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Tuna longline catch rates in the Indian Ocean: Did industrial fishing result in a 90% rapid decline in the abundance of large predatory species?

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Abstract

Myers and Worm claim that their analyses of catch rates following the commencement of industrial longline fishing for tuna and billfishes show that these longline fisheries rapidly depleted the abundance of these large oceanic predators by 90% (Myers RA, Worm B. Rapid worldwide depletion of predatory fish communities. Nature 2003;423:280–3). Their analyses were published in a high profile science journal along with an accompanying press release, which then attracted substantial international media focus and public attention. This media focus in turn has been used as a base for advocating major marine policy changes for pelagic tuna fisheries (e.g. a minimum of a 50% reduction in catches and establishment of extensive marine reserves). However, among numerous scientific experts involved in tuna and pelagic fishery research substantial concerns exist that Myers and Worm's analyses provide a misleading picture of the status of large predatory pelagic fishes. These concerns are reviewed using data from the Indian Ocean for illustrative purposes and indicate that the initial longline catches were not responsible for a rapid depletion of the main tuna and billfish stocks nor were they threatening the overall sustainability of these stocks. However, the status of a number of theses stocks is of concern as a result of large increases in catches in more recent years. The debate sparked by Myers and Worm's paper should not distract from the critical problem of developing and implementing effective international management policies. In addition to implications for fishery management, the publication, peer-review, scientific response and publicity process associated with the publication of Myers and Worm's paper are discussed. Concerns are raised that if these become standard practices for articles in high profile science journals that this would undermine the trust placed in such journal to provide an accurate and well-balanced representation of the most important new scientific findings and in their role to inform policy decisions based on these findings.

Keywords: Longlining; Tuna abundance; Press releases; High profile science journals

1. Introduction

In a recent letter to the editor of *Nature*, Myers and Worm [1] 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. Myers and Worm's letter highlights the importance for marine policy of taking into account the state of unexploited communities when establishing benchmarks for assessing the effects of exploitation. Their letter was particularly effective in this regard for the oceanic systems they examined as they used historical data that went 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

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detail data and as such are unable to provide management benchmarks based on unexploited status.

Nature chose to make this letter its cover story, and this with an accompany press release[1] by the author resulted in the article attracting substantial international media focus and public attention. For example, the article and accompanying press release resulted in numerous media interviews by the authors (including interviews on CNN, the BBC and NPR) and a large number of stories in the print news media (including *the Economist, The Guardian of London, the Washington Post*, *the London Times and Time* magazine—to name only a few). In addition, the United States Senate Committee on Commerce, Science and Transportation convened hearings on global overfishing and international fishery management in which Dr. Myers was one of two scientists invited to give oral testimony. Nevertheless, among numerous scientific experts involved in tuna and pelagic fishery research substantial concerns exists that for the nine oceanic systems examined by Myers and Worm their analyses provide a misleading picture of the status of large predatory pelagic fishes.[2] As discussed below, if the trends they reveal are accepted on face value, they would imply that the fisheries, by themselves, were unlikely to be the primary cause underlying the declines. *Nature* has been unwilling to publish concerns raised about Myers and Worm's letter and there has been little published scientific or popular critical review. The current paper presents a number of the concerns that exist with Myers and Worm's analyses using data from the Indian Ocean for illustrative purposes. It also raises questions about the role of high profile science journals and press releases in informing and controlling public policy debates on matters requiring scientific advice and input.

2. Concerns with Myers and Worm's analyses

2.1. 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 of 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 multispecies 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 [3]). Without additional information, it is not possible to determine solely from observed trends 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.

Fig. 1 shows the catch rates and estimated total catches for the four principle tuna species and the main billfish species harvested in the Indian Oceans.[3] Note that this paper considers effects at the species/stock level since species replacement can mask the non-sustainable effects in aggregated data. This paper also presents the data for each species for the entire Indian Ocean since all of these species are found through 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,[4] 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

[1]Press release available on the WEB site of Dr. Myers, University of Dalhousie (http://ram.biology.dal.ca/~myers/depletion/).

[2]See [2] and the WEB site of the Pelagic Fisheries Research Program, University of Hawaii (http://www.soest.hawaii.edu/PFRP/large_pelagic_predators.html).

[3]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 (http://www.iotc.org).

[4]There appear to be some differences between the data used in Myers and Worm's letter and those available directly from the IOTC, although both are from same original source. Part of the discrepancy appears to be 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.

