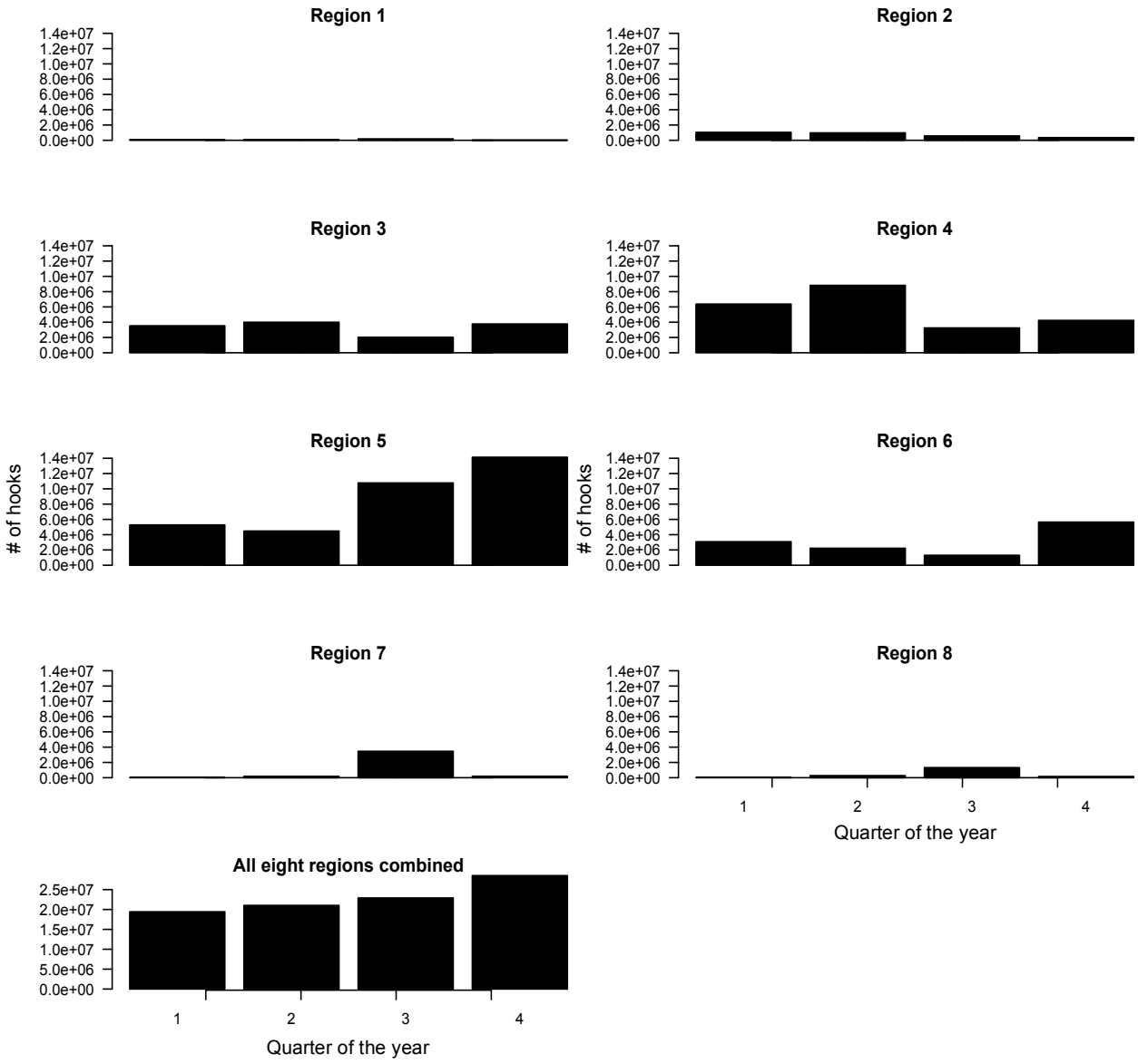

Figure 3. Total fishing effort by the deep-set sector of the Hawaii-based pelagic longline fishery in number of hooks by quarter of the year and region in 1995-2012.

