Tuna Longline Catch Rates in the Indian Ocean

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Myers and Worm's recent letter to the editor raise serious concerns about the impacts of the industrial fishing on large predatory fish and the associated biological community in four continental shelf and nine pelagic oceanic systems. They suggest that in these systems industrial fisheries have removed 90% of the large predators and that these removals may compromise the sustainability of fishing and have widespread ecosystem effects. Their letter highlights the importance of taking into account the state of unexploited communities when establishing benchmarks for assessing the effects of exploitation. This is particularly true for the oceanic systems they examined in which they have used historical data going back to the commencement of any substantial fishery. This contrasts with many fishery stock assessments where analyses are limited to more recent periods with more complete or detail data and as such are unable to provide management benchmarks based on unexploited status. Nevertheless, we are concerned that for the nine oceanic systems, their analyses provide a misleading picture of the status of large predatory fishes in these systems. As discussed below, if the trends are accepted on face value, they would imply that the fisheries, by themselves, were unlikely to be the primary cause underlying the declines.

Catch and Catch Rate trends

Myers and Worm's analyses rely solely on temporal trends in catch rates reported from commercial fishing operations by pelagic longliners and take no account of the actual levels removals or fishing effort. Interpretation of catch rates from commercial fisheries as indices of abundance is notorious for potential biases because fishery data do not provide representative sampling (i.e. fishermen are trying to maximize economic returns) and because of the large number of factors beside abundance that can affect catch rates. In multi-species fisheries, such as pelagic longline, interpretation can be further confounded by changes in targeting in response to market and related economic considerations. In most instances, fishery biologists are concerned that declines in catch rates will underestimate the actual declines in abundance because fishermen will compensate for the declines in abundance through increased knowledge, technological improvements and changes in fishing grounds. However, catch rates can also initially decline at rates much faster than abundance due to fish behaviour, changes in spatial distributions and changes in age/size of fish being targeted (see discussion in Hilborn and Walters 1992). Without additional information, it is not possible to determine solely from observed trend in catch rates whether they are providing a biased picture of actual abundance trends and, if so, in what direction the bias lies.

Retrospectively, one strong indication that catch rates may have declined substantially faster then abundance during the initial phase of a fishery is when substantial increases in catch and effort in the fishery subsequently occur without concomitant declines in catch rates. Intuitively, if catches of a given magnitude, resulted in large (e.g. 50-80%) decline in stock sizes, the expectation would be that a subsequent doubling or tripling of catches should engender further large declines and not be sustainable.

Figures 1-4 show the catch rate and estimated total catches for the four principle tuna species and the main billfish species harvested in the Indian Oceans[1]. Note that this paper considers effects at the species/stock level since species replacement can mask the non-sustainable effects in aggregated data. We have also chosen to present the data for each species for the entire Indian Ocean since all of these species are found though out the Indian Ocean without clear or known stock boundaries. For the three tuna species, rapid and large declines in Japanese longline rates were observed when industrial fisheries began in the 1950s such that by the early 1970s catches rates were less then 20% of their initial level. These are based on the essentially the same data used by Myers and Worm[2], and, as such, show a similar trend as their species aggregated, regional results. Around 1980, catches began to increase, particularly for yellowfin and bigeye such that catches by 2000 were at least two to six times that in early 1970. However, these large increases in catch were not accompanied by any subsequent decline in longline catch rates (and in some cases there were actual increases). The high levels of catch that have been taken since 1980s would have been predicted to be impossible without causing major stock collapses if in fact, what were retrospectively relatively small catches, resulted in the 50-80% declines from a naïve interpretation of the early catch rate data. For swordfish, the picture is somewhat different in that no decline in catch rates is evident during the early period of the fishery, nor was there a sustained decline over the entire 50 year time period. This is despite a fivefold increase in catch. Similar patterns of rapid initial declines in longline catch rates followed by subsequent large increases in catches without concomitant decreases have been observed in both the Atlantic and Pacific ocean.

Thus, if CPUE is taken to reflect actual stock trends, the initial rapid decline in catch rates followed by a period of stability with large increase in catch would suggest that the other factors besides the catches were responsible for the initial large declines (e.g. the stocks would have declined independent of the fishery because of external changes in the ecosystem)[3]. However, this is clearly an over-simplification as it does not take into account the age/size range of fish being captures and the dynamic response of a population or community to reduced abundances (e.g. reduction in competition and increase prey resources can lead to increased productivity). The age/size range is particularly important to consider in the case of yellowfin. Thus, a

[1] Results are presented here for the Indian Ocean because the Japanese CPUE data for the entire time period of exploitation are only freely available for this region via the IOTC Web site.

[2] There appear to be some differences between the data used in Myers and Worm's article and those available directly from the IOTC, although both are from same original source. Part of the discrepancy is due to which ocean 5° squares that border the Indian and Pacific are classified in. Another is that the IOTC data are lacking small amounts of skipjack tuna that were included in the data used by Myers and Worm.