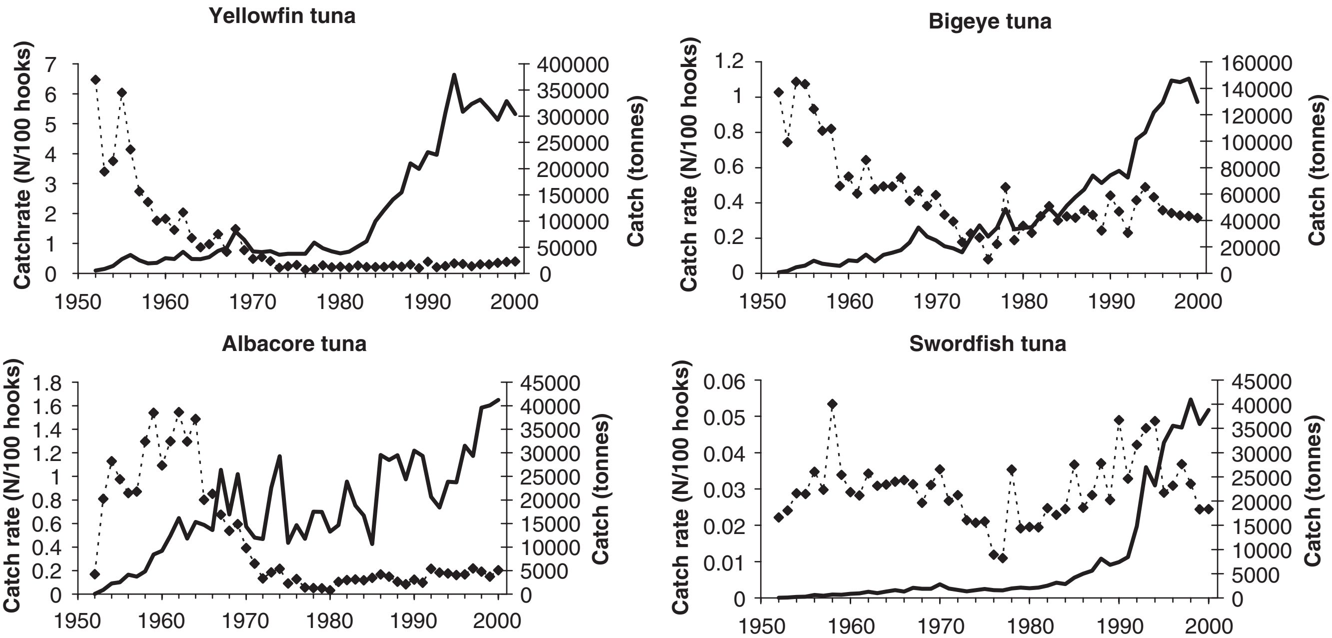

Fig. 1. Comparison of the annual nominal catch rates by Japanese longliners (dotted line) and estimates of total catch from all fisheries (solid line) for the four principle species of tuna and billfish caught by longliners in the Indian Ocean.

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 oceans.

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 increases in catch would suggest that 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).[5] 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 large fraction of the increases in yellowfin catches observed in these oceanic systems have been the result of the development and expansion of purse seine fisheries (Fig. 2). 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 span a wider size range with purse seiners harvesting a large number of smaller/younger fish (i.e. <90 cm) that are rarely caught by caught by longliners. Mortality rates for younger/smaller fish appear to be high [5] and maturity occurs at relatively young ages. As such, a 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, considerable overlap exists in the size of fish caught by the two gears with fish over 90 cm representing the largest proportion of the purse seine catches in numbers and the overall annual number of large yellowfin caught in the 1990s greatly exceeded (by a factor of 2–3) the number caught prior to 1980s. As such, the large scale increases in catches (including catches of large fish) resulting from expanding purse seine fisheries with relatively stable longline catch rates indicates that the initial longline

[5]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 [4]. Nevertheless, this does not seem the most likely cause of the CPUE and catch patterns seen in industrial tuna fisheries in part because the pattern has been seen 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.

