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Re: Revised Nature Manuscript **M11610 RH/mmh**

Dear Dr. Howlett,

We would like to submit our revised manuscript "Rapid worldwide depletion of predatory fish communities**"** as a letter to ***Nature***. We appreciate the thoughtful comments and suggestions by the editor and the three referees. We have positively responded to all comments and have revised our manuscript accordingly. We have also added an extensive, illustrated and referenced discussion of the individual datasets and their interpretation to the Supplementary Information.

In the following we provide a detailed point-by-point discussion of the improvements that were made. We respectfully disagree with the notion of reviewer #2 that our results may not be novel. We provide for the first time a global estimate of relative biomass of large marine predators, something that nobody has attempted before (the two other reviewers strongly support this). By compiling all available data, we also show for the first time that ten-fold declines in community biomass consistently occurred during the first 5-15 years of exploitation. The important management implication is that the state of marine fish stocks and ecosystems cannot be assessed if these early data are not collected or dismissed (as it is usually the case). Because most scientists do not have access to these early data, the magnitude of decline in worldwide fish communities has been severely underestimated. Several experts in the field have been very interested in, and surprised by these striking patterns.

The revised ms consists of an introductory paragraph (XXX words), a ms body (XXX words), a method section (XXX words), 30 references, 3 figures, and one table. We estimate this will take about 2.5 pages of printed space in ***Nature***.

We look forward to hearing from you soon.
Yours sincerely,

Ransom A. Myers
Boris Worm

Editorial comments

You remarked that the opening paragraph should serve as an introduction and non-technical summary, rather than an abstract. We have revised the opening paragraph accordingly, and presented it to colleagues specializing in other areas to check for general understanding.

Referee 1

This reviewer was very supportive of the paper. His only suggestion was to improve it by integrating three of the global maps from the supporting materials into one figure and presenting the meta-analysis (Fig. 2) as a table instead of a figure. We followed this suggestion. The advantage of presenting these maps is, that we can now discuss the spatial, as well as the temporal dynamics of early exploitation (see revised text).

Referee 2

The second reviewer supported our general conclusions, but questioned their novelty, contrasting our paper to D. Pauly's paper in SCIENCE ("Fishing down marine food webs", Science **279**:860-863, 1998). He also had questions about the declines of other marine predators, and the interpretation of the South Georgia trawl survey and Japanese longlining data sets.

Novelty of this contribution. Reply: Although our paper deals with a similar topic as D. Pauly's work, i.e. the effects of global fisheries on marine communities, it is original in many important respects. Pauly and colleagues' major finding was that they demonstrated a gradual decline in the mean trophic level of worldwide fish catches (from 3.3 – 3.1 from 1950 – 1994). This was suggestive of declines in apex predators, but since only catch data were used, no estimate of relative abundance could be derived. We provide such an estimate (along with confidence limits) for the first time. As we outline in our paper, such estimates of relative abundance are important for setting clear restoration targets (reviewer 1 and 3 also emphasize this point). Further, in contrast to Pauly's work we demonstrate that severe declines in apex predators generally occurred rapidly during the first few years of fishing. Pauly's report on mean trophic levels suggested a gradual, and possibly less severe decline (see their Fig. 1A). The important management implication of our finding is, that one is likely to be completely mislead about the state of the fishery and ecosystem, if data on the first years of fishing are not available, or ignored (which is often the case). Importantly, we do not present merely a few "case studies", but for the first time a global compilation of all data sets covering the early period of fishing. Almost all fishery biologists that we communicated with have been surprised by the magnitude and the striking generality of the declines. Finally, we dispute the compensation hypothesis, by presenting data, which suggest that initial compensatory responses happen, but are often reversed by new fisheries. In conclusion, our paper builds on earlier contributions by Pauly's group and others, but at the same time goes well beyond it