[3] The large fluctuations seen in recent analyses of historical Atlantic bluefin catch rate records from traps in the Mediterranean indicate that hypotheses of large non-fishery induced fluctuations in tuna stock can not be totally excluded (Ravier, C. and J. Fromentin. 2001. Long-term fluctuations in the eastern Atlantic and Mediterranean bluefin tuna population. ICES J. Mar. Sci. 58:1299-1317.). Nevertheless, we do not think that this is the most likely cause of the CPUE and catch patterns seen in industrial tuna fisheries in part because the pattern has been across a large number of stocks in different ocean and it seems too coincidental that these fisheries were always initiated at a time when stocks were collapsing from natural causes.

large fraction of increases in yellowfin catches observed in these oceanic systems have been the result of the development and expansion of purse seine fisheries (Figure 5). These fisheries capture surface or near surface schools of tuna compared to deeper swimming fish caught by longliners. More importantly, the size/age of fish captured tends to be smaller/younger than those caught by longliners, although considerable overlap can still exist[4]. In addition, mortality rates for younger/smaller fish appear to be high[5] and maturity occurs at relatively young ages. As such, a large fraction of the smaller fish being caught would never live long enough to contribute to the longline catches, while the productivity in terms of spawning capacity is not solely dependent upon the size range of fish being taken by the purse seine fisheries. Nevertheless, the large scale increases in catches resulting from expanding purse fisheries with relatively stable longline catch rates indicates that the initial longline catches were not threatening the overall sustainability of this species[6]. Moreover, in the case of bigeye, the large increase increases in the Indian Ocean have been primarily due to increases by longline fleets (Figure 6), which strengthens the conclusion that the initial longline catches were not threatening the overall sustainability in this case.

Further, the aggregating of catch rates across species in Myers and Worm's analyses without consideration of either stock structure or economic factors also resulted in misleading interpretations of the catch rate trends. For example, associated with the large decline in longline catch rate trends in Myers and Worm's subtropical Indian Ocean (Figure 7) were large changes in the species composition of the catches (Figure 8). Albacore and southern bluefin tuna dominated the catches until the mid-1960s, after which, SBT was essentially absent from the catch and albacore declined to about 20% of the total. If in fact these trends were reflecting abundance, the conclusion one would draw is that SBT had been fished to near extinction in this region and albacore had been reduced to low levels. However, in both cases, this would be an inappropriate inference. In both cases, the changes in catch rates reflect changes in targeting practices. The early Japanese longline fishery was primarily targeting fish for canning. In the late 1960's, the fishery switched to targeting fish for the sashimi market as the result of the development of ultra-deep freezing and other technological developments[7]. Thus, the absence of SBT in the Japanese longline catches in sub-tropical waters reflects the switch to fishing for the sashimi market. The fishery moved south to areas where fish quality for sashimi was much higher and the industry imposed a voluntary ban on fishing for SBT in a large fraction of the area where SBT are found in the sub-tropical waters of the Indian Ocean. However, SBT continued to be found in these sub-tropical waters as these waters contain the only known spawning ground for SBT and surface fisheries in Australia consistently continued to

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[4] The situation for albacore tends to be more complicated. For example, in the Indian Ocean, the large increases are due to expansion of Taiwanese longlining targeting albacore in areas which tend to have high juvenile abundances.

[5] Hampton, J. 2000. Natural mortality rates in tropical tunas: size really does matter. Can.J.Fish.Aquat.Sci.57:1002 –1010.

[6] The situation for southern bluefin tuna is more complex as this species matures late, is long-lived and undertakes extensive migrations to a relatively small area for spawning. Initial longline catches for this species were concentrated on the spawning grounds and appear to have substantially reduced stock levels (Caton, A.E., 1991. Review of aspects of southern bluefin tuna biology, population and fisheries. pp181-357. In: World Meeting on stock assessment of bluefin tunas: strengths and weaknesses. Special report. Edited by R.B. Deriso and W.H. Bayliff. La Jolla, California: Inter-American Tropical Tuna Commission).

[7] Kashara,H. 1972: Japanese distant-water fisheries: a review. Fisheries Bulletin 70:227-282.

catch substantial numbers of juvenile (1-3 year olds) while Indonesian longline fisheries which developed in the 1990's have been responsible for around 10% of the global SBT catches. All of the above demonstrates that SBT continued to be present in the sub-tropical Indian Ocean despite their near total absence in Japanese catches[8]. Similarly, in this late 1960's period, albacore became a by-catch species for the Japanese fishery, while it remained a target species for Taiwanese longliners that continued to catch tuna for the canning market. Thus, in the same post 1970's period when Japanese albacore catch rates declined, catch rates by Taiwanese longliners remained constant and it was only around 1990 that any decline was seen (Figure 9). Thus, in this region, Japanese longline catch rates provide no basis for concluding that tuna abundances had declined by 90%.

All of the above points to the need to be cautious when interpreting catch rates from only one sector of an overall complex fishery that harvests a range of species for a range of different markets. The assessment of effects of fishing on both a population and an ecosystem is complex. This is not to say that fishing has not affected these stocks. An integrated approach that consider all available relevant data is the appropriate scientific approach and not selective use of only one information source. In this regard, the stock assessments performed by fishery assessment scientists attempt to undertake this integration within a population dynamic context. While these assessments contain substantial uncertainty, they do provide an indication of what such integrated approaches suggest about the status of the large pelagic tuna and billfish resources. Fishery scientists have long been aware of the rapid early declines seen in longline catch rates. In the integrated population modelling framework, these early catch rates have consistently been found to be a poor predictor of subsequent catches and catch rate trends. Generally, it is not possible to construct a consistent model that can explain the rapid decline in the early catch rates observed in a number of tuna longline fisheries as a result of the removals from the stock. Stock assessments for most tuna populations (with the exception of some bluefin stocks) do not suggest that these stocks have been reduced to anywhere near 10% level of their pre-exploitation levels.