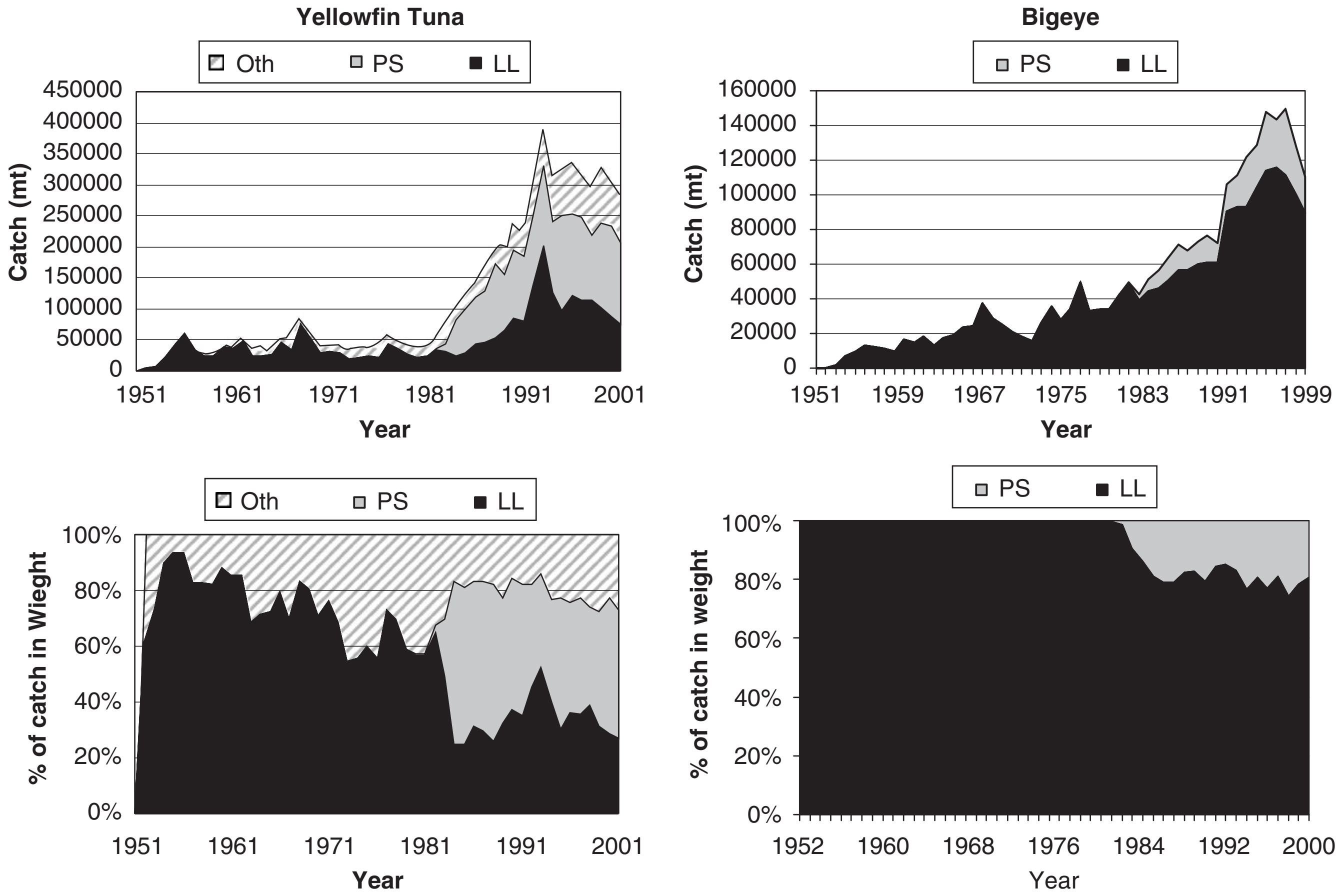

Fig. 2. Estimates of the annual total catch of yellowfin and bigeye tunas in the Indian Ocean (upper panels) and the percentage of the annual catch (lower panels) by gear type.

catches were not threatening the overall sustainability of this species.[6,7] Moreover, in the case of bigeye, the increases in the Indian Ocean have been primarily due to increases by longline fleets (Fig. 2), 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 (Fig. 3) were large changes in the species composition of the catches (Fig. 4). Albacore and southern bluefin tuna (SBT) dominated

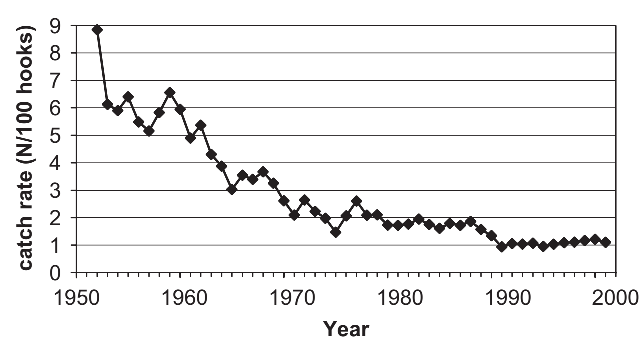

Fig. 3. Nominal annual catch rates for all species for Japanese longliners in the southern "subtropical" region of the Indian Ocean (10–35°S).

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

[6]The situation for southern bluefin tuna is also 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 spawning stock levels [6].

[7]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.

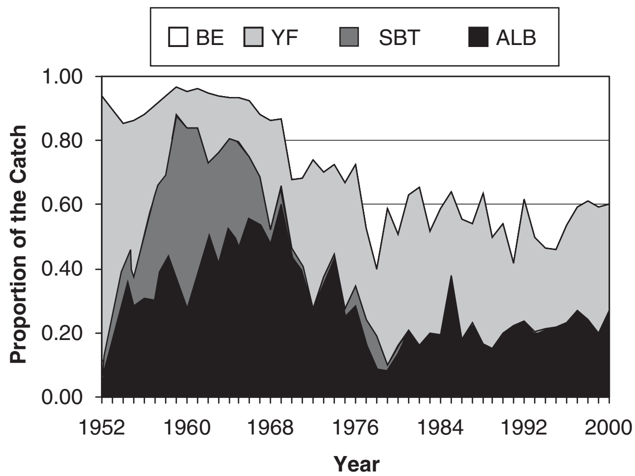

Fig. 4. Relative species proportion for the catch by Japanese longliners in the southern ''subtropical'' region of the Indian Ocean (10–35°S).

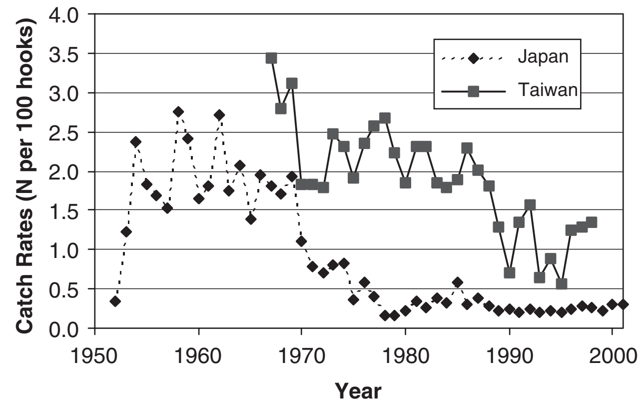

Fig. 5. Comparison of annual nominal catch rates for albacore tuna by Japanese and Taiwanese longliners in the southern ''subtropical'' region of the Indian Ocean (10–35°S).

changes in targeting practices. The early Japanese longline fishery was primarily targeting fish for canning. In the late 1960s, the fishery switched to targeting fish for the sashimi market as the result of the development of ultra-deep freezing and other technological developments. 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 [6]. 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 catch substantial numbers of juvenile (1–3 year olds). Moreover, Indonesian longline fisheries which developed in the 1990s have been responsible for around 10% of the global SBT catches in recent years [7]. 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 1960s 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 [8]. Thus, in the same post 1970s 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 (Fig. 5). Thus, in this region, Japanese longline catch rates provide no basis for concluding that tuna abundances had declined by 90% during the early years of pelagic longlining.