South Georgia data: The reviewer questions the quality of this dataset, citing concerns about the early Russian data, and the lacking of Patagonian toothfish from the dataset. The reviewer also criticizes the fact that we do not provide complete species information. **Reply**: We now provide complete species information on all data sets in the supplementary materials. With respect to the South Georgia data, we found that these are the best published data we could find on Antarctica, but agree with the reviewer that they are probably the weakest of our 13 datasets. To account for this uncertainty, we performed a sensitivity analysis, where we re-ran the meta-analysis without the South Georgia data. The results were virtually the same (initial rate of decline 14.8% [CI: 10.1-19.5], residual biomass proportion 9.6% [CI: 7.0-13.3]). The South Georgia time series was originally published by K.-H. Kock, an internationally recognized expert on Antarctic fisheries. We extracted the data from Fig. 1 in Kock and Shimadzu (1994). The authors combined VPA estimates with subsequent, more reliable survey data in order to derive an approximate estimate of original biomass on the South egorgian shelf (750 kt). In their analysis, they considered several species of icefish and notothenias (or rockcod), which are by far the most abundant demersal fishes in this area. The problem is that information on species other than the dominant rockcod *Notothenia rossii* was fragmentary in the early years, and there may have been some initial under-reporting of catches. However, this would make the results only more conservative, as the magnitude of the decline would be underestimated. We used the approximate estimates of other species biomass provided (with question marks) by the authors. These suggest an approximate biomass of 160 kt after the first two years of fishing. Together with the total reported removals of 514 kt (after CCAMLR catch statistics, Ref. 29), this comes close to the total biomass estimate of 750 kt, supporting this number as a reasonable estimate of total biomass prior to industrial exploitation. When we consulted with Dr. Kock, he confirmed that this is the best available estimate of initial biomass for South Georgia. Patagonian toothfish (*Dissostichus eleginoides*) is a pelagic predator, which is not reliably assessed by bottom trawls. Using trawl data, we do not make inferences about pelagic fish in the South Georgia ecosystem. However, it is well known that *D. eleginoides* is another typical example for a boom-and-bust fishery, where initial catches declined rapidly due to overfishing.

RAM CHANGED THE FOLLOWING:

Longline CPUE data: The reviewer questions whether the longline CPUE taken by itself is a useful index of abundance. GIVE QUOTE The concern is that the rapid initial declines could not be “real”.

WE SHOULD PERHAPS DROP THE NEXT POINT

We are well aware of this “belief” as we have had a Ph.D. student working on the issue for the last 2 years. No citation in the refererred scientific lieterature is given for this belief, because none appears to exist.

Below we show why this belief is incorrect, but from first principles a naïve observer would have to believe that it is unlikely that with all the new technology in the last 50 years, Japanese fishermen have become progressively less efficient in catching tuna. One also has to believe that large areas that once supported very productive fisheries, e.g. the tropical west Atlantic in 1950’s were abandoned to any longline fishing around 1980 for no reason.

DROP NEXT LINE?

We also point out that the claims that the decline in the whales stocks in the worlds oceans and the cod stocks off of eastern Canada could be true was dismisssed prior to careful data-analysis.

Reply: We have addressed this important question in detail in the revised ms and supplementary materials. The reliability of the longline CPUE series has been questioned for 4 principle reasons (only the first was cited by refreee 2, but we are trying to be thorough):

First, it has been claimed for some species that the declines in CPUE could not be accounted for by the estimated catches. When careful analysis of data with good catch data, e.g. 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 www.???GIVE WEB CITE). As this was the prinicpal initial species in the three “temperature” regions, we assume the referee has no difficulty with this part of our data and analysis. Similarly, there is no difficulty in accounting for the changes in abundance of western Atlantic bluefine tuna by estimated catches (www.iccat.es). However, reliable inference of age-structure is rarely available for the early years of a fishery, so simple models without age-structure are usually fit to such data. The idea that catches cannot explain declines in CPUE appears to be based upon the naïve application of these simple models, e.g. assuming simple logistic population dynamics. However, where this suggestion has been tested, it has not been found valid. For example Goodyear (REF) has shown that the rapid declines in North Atlantic swordfish and blue marlin are completely consistent with a simple model that includes age structure. We have found no documented case where this argument has been shown valid for the data considered here.