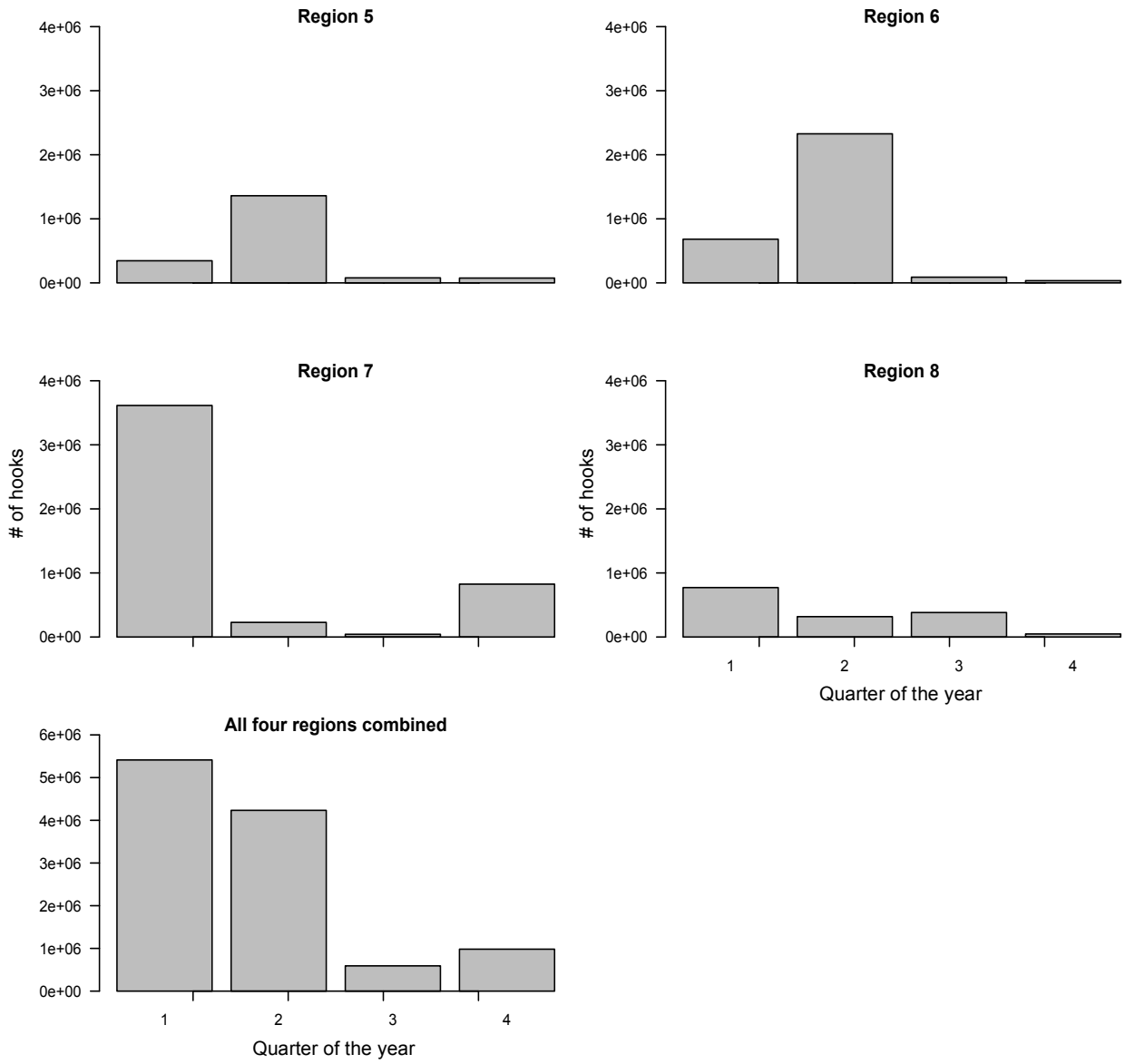

Figure 4. Total fishing effort by the shallow-set sector of the Hawaii-based pelagic longline fishery in number of hooks by quarter of the year and region in 1995-2012.