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 considers 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 a 10% level of their pre-exploitation levels.

2.2. 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

[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 [7,9]. 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.

maps of the spatial distribution of catches in four discrete years (1952, 1958, 1964 and 1980). 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 (Fig. 6). 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 (Fig. 6). Thus, in both the Tropical and Temperate regions, catch rates in newly fished squares were similar or less than those in previously fished squares. In fact in the temperate region, average catch rates in squares which were newly fished seemed to have declined faster than 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

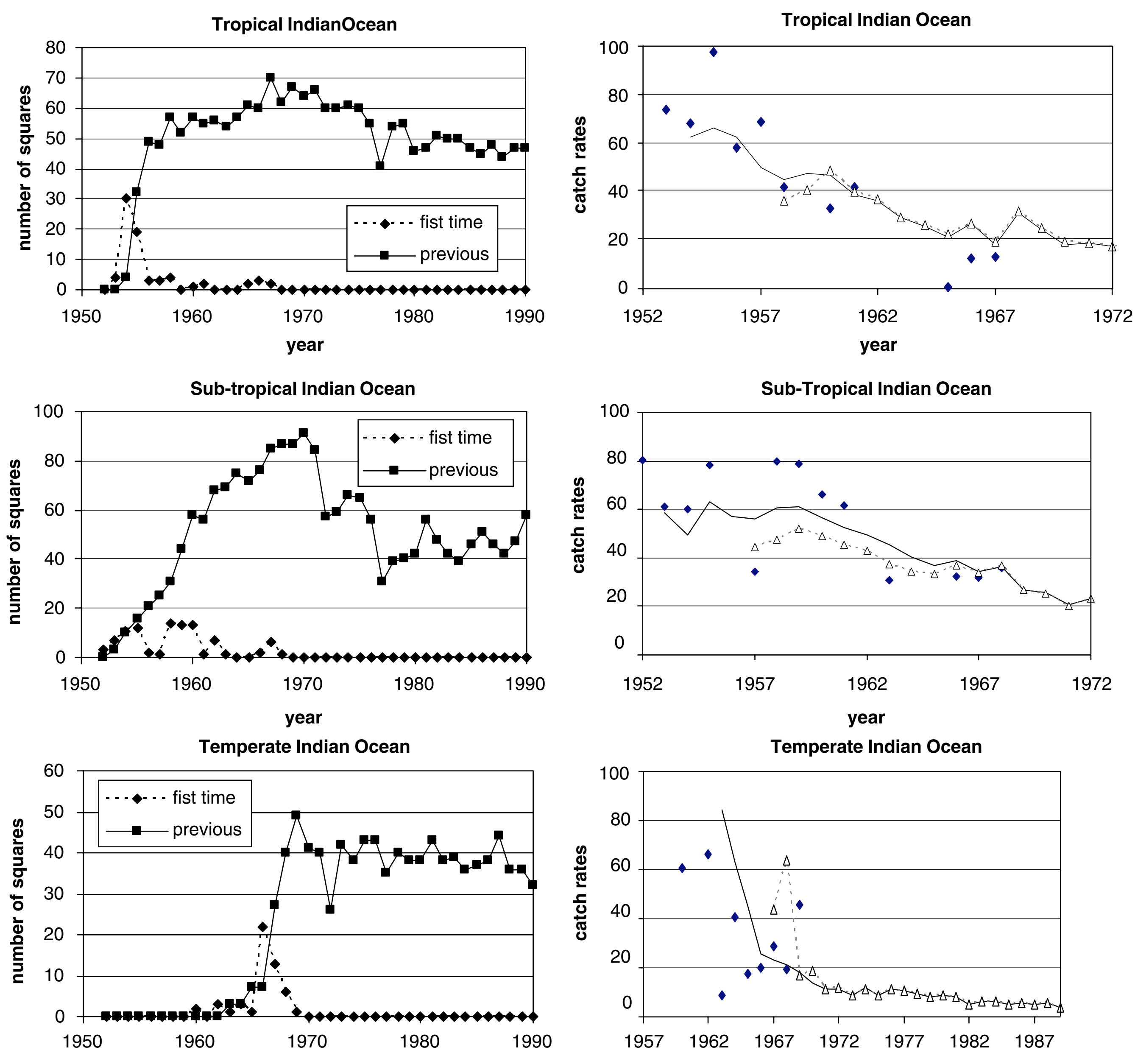

Fig. 6. Comparison of spatial expansion and catch rates in new fished areas for Japanese longliners for three latitudinal regions within the Indian Ocean. Left hand panels compare the number of 5° squares fished that were fished for the first time and the number that had been fished previously in a given year. The right hand panels compare catch rates (number per 1000 hooks) 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).

be lower than 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.

2.3. 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 most likely have manifested themselves. Fig. 7 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 have 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. Considering the functional role of tuna as high level predators and the relative magnitude of the removals in terms of primary production that would be required to generate this amount of biomass suggests that the possibility of

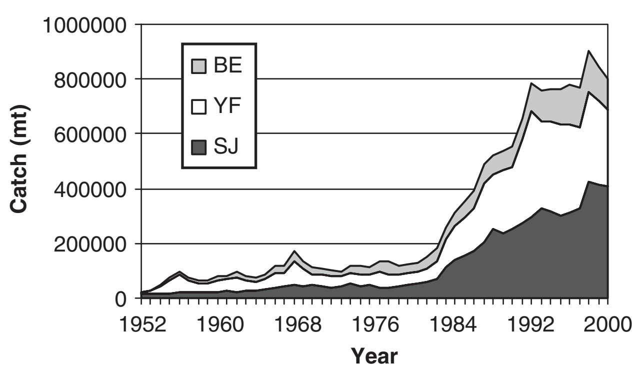

Fig. 7. Estimated total annual catch by all fleets of bigeye, yellowfin and skipjack tuna in the Indian Ocean.