Spatial Pattern of the Decline in Catch Rates

Myers and Worm suggest that "most newly fished areas showed very high catch rates but declined to low levels after a few years". They base this conclusion on maps of the spatial distribution of catches in four discrete years. However, a closer examination of the catch rates by region in relationship to the frequency of fishing does not support a general pattern of spatial serial depletions, at least in most regions of the Indian Ocean. Within each of the three basic regions, the fishery expanded quite rapidly (Figures 10, 12 and 14). Thus, after 10 years of the fishery entering a region, there were essentially no areas which had never been fished. In general catch rates in newly fished areas were not greater than in previously fished areas (Figures 11, 13 and 15). Thus, in both the Tropical and Temperate regions, catch rates in newly fished squares were similar or less then those in previously fished squares. In fact in

[8] In the case of SBT, the combination of the longline and surface fishery have had a substantial and well documented impact on the stock, with estimates of current spawning biomass being 5-15% of their pre-exploitation levels. The point here, however, is that the Japanese longline catch rates in the sub-tropical Indian Ocean clearly do not provide a reliable measure of the overall decline of the stock or the relative density of SBT in the region.

the temperate region, average catch rates in squares which were newly fished seemed to have declined faster then in squares which had been fished previously. In the Sub-Tropical region, catch rates in newly fished squares tended to be more variable with respect to previously fished area and tended to be somewhat higher than those in previously fished squares and catch rates in squares which had been fished at least five years also tended to be lower then squares fished less. However, even in this case there is little difference in the catch rate after ~7 years between newly fished and previously fished squares. Overall, the comparison of catch rates in newly fished and previously fished squares suggest that the decline in catch rates was spatially broad and did not result simply from serial depletion.

Ecosystem Effects

Any fishing activity will potentially have ecosystem effects. By harvesting fish, humans assume the functional role of a top predator in the system. The magnitude of the ecosystem effects will depend both on the functional role of the fish being harvested and the magnitude of the removals from the system. In the case of tuna fisheries and pelagic ecosystems, there is a lack of data and understanding of the effects on the functioning of the ecosystem as the result of changed abundances in the tuna component. However, the magnitude of the removals can provide some indications of when any potential effects, if they occurred, would mostly likely have manifested themselves. Figure 16 provides estimates of the total removals of tuna from the Indian Ocean from the beginning of commercial fisheries. What is clear from this figure is that if tuna catches are having a significant impact on ecosystem function, the major impacts would have been expected to begun in the mid 1980s. Total removals during the period when the rapid decline in longline catch rates occurred were relatively minor compared to recent catches. Thus, it is not the period of the early longline fishery, but it is the more recent catches (of which the largest proportions are from purse seiners) that may be of concern.

Current total removals for the Indian Ocean are on the order of 800,000 mt. The scale of removals in other oceans is of a similar or greater magnitude. “Back of the envelope” calculations suggest that the current levels of removals represent on the order of~5%[9] of the total primary production in the Indian Ocean taking into account that tuna are high order predators (i.e. an average tropic level of 3.5 was assumed in these calculations). Combining the functional role of tuna as high level predators and the relative magnitude of the removals in terms of primary production suggests that the possibility of widespread ecosystems impacts can not be ruled out. However, the removals, in and of themselves, do not provide a sufficient basis on which to conclude that any such impacts have occurred. In this regard, it is of particular concern that there has been, and continues to be, a paucity of data being collected from which any widespread impacts could be detected, if in fact they were occurring.

[9] This figure needs to be checked and refined. It was calculated assuming an average production figure of 8 grams of carbon per meter square per year, an area for the Indian Ocean of 73,000,000 square km, a conversion factor of 14.25 grams wet weight per gram of carbon, a 3.5 tropic level for tuna and a 10% efficiency factor in the conversion of carbon between trophic levels.

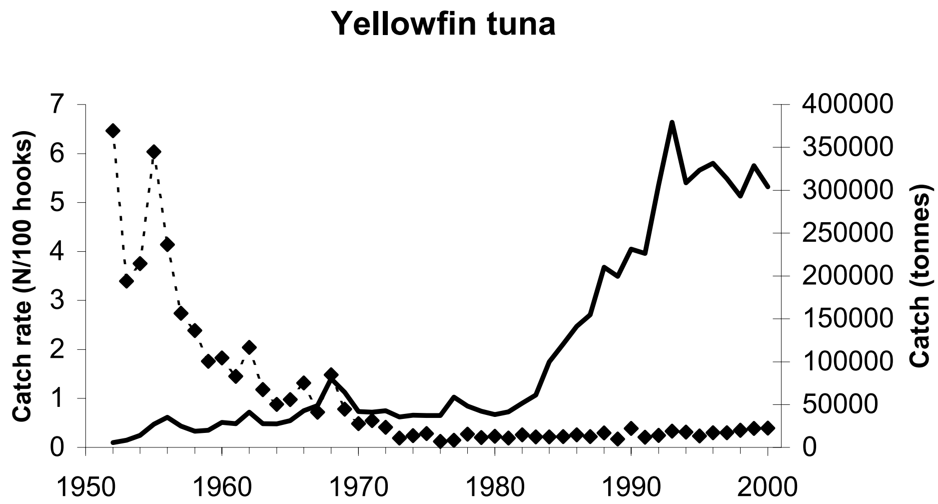


Figure 1: Comparison of the annual nominal catch rates by Japanese longliners and estimates of total catch of yellowfin tuna from all fisheries for the entire Indian Ocean