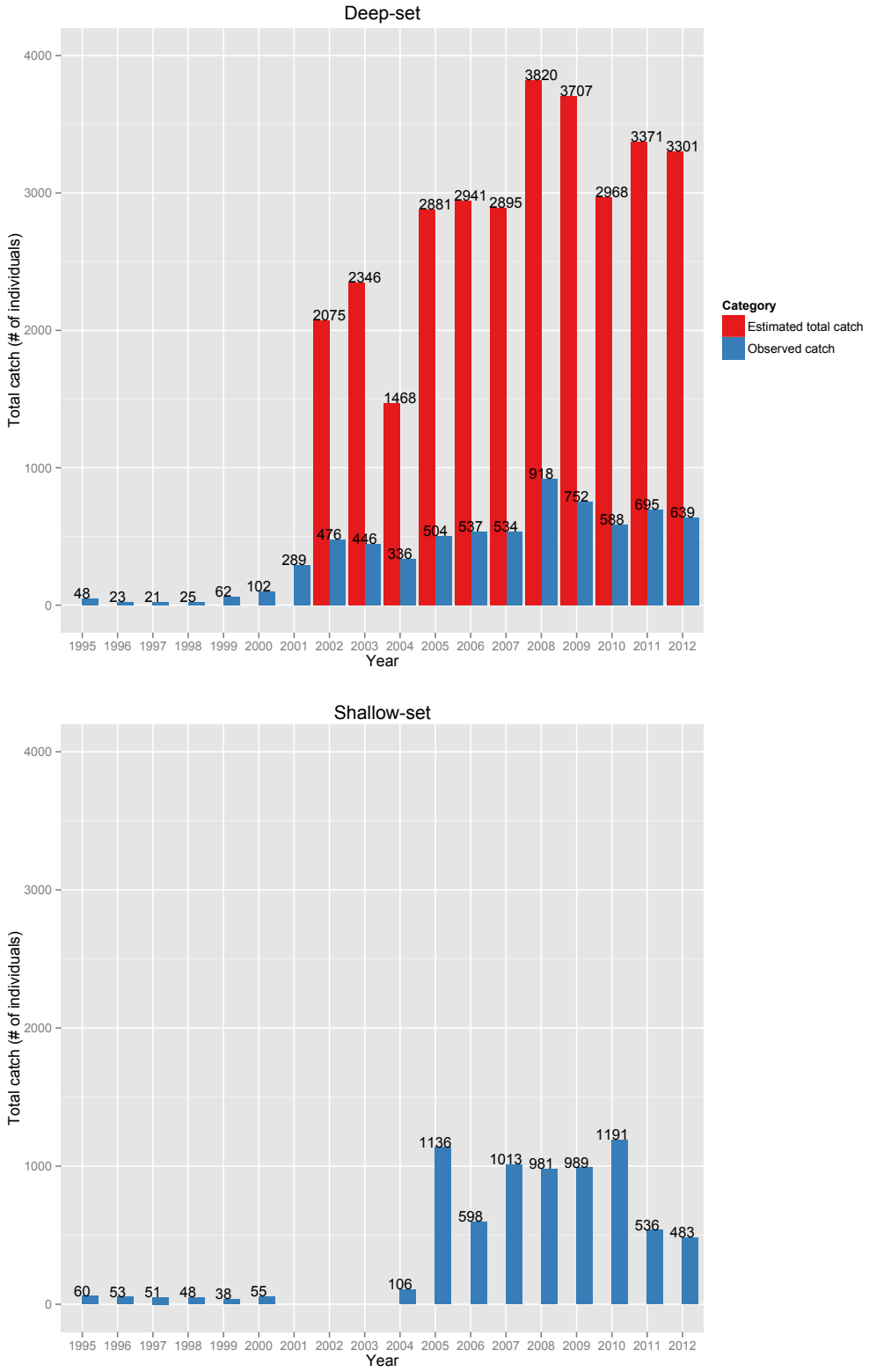

Figure 5. Total annual catch of shortfin mako shark by the deep-set (top panel) and shallow-set (bottom panel) sectors of the Hawaii-based pelagic longline fishery in 1995-2012. Total catch values are displayed at the top of the bars.