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.

2.4. Change in size distribution

Harvesting will almost inevitably lead to changes in the age and size structure of populations. Unless the gear being used is selective for younger ages/smaller sizes (e.g. because of small hooks or too weak line) or larger fish have refuges from fishing (e.g. by moving to deep water), the age structure of a population will be skewed towards younger ages simply because the increased mortality rates reduces the probability of surviving to an old age. Since fish continue to grow throughout their entire life, fishing also tends to reduce the mean size in a population. A large change in the size structure of top predators might also have ecosystem ramifications since diet and size range of prey may vary with size, although there is little known about this for most large pelagic species.

In addition, one potential contributing factor to the early and rapid decline in longline catch rates might a depletion of large fish. Thus, it is conceivable that there was a relatively, large standing stock of relatively old, big fish that were quickly depleted at the on-set of the fishing, although some reduction in average age and size, as noted above, is generally a demographic consequence of any harvesting. In terms of population sustainability, this would only be a major concern if it was only the very oldest animals that were contributing to the spawning stock, which is not the case for the main tuna stock.

Data on the size distribution of the catch from the inception of a fishery is often rare. However, at least for bigeye, yellowfin and southern bluefin tuna, estimates of the size distribution of the catch taken by the longline fisheries in the Indian Ocean exist since the beginning of these fisheries. While there are uncertainties in these estimates which are difficult to quantify (particularly for the early years), the estimates do not suggest that there has been a substantial change in the size distribution of the catches reflecting major impacts on in functional trophic relationships. Thus, there has been no discernible change in the estimated average size of bigeye tuna being taken (Fig. 8). For yellowfin tuna, there was a decrease of ~18 kg or ~10 cm in the mean size during the first 10–11 years of the fishery ([10], Fig. 8). After this, the average remained relatively stable—fluctuating from 28 to 44 kg (mean 37 kg) and is well above the size of maturity for this species. Moreover, the upper end of

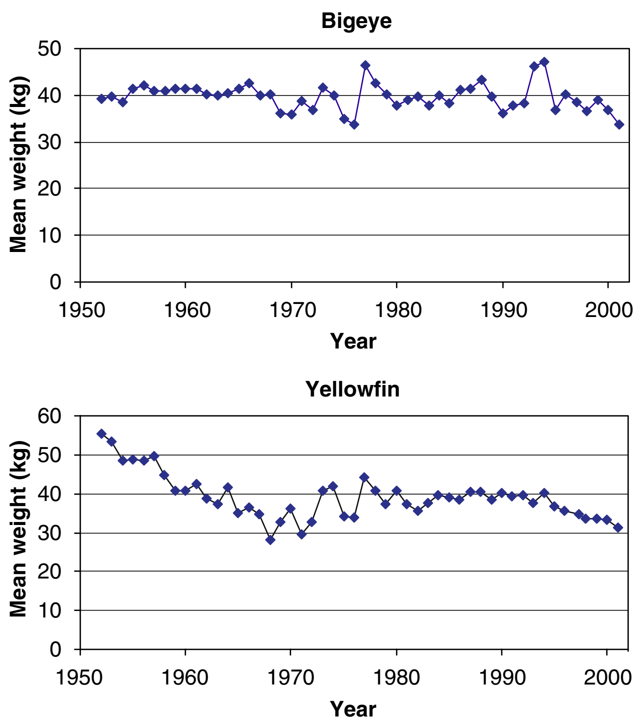

Fig. 8. Estimated mean weight of bigeye and yellowfin tun caught in the Indian Ocean by longline vessels.

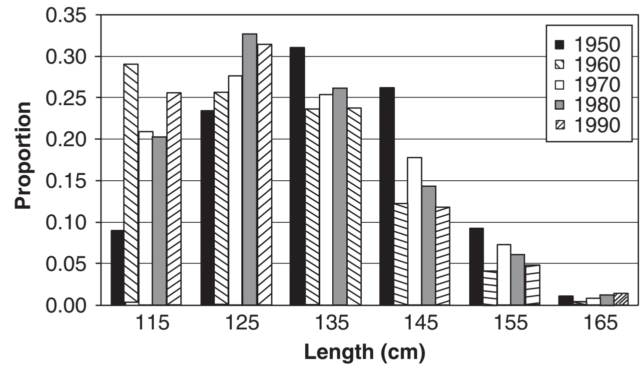

Fig. 9. Size frequency distribution by decade of large yellowfin (i.e. greater than a 110 cm) caught by longliners fishing in the Indian Ocean.

the size range still occurs with reasonable frequency in the catch. In addition, there has been little change in the relative frequency of larger fish and the decrease in average size appears to be due in large part to increased selection on smaller size fish (Fig. 9). For SBT, the data suggests that fish are actually growing faster to possibly to a larger maximum size than they did when the fishery began [11], confounding any interpretation of change in size for this species as an indication of heavy exploitation. Overall, the estimates of average size do not support that the rapid initial decline in catch rates was the result of fishing out the largest sized fish or suggest that there has been a major change in the functional role of these predators.