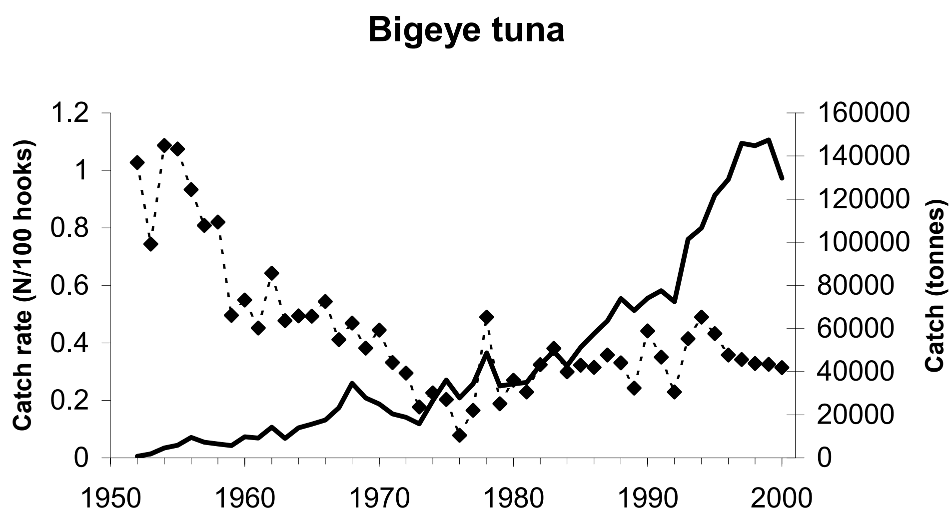


Figure 2: Comparison of the annual nominal catch rates by Japanese longliners and estimates of total catch of bigeye tuna from all fisheries for the entire Indian Ocean

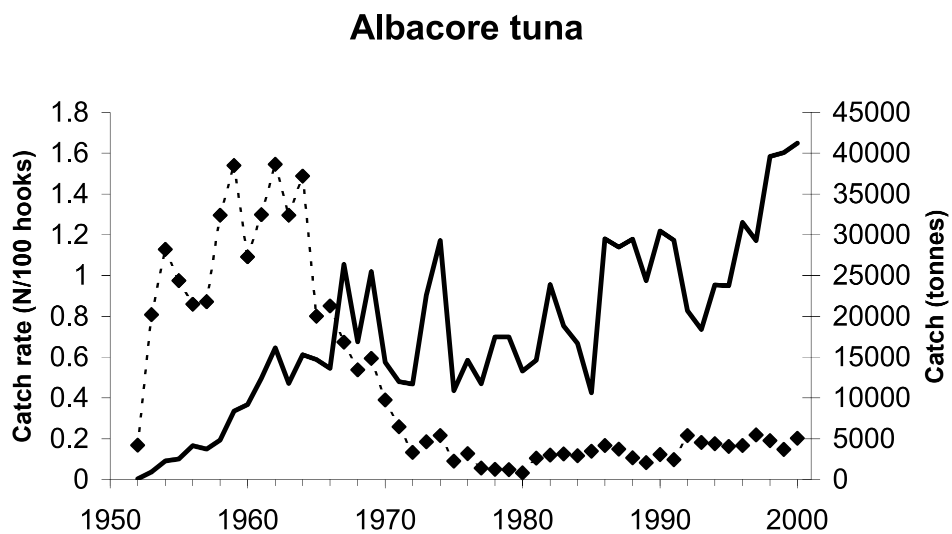


Figure 3: Comparison of the annual nominal catch rates by Japanese longliners and estimates of total catch of albacore tuna from all fisheries for the entire Indian Ocean.