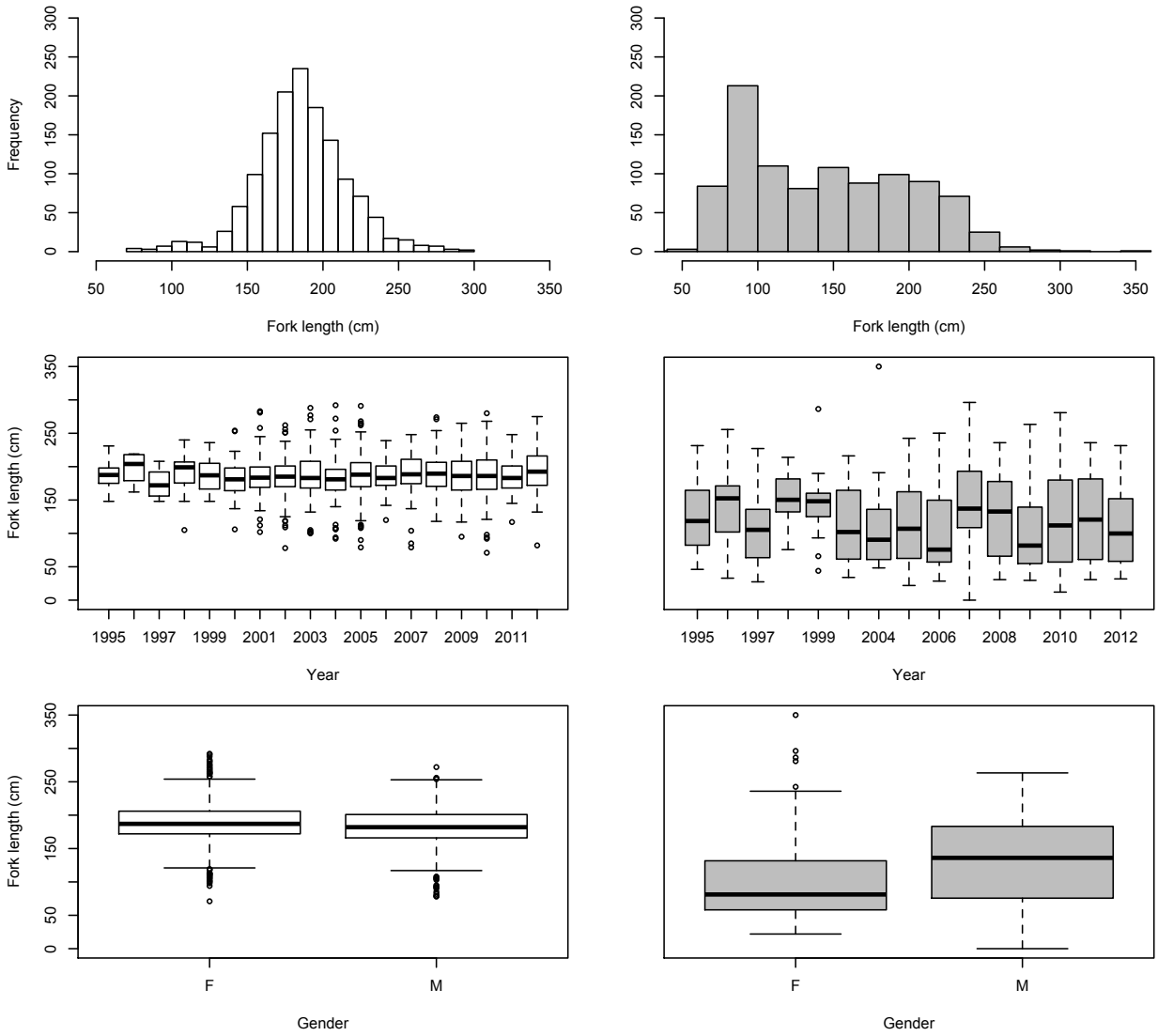

Figure 6. Size distribution (Fork length in cm) of shortfin mako shark caught by the shallow-set (right panel) and deep-set (left panel) sectors of the Hawaii-based pelagic longline fishery by year and gender in 1995-2012.