It is worth noting that within their letter to *Nature*, Myers and Worm do not address the issue of change in size and provide no data that would allow for this to be evaluated. Nevertheless, in the press release that they prepared to coincide with the publication of their letter they make strong statement unsubstantiated in their, article related to change in size. The press release states that "these great fish are not only declining in numbers, but with intense fishing pressure they can never attain the sizes they once did". It goes on to quote Dr. Myers as saying "Where detailed data are available we see that the average size of these top predators is only one fifth to one half of what it used to be. The few blue marlin today reach one fifth of the weight they once had". However, in fact, substantial data from the Atlantic indicates that there has not been a change in size of blue marlin in the commercial longline catches (and also for white marlin) [12,13].[9] Myers and Worm were clearly aware of the first of these references as they cited it in the supplementary WEB material provided to their *Nature* letter. In fact, in that supplementary material they use a simulation study by Goodyear [15] to argue why the lack of a change in size is not a valid objection to the changes in CPUE being consistent with changes in abundance.

2.5. Myers and Worm's response to concerns that have been raised

Myers and Worm's letter suggest that "most scientists and managers may not beware of the true magnitude of change in marine ecosystems because the majority of the declines occurred during the first years of exploitation, typically before surveys were undertaken" and in their accompanying press release state that "the tendency in fisheries biology to use only the most recent data increases the problem of shifting baselines". They consider that their results represent "new discoveries from oceanic systems" and "provide the 'missing baseline'". An implication embedded in these statements is that those scientists involved in providing assessment advice have been either ignorant or negligent in not taking into account the historically available data and "only serve to stabilize fish biomass at low levels". However, throughout the tuna fishery literature (much of it in the form of working papers to scientific committees) are presentations of time series of longline catch rates going back to the 1950s which present

[9]In regard to Myer's claim that "they can never achieve the size they once did", it is worth noting that recreational catches from Bermuda also show that it is still possible to catch the very largest blue marlin (i.e. what are referred to as a "grander" or a fish over 455kg). Thus, a total of nine "granders" have been caught through 2002—the first in 1984 (well after the initial decline in blue marlin CPUE) and two were caught in 2001 [14].

essentially the equally long term series and trends as presented here or in Myers and Worms document ([16–21] are just a few examples).

Those involved in tuna assessments have long been aware of the apparent contradiction between the rapid declines in the early CPUE series with small catches relative to those taken subsequently. Comparison of early tuna stock assessment predictions of maximum sustainable yield based on early longline catch and effort data have consistently underestimated subsequent catches by up to an order of magnitude or more (e.g. [22,23]). Discussion of the reasons for this occurred at tuna scientific meetings where there has been speculation on a range of hypotheses that might explain why changes in early longline CPUE were not a good predictor of changes in relative abundance and the lack of evidence for direct interaction between surface catches and longline catch rates (e.g. [21,24] Polacheck and Fontenau, personal communication). However, with some exceptions (e.g. [21,25–27]), little of this discussion has found its way into either the primary or even ‘‘grey’’ fishery literature as speculation generally does not constitute acceptable basis for a scientific publication. Nevertheless, the report of the IOTC Working Group on Tropical Tuna (WPTT) provides one clear demonstration that tuna experts are aware of both these early declines in CPUE and the difficulty in interpreting them. Thus, in its discussion on Japanese longline yellowfin catch rates in the Indian Ocean the report concludes [21].

> The WPTT noted two features of the trend that were difficult to interpret. The first is initial steep decline in CPUE, at a time when catches were relatively low and stable. Secondly, CPUE has been stable since the late 1970s, despite catches rising strongly (6-fold) during the 1980s. This pattern does not correspond well with the expected response of CPUE to changes in catch and biomass. There are a number of possible explanations, including changes in catchability or behaviour, or the population existing in two fractions of differential ability to purse seine and longline fishing, but there is no scientific information from which to judge which (if any) of these hypotheses is correct.

Myers and Worms in their *Nature* letter do not address the concerns about the incompatibility between the early declines in CPUE and subsequent large catches from these stocks. However, in the supplementary material provided by Myers and Worms with their letter on the *Nature* web site[10] demonstrate that they were aware of the concerns by tuna fishery scientists. However, they claim that

> When a careful analysis of fisheries with good catch data is undertaken (for example for southern bluefin tuna), there has been no difficulty in explaining the trends in CPUE (see assessments carried out by the Commission for the Conservation of Southern Bluefin Tuna; URL: www.ccsbt.org and Ref. 2). Similarly, there is no difficulty in accounting for the changes in abundance of western Atlantic bluefin tuna by estimated catches (www.iccat.es).

However, examinations of the sources they cited do not support their claim. Thus, even a quick examination of the data section in their Ref. 2 (i.e. [28]) reveals that the longline CPUE time series used in this paper only started in 1969. 1969 was after the period of rapid declines in SBT catch rates and after the years of largest catches taken from the stock. The CCSBT web site cited to support their claim provides no detailed assessment results. Moreover, an examination of all recent assessments of SBT (i.e. since at least the late 1991)[11] reveals that these assessments have never used CPUE series which extend back further than 1969 with two exceptions [29,30]. These two exceptions included longline CPUE series from the SBT spawning ground from 1965–1971. However, these assessments could not explain well the drop in the spawning ground CPUE over this 7-year period given the catch history, while even this CPUE series did not include the years with the greatest decline [31]. Similarly, examination of the ICCAT web site revealed that all recent western bluefin assessments only begin in 1970 or latter—after the period of rapid CPUE decline on which Myers and Worms base their argument. Thus, the references cited by Myers and Worm provide no support for their claim and the author is unaware of any analytical assessments that account for both the large observed drops in longline catch rates as indicting a 90% reduction in abundance and the subsequent catches taken from the stock.[12]

3. Scientific debate, advocacy, responsibility and presentation

Policy makers and the public need to be fully informed about scientific findings that have important

[10] See http://www.nature.com/nature/journal/v423/n6937/suppinfo/nature01610.html.