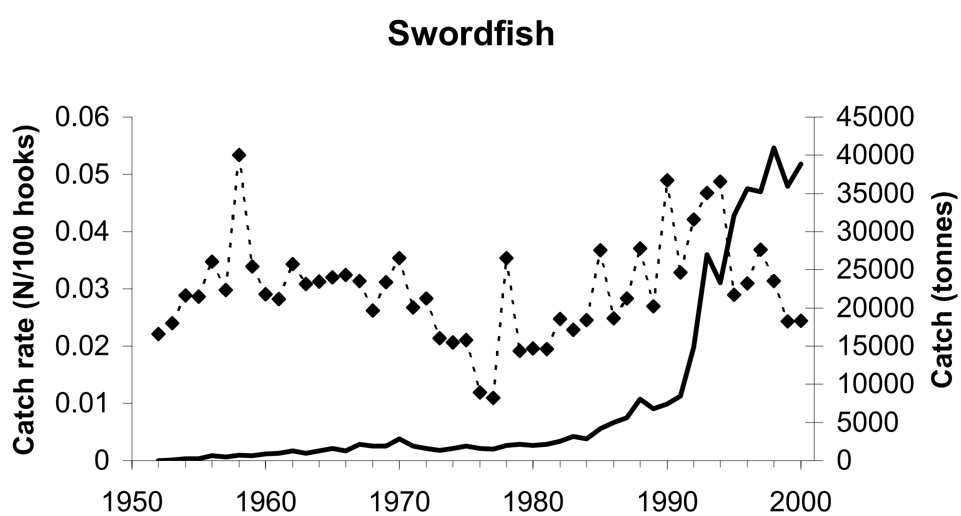
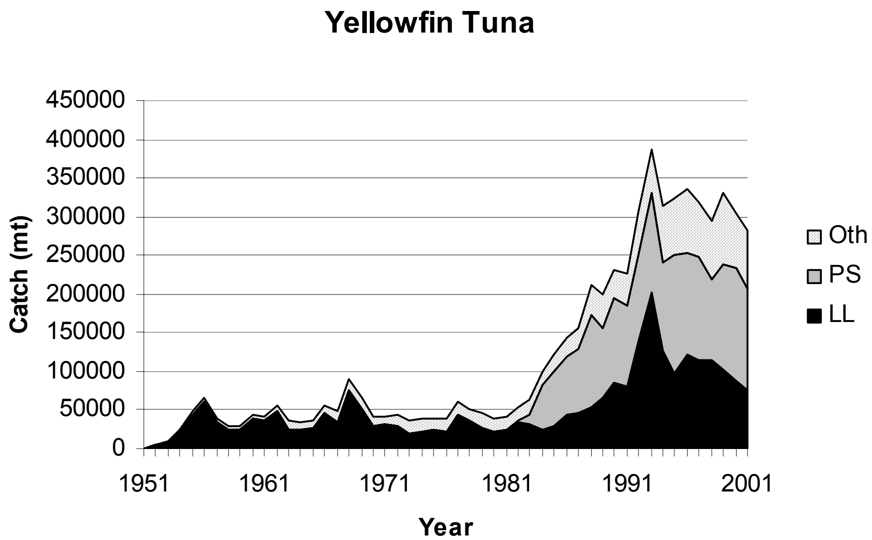


Figure 4: Comparison of the annual nominal catch rates by Japanese longliners and estimates of the total catch of swordfish from all fisheries for the entire Indian Ocean



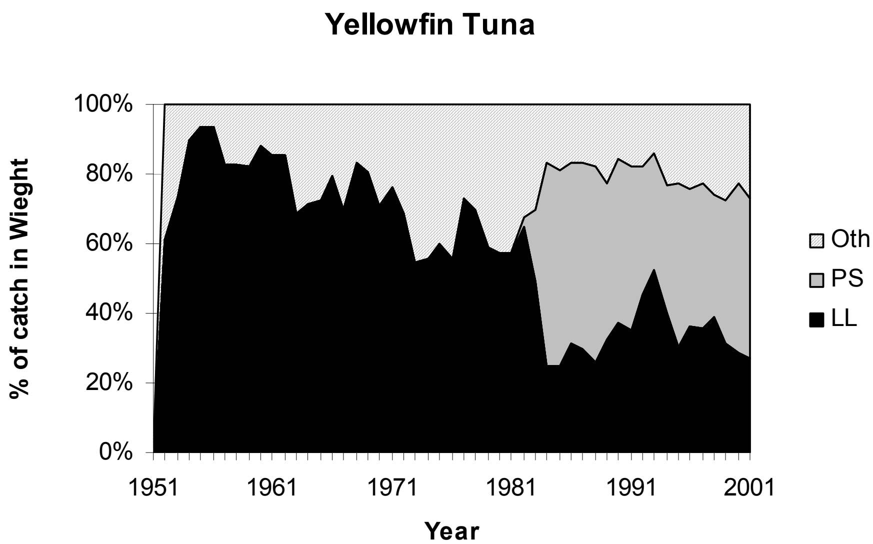


Figure 5: Estimates of the annual total catch of yellowfin tuna in the Indian Ocean (upper panel) and the percentage of the annual catch (lower panel) by gear type.

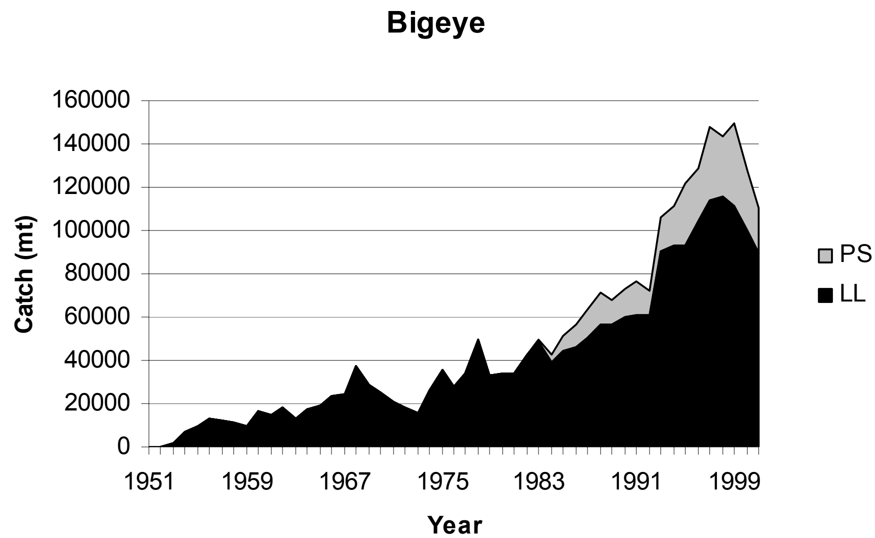


Figure 6: Estimates of the annual total catch of bigeye tuna in the Indian Ocean (upper panel) and the percentage of the annual catch (lower panel) by gear type.