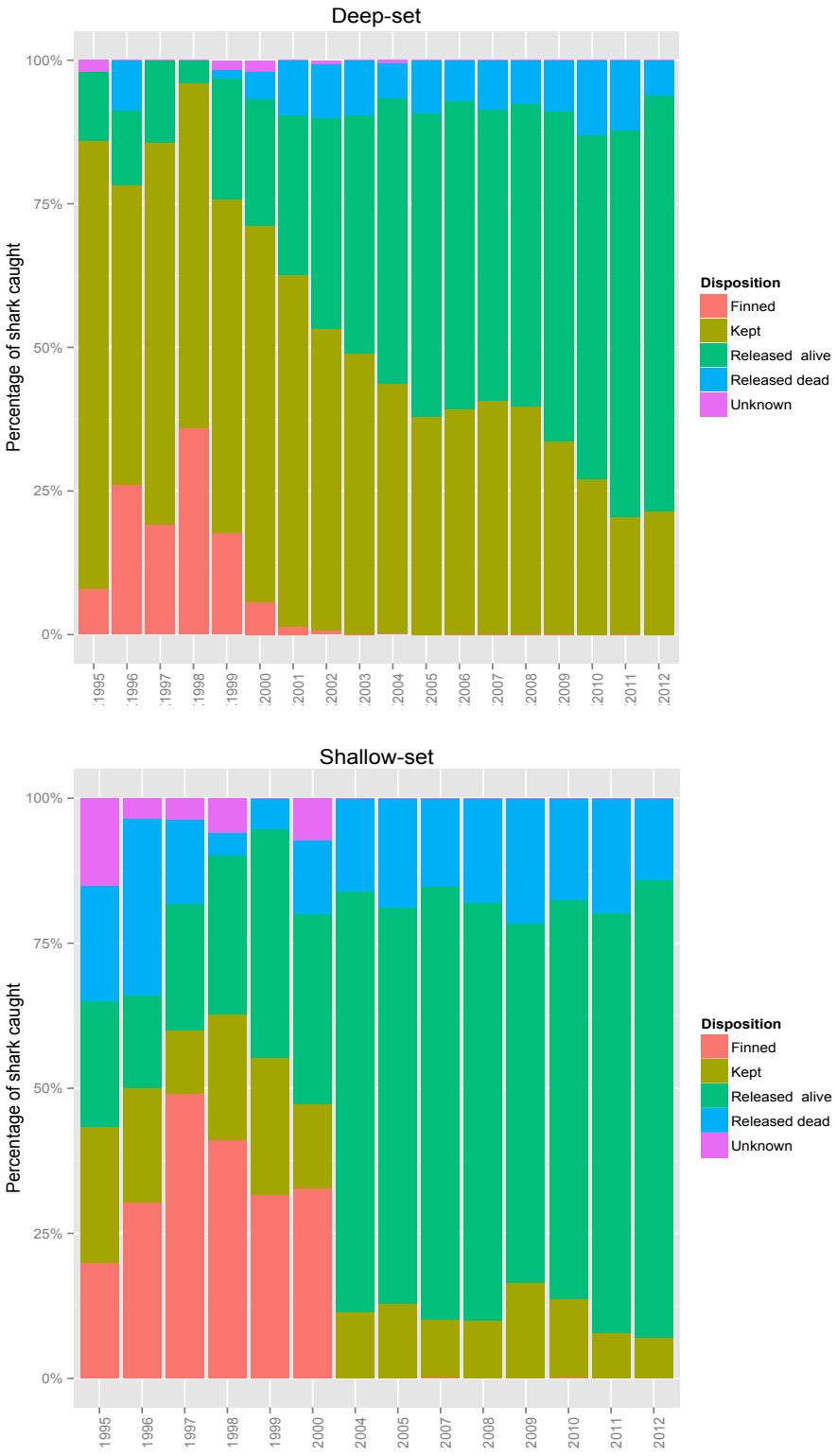

Figure 7. Disposition of shortfin mako sharks caught by the deep-set (top panel) and shallow-set (bottom panel) sectors of the Hawaii-based pelagic longline fishery in 1995-2012.