[11] References for these are contained in the CCSBT and Tri-lateral Scientific Committee Reports and copies of the actual assessments documents are available from the CCSBT for the more recent years and the CSIRO Marine Research Library (Hobart, Tasmania) for all years.

[12] Hampton [32] recently completed an assessment of yellowfin tuna in the western tropical Pacific using Japanese longline catch rates back to 1950. The way the assessment model fitted the early CPUE time trend was to create a large positive recruitment anomaly just prior to the CPUE and was not able to explain the decline in CPUE as large decline from a mean pre-fishery level as a result of the catches.

policy implications. However, in doing this, it is critical that the underlying scientific principles are maintained both when drawing conclusions from the research and in their presentation. These principles include (1) full consideration and testing of alternative plausible hypotheses; (2) ensuring consistency among relevant data sources; (3) accurate use of the scientific literature in support of findings; (4) objective response to comments by scientific peers and (5) clear separation of the scientific results from subjective or valued based policy implications drawn from the results. In particular, before drawing definitive conclusions from a set of data and analyses, a scientific approach requires that the consistency of the conclusions in light of other data and alternative hypotheses be fully examined. When inconsistency among data sources exists or when alternative hypotheses offer reasonably plausible explanation for a set of data, then these need to be acknowledged and openly discussed based on their scientific merit. If the conclusions have substantive policy implications, the scientific debate and lack of certainty surrounding such conclusions needs to be brought into any high-profile non-specialist publications and public foray dealing with the policy implications if informed decisions are to be made.

Myers and Worm's letter appears to represent one example in which such basic principles have not been adhered to. The letter and activity associated with its publication have tended to pre-empt substantive debate through a combination of the following:

1. Not acknowledging and addressing the major concerns of tuna fishery scientists in the main letter, but burying these in the technical material accompanying the letter;
2. Inaccurate citing or misunderstanding of references and claiming that these demonstrate consistency between two apparent inconsistent data sets, when in fact they contain no such demonstration (see above).
3. Turning a well known phenomena among experts in the area into a claim of new discoveries involving substantial work;[13]
4. Undercutting the potential criticism by scientists who have spent years working in the field through implications of tunnel vision and emotional attachment to their work.[14]
5. Making emotive and undocumented universal claims in publicity statements that are not dealt with in the primary article and for which there are at least a number of well documented exceptions.[15]

The above list reads more like a set of tactics that we have come to expect in a political campaign than those underlying a serious scientific debate and have the potential, if used widely, to undermine the credibility of science to inform policy debates.

Myers and Worm's article provided them a platform for advocating major changes to fishery policy (i.e. Myers and Worm have been advocating a minimum of a 50% reduction in catches and establishment of extensive marine reserves). Myers "has become something of an activist, catalyzed by his own research into lobbying foreign capitals—including Washington, DC—to act quickly to stop the marine holocaust" [33]. Scientists have a right and arguably a responsibility to take on advocacy roles as informed members of a community and be involved in the political policy setting process. However, the distinction needs to be maintained between the role of science in informing the policy debate on the consequences of different actions and the policy/political decisions on what actions to actually take. It is important that scientists do not misuse their status of expertise and the opportunities provided to access the media as a result of articles in the high profile scientific journals.

Press releases, which are now a "standard" part of the publication process in *Nature* and similar journals, are of particular concern in maintaining the distinction between scientific results and an advocacy role. While press releases provide a useful bridge between the

[13]The accompanying press release refers to the authors "taking 10 years to assemble data sets" when in fact for the tuna and billfish data set the only work involved was obtaining access to these data from the Japanese National Research Institute for Far Seas Fisheries. (NRIFSF), who are the ones who have actually been doing the hard work of diligently compiling and maintaining this data set for over 50 years. Moreover, portions of this data set are easily accessible on the WEB, including the complete time series for the Indian Ocean used in the current paper.

[14]For example, the section of the press release dealing with the comments from fishery scientists is titled "shocking results are hard to accept" and goes on to include a quote from Jeremy Jackson that "'This is because we have forgotten what we used to have'". The press release further state "We are in massive denial and continue to bicker over the last shrinking numbers of survivors, employing satellites and sensors to catch the last fish left," Also see the discussion above.

[15]See section above on changes in sizes. Further examples include the statements from the press release:

> I want there to be hammerhead sharks and bluefin tuna around when my five-year-old son grows up. If present fishing levels persist, these great fish *will* go the way of the dinosaurs.
>
> In many cases, the fish caught today are under such intense fishing pressure, they never even have the chance to reproduce.
>
> We have to understand how close to extinction some of these populations really are.

The letter to *Nature* contains no mention or data on hammerhead sharks or on the relationship between size/age of reproduction and of fish being taken. The letter also does not deal with the issue of extinction, while their results suggest that the depletion occurred rapidly in the first 10 years of the fishery and that since then levels have remained stable in spite of increasing effort and catches.

technical scientific material and the non-scientific reporter and public, they receive no independent or peer review. In order to maximize their impact, they are libel to distortions, generalizations, introductions of additional material and the confounding of science as providing "the answer" to difficult policy or political decisions. Many large research institutions and universities have public relation or communication departments, whose primary interests include the maximization of publicity from the media opportunities provided by a *Nature* or similar type publication. While these public relations departments may prepare the press releases, the authors (e.g. scientists) are ultimately responsible for their contents. As scientists it is critical to maintain scientific accuracy and rigor in the translation of scientific results to the public media.