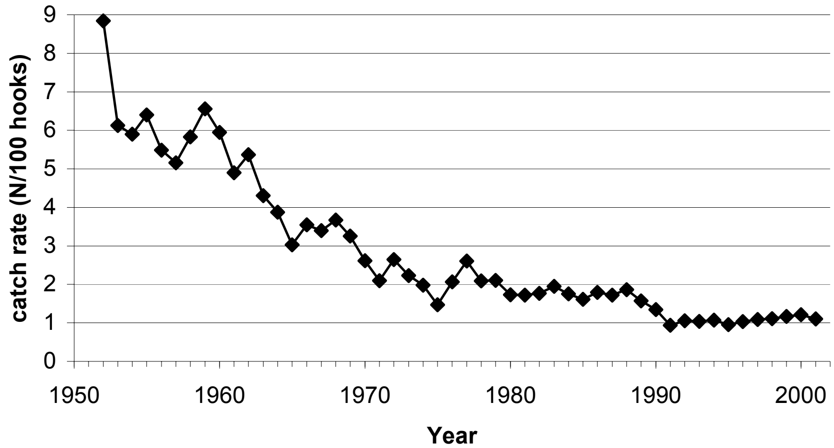


Figure 7: Nominal annual catch rates for Japanese longliners in the southern "subtropical" region of the Indian Ocean (10-35° S).

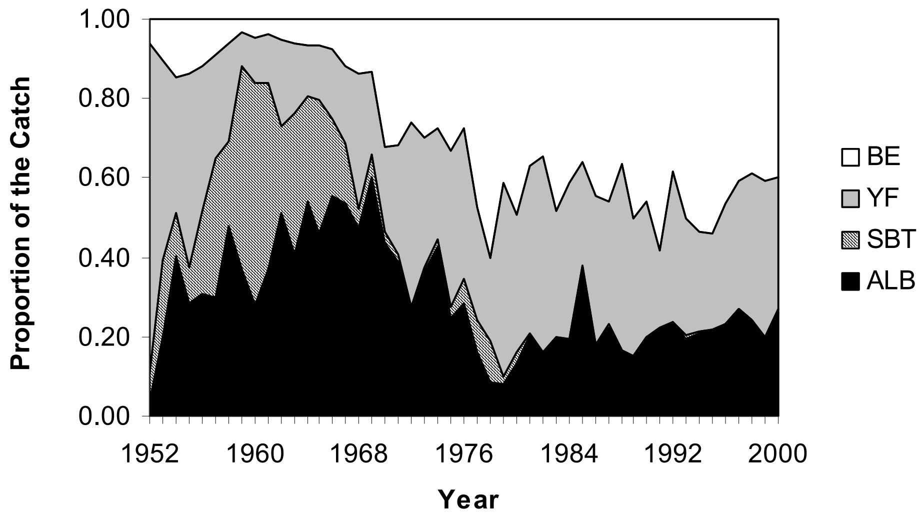


Figure 8: Relative species proportions for the catch by Japanese longliners in the southern "subtropical" region of the Indian Ocean (10-35° S).

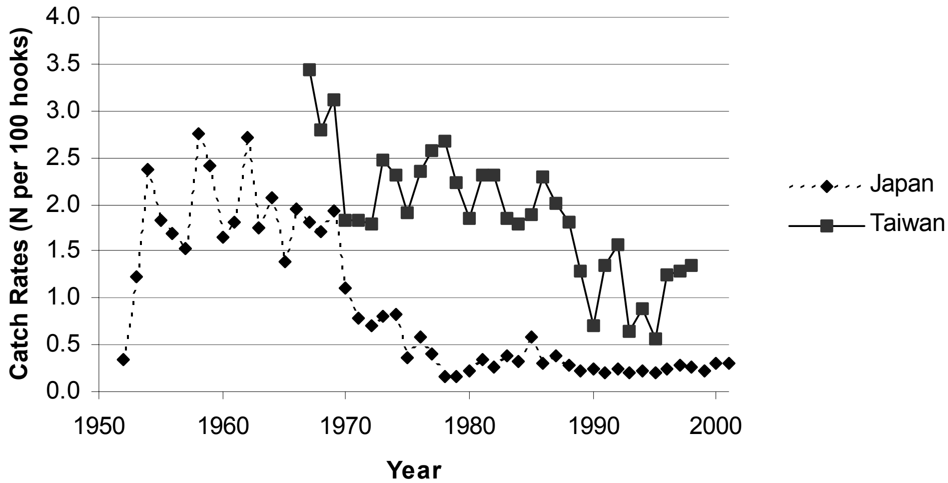


Figure 9: Comparison of annual nominal catch rates for albacore tuna by Japanese and Taiwanese longliners in the southern “subtropical” region of the Indian Ocean (10-35°S).