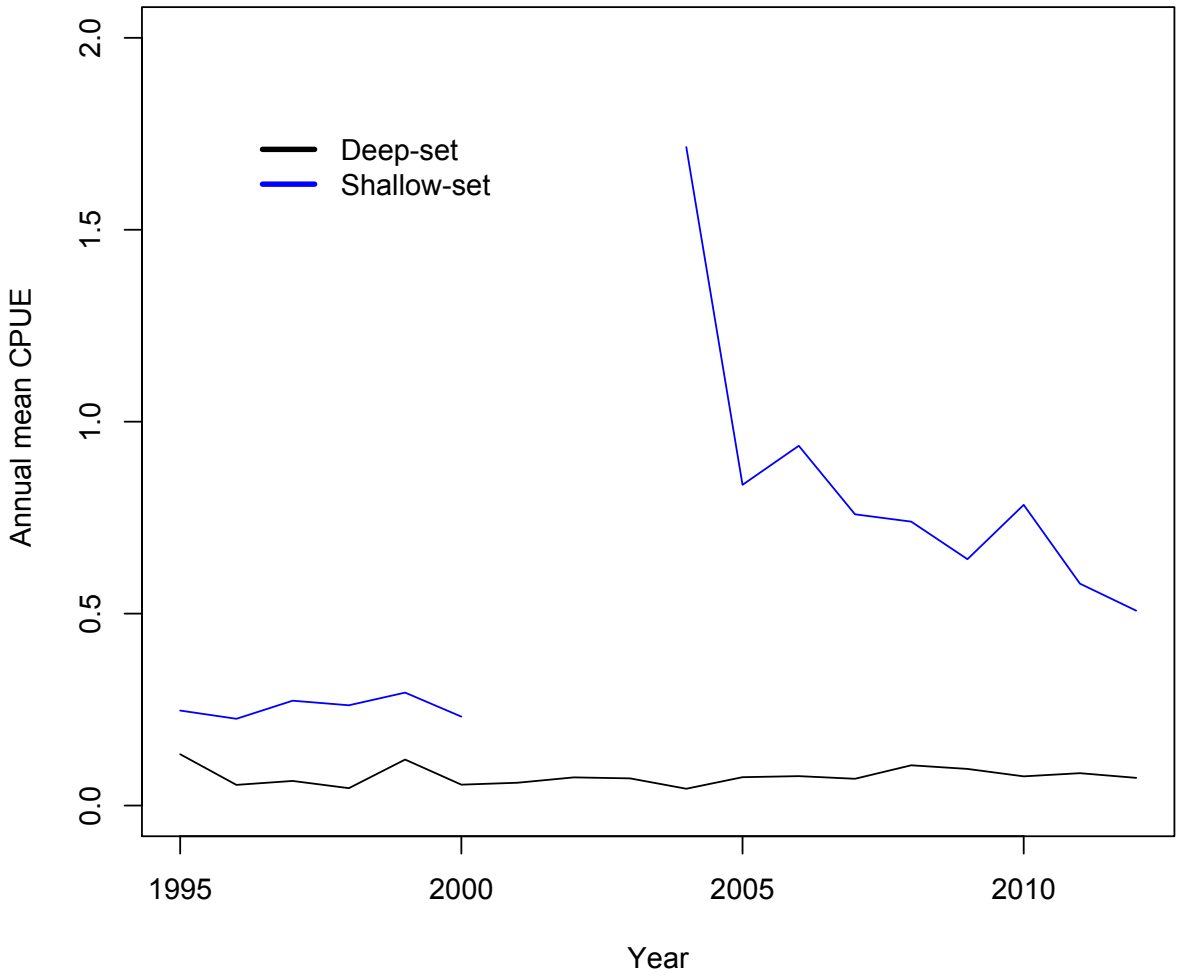

Figure 8. Annual mean nominal CPUE of shortfin mako shark caught by the shallow-set (blue line) and deep-set (black line) sectors of the Hawaii-based pelagic longline fishery in 1995-2012.