The Myers and Worm article also raises concerns about the role of high profile science journals in informing and controlling public policy debates on matters requiring scientific advice and input. *Nature* is among the most prestigious of scientific journals in which to have an article published. Articles from *Nature* form a frequent source of material for science reporting in the non-technical press, radio and television. As such, such article can lead to them having large influence in the formation of subsequent policy decisions. The *Nature* publishing group clearly recognizes this. Thus, to quote it's own WEB site:

> The importance of *Nature* papers often extends well beyond the confines of the specific discipline concerned. (*Nature*'s "impact factor", measured by the independent organization the Institute of Scientific Information in Philadelphia, is higher than any other interdisciplinary scientific journal.)[16]

Along with the recognition of its influence, one would hope would comes a responsibility to ensure that alternative interpretation and scientific debate are presented especially when an article has large implications for public policies and is given the high profile of being a cover story.

The editors of *Nature* should have been well aware that there are serious concerns in the scientific world about the reliability of longline CPUE as a measure of abundance as these are clearly acknowledge in the supplementary material accompanying the paper that they posted on their WEB site. One would have hoped that before publishing what should have been recognized as having controversial conclusions with major social and economic consequences, alternative interpretations would have been sought. If *Nature* then decided to proceed with publication, it should have provided the alternative perspectives to ensure that the public and broader scientific community are aware of and have access to the nature of the scientific debate.

Nature, however, seems to have a different view on its responsibility in this regard. In reply to a letter submitted by Dr. Mark Maunder (IATTC) in response to the Myers and Worm's paper, *Nature* initially rejected the letter without explanation and suggested that issues be taken up directly with the author.[17] Maunder along with five other prominent tuna scientists[18] followed up this response with a letter to the editor in which he reported that he was unable to resolve the issues with the authors and pointed out that "there are many highly qualified fisheries experts that are also concerned about the Myers and Worm article". Maunder went on to state "Publishing highly questionable science and promoting it to the public without allowing timely critical review by qualified people (those who know the data and the methods) does science a disservice and will eventually destroy the already tarnished public perception of science".[19] In response to this follow-up letter, *Nature* acknowledge that the wide-spread criticism by experts in the field but refused to publish the response because it does not "take our knowledge forward in some discernible way."[20,21]

Based on their response, *Nature* appears to divorce itself from responsibility on the accuracy or general validity of the conclusions of an article once it has been published. However, knowing that what has been presented as fact is in fact uncertain is an "importance advance", particularly if such "facts" are having substantial impact on policy debates and management decisions. Given the well known and acknowledged impact that a publication in *Nature* can have, such a publication policy in the long run is likely to undermine the trust placed in *Nature* and similar journal to provide

[16]http://www.nature.com/nature/author/natureguide.html

[17]Personal communication, Dr. Mark Maunder, IATTC, LaJolla, CA.

[18]Dr. John Sibert, Pelagic Fisheries Research Program, University of Hawaii, Honolulu, HI; Dr. Alain Fonteneau, French Institut de Recherches pour de Dèvelopment, Victoria Iles, Seychelles; Dr. John Hampton, Oceanic Fisheries Program, Secretariat of the Pacific Community, Noumea, New Caledonia; Dr. Pierre Klieber NOAA Fisheries—Honolulu Laboratory, Honolulu, HI; Dr. Shelton Harley, IATTC, La Jolla, CA.

[19]Copies of this letter can be found on the WEB site of the Pelagic Fisheries Research Program, University of Hawaii (http://www.soest.hawaii.edu/PFRP/large_pelagic_predators.html).

[20]http://www.soest.hawaii.edu/PFRP/large_pelagic_predators.html and Dr. Mark Maunder (personal communication).

[21]Dr. Maunders and his co-authors persisted in their efforts to have Nature publish some form of response. Subsequent to the current article having been written and submitted for publication, Nature agreed to publish a response under "brief communications arising". Such communications are limited to 500 words (700 without figures) and are only available on line. The brief communication and response by Myers and Worm were "published" in May 2005 in the electronic version of Nature and nearly 2 years after the original Myers and Worm's letter to Nature [34,35].

an accurate and well-balanced representation of the most important new scientific findings, as well as a lack of understanding of the importance of uncertainty and criticism in the overall scientific process.

4. Concluding remarks

The issues raised in this paper about Myers and Worm's interpretation of the early declines in pelagic longline CPUE rates should not be taken to indicate that no problems exist with the present status of many of the stocks being fished, the sustainability of current catches and flow-on ecosystem effects from these removals. Regional fishery organizations (i.e. IOTC, CCSBT, ICCAT and IATTC) have raised serious concerns about the status and/or level of catch for a number of tuna and billfish stocks based on stock assessments that attempt to integrate all available information on the catch, effort, size distribution of catches and tag return data (where available). However, it is not the first 10 years of longline catches that are responsible for these concerns but the combination of increasing levels of longline catches and/or effort in conjunction with increasing purse seine catches (which includes sub-adult fish). In this context, it would be unfortunate if the debate sparked by Myers and Worm's paper about the effect of early longline catches distracted from the critical problem of developing and implementing effective management policies for these international tuna and billfish resources.

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