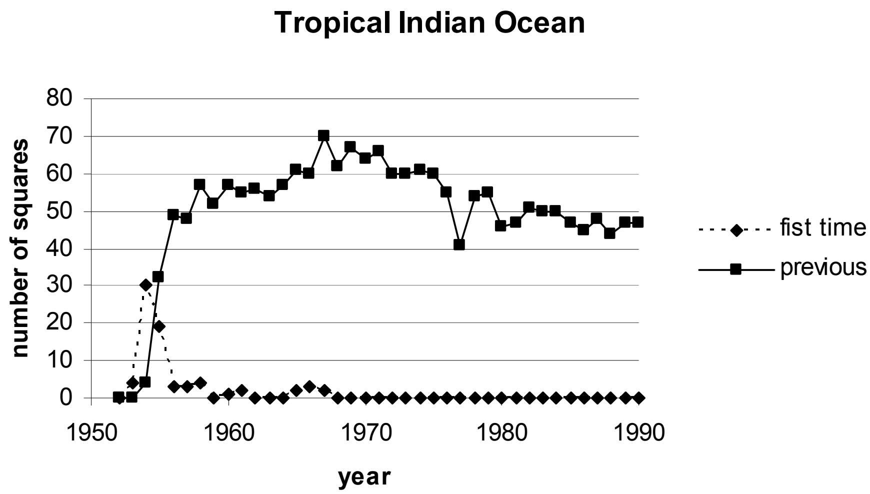


Figure 10: Number of squares fished in a given year by Japanese longliners in the tropical Indian Ocean that had been fished for the first time and the number that had been fished previously.

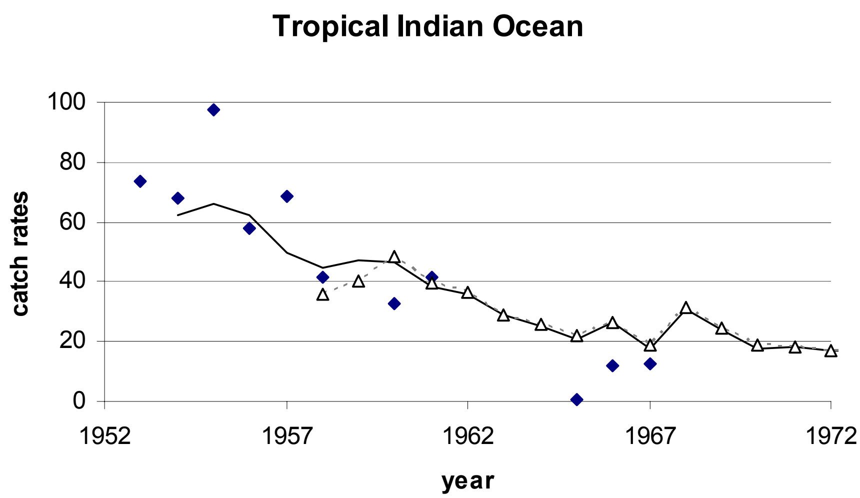


Figure 11: Comparison of catch rates (number per 1000 hooks) by Japanese longliners in the tropical Indian Ocean in 5° squares that were fished for the first time in a given year (solid diamonds), squares that were fished previously (solid line) and squares that had been fished in at least five previous years (open triangles).

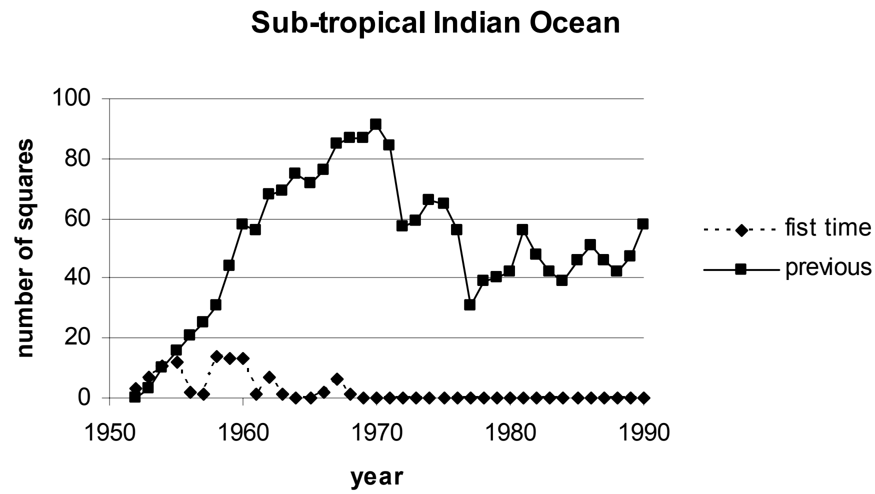


Figure 12: Number of squares fished in a given year by Japanese longliners in the sub-tropical Indian Ocean that had been fished for the first time and the number that had been fished previously.

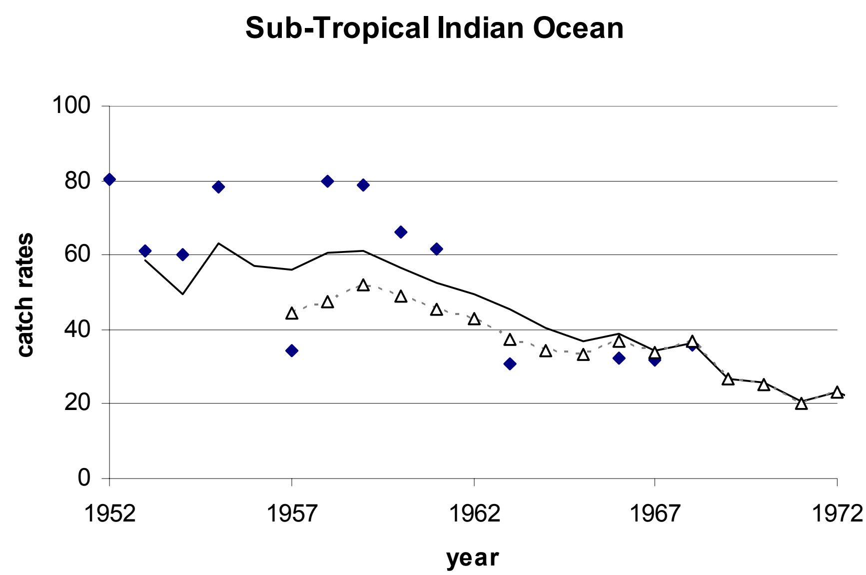


Figure 13: Comparison of catch rates (number per 1000 hooks) by Japanese longliners in the sub-tropical Indian Ocean in 5° squares that were fished for the first time in a given year (solid diamonds), squares that were fished previously (solid line) and squares that had been fished in at least five previous years (open triangles).

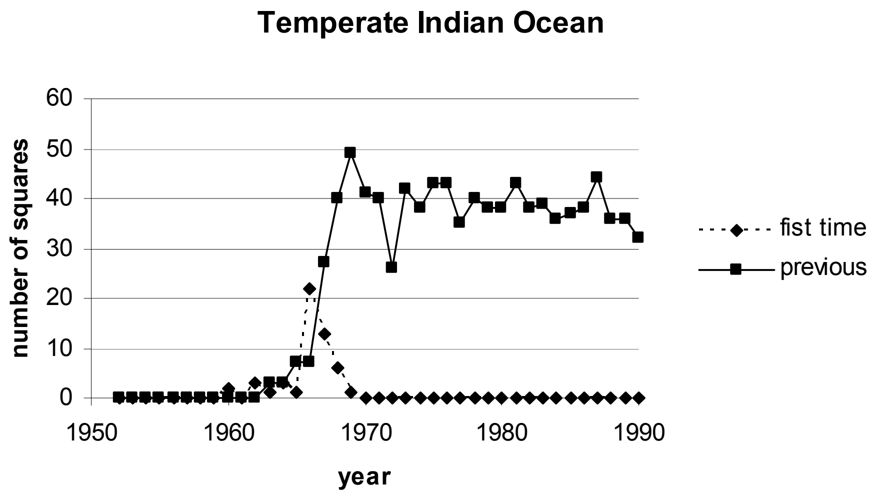


Figure 14: Number of squares fished in a given year by Japanese longliners in the temperate Indian Ocean that had been fished for the first time and the number that had been fished previously.

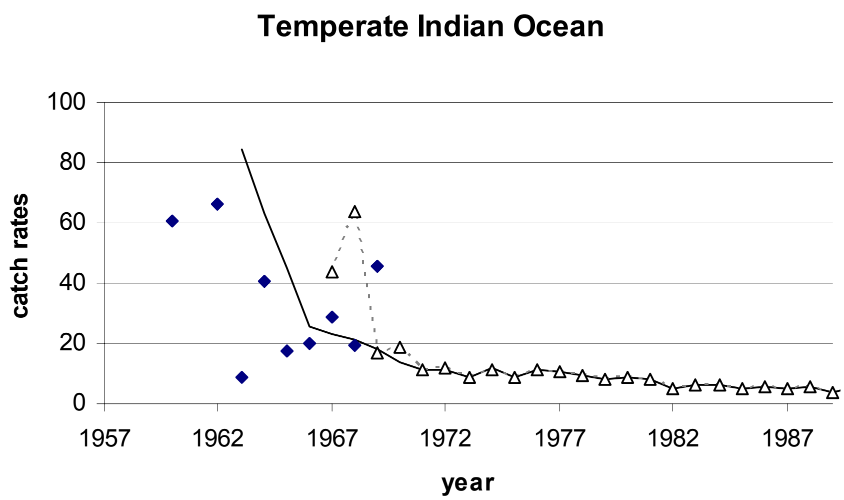


Figure 15: Comparison of catch rates (number per 1000 hooks) by Japanese longliners in the temperate Indian Ocean in 5° squares that were fished for the first time in a given year (solid diamonds), squares that were fished previously (solid line) and squares that had been fished in at least five previous years (open triangles).

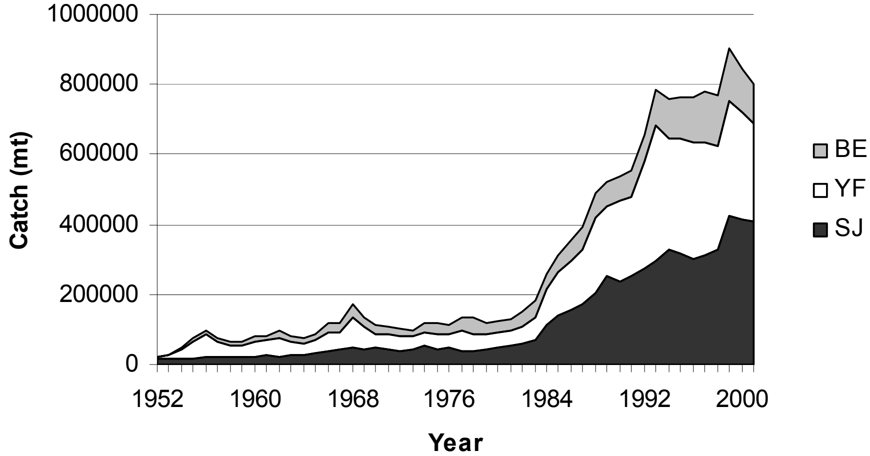


Figure 16: Estimated total annual catch by all fleets of bigeye, yellowfin and skipjack tuna in the Indian Ocean.