Second, it has been suggested that the longline CPUE declines may not represent true changes in abundance because catches for some species, particularly for yellowfin tuna have remained stable, or increased after the decline in longline CPUE has occurred (Alain Forteneau (CHECK SPELLING) pers.com. Indian Ocean Tuna Comm. (give address). This pattern is consistently in all three oceans for yellowfin tuna. For example, the catches and estimates of maximum sustainable yield for Atlantic yellowfin increased gradually from 1970-1995 (Restrepo 1998). This pattern was not seen for the other major species (Restrepo 1998). These species have higher age at maturity than yellowfin, and therefore less potential for rapid increases. The pattern for yellowfin is most easily explained as an increase in survival of juvenile fish, likely linked to the 10-fold declines in their predators. Such patterns are clearly predicted by ecosystem models that take species interactions into account (REF). Similar changes due to release from predation or competition appear to occur in some billfishes, as seen in Fig. 3A of our ms. Traditional assessments have ignored such interactions among species and the effects of fishing down predator biomass on remaining stocks.

The third reason that has been raised as to why the CPUE are not consistent with changes in abundance is that they are not consistent with changes in the length of fish caught over time (this reason has only been for marlin as far as we know, e.g. Suzuki??). However, when Goodyear (2001?) has shown using simulations that this objection is not valid.

Fourth, it has been suggested that the changes in the average depth at which longline fishing occurs makes the trends in CPUE difficult to interpret. As was discussed in the main text, these changes occurred around 1980, well after the CPUE declines had occurred. While the deeper depth of the hooks may reduce the catch of surface-dwelling marlins, depth has little effect on the catch rates of swordfish and bluefin tuna, and increases the catch rate for albacore and bigeye tuna (GET NAKANO REFERENCE). Different studies vary on the effects of depth on yellowfin catch rates. Thus, the shift in depth of hooks appears to increase the estimated relative abundance of the major species caught during the period (bigeye and albacore) or have little consistent effect (swordfish, yellowfin, bluefin). Increasing depth will reduce the estimates of the marlins, but they represent only a very small proportion of the catch since 1975.

Thus we argue that the decline in CPUE represent real data, which can be reconciled with catch data when considering age structure and multi-species interactions. Where we have reliable biomass data from research surveys, we see exactly the same pattern, of rapid initial declines in biomass (Fig. 1 j-m), resulting in an roughly 10-fold reduction in biomass. There is no reason, and no mechanism has been suggested, why similar declines should not occur in the open ocean. We feel that this striking generality across many disparate data sets and oceans is one of the most surprising and important results of our analysis. This generality only emerges, when looking at all the data, not by looking at single data sets, stocks, or species.

Thailand data: The reviewer notes that shrimp and squid may have increased in the Gulf of Thailand, despite general declines.

Reply: The data do suggest moderate increases (around 20%, on average) in squids (*Loligo* sp.), but not shrimp. However, this does not affect our conclusions about predatory fishes, all of which declined in abundance. Furthermore, *Loligo* is a pelagic species, and likely not reliably assessed by trawl gear.

Declines in other predators: the reviewer questioned whether our claim that "declines in other large predators such as marine mammals and sharks are not captured by our data, but may be of similar or greater magnitude than those of bony fishes" was well founded, specifically with respect to recovering marine mammal stocks.

Reply: We concur with the reviewer that the situation for mammals is more complex than for fish, due to the recent recovery of some populations. We therefore removed the statement that referred to mammals. For sharks and skates however, there can be no doubt that declines were as severe as for bony fishes. Our recent analysis of shark declines in the Northwest Atlantic, a global overview of shark fisheries (Stevens et al. 2000), and published information on the near extinction of large skates (Brander 1981, Casey and Myers 1998) re-enforce this point.

Ignorance to detail: In closing, the reviewer suggests that we may have ignored details of the fisheries that contributed to our data sets, and that we should obtain expert comment on these fisheries.

Reply: We have assembled these data sets over the last 5 years, constantly checking the data for consistency, and communicating with the scientists that were involved in collecting or analysing these data. The Northwest Atlantic data sets alone are the result of an intense 2-year research effort by R.A. Myers and J.M. Casey, involving careful standardization, analysis, and checking for errors. The Thailand data were discussed with several colleagues, such as V. Christensen, one of the most knowledgeable scientists working on Asian fisheries. With respect to the South Georgia data we consulted extensively with K.-H. Kock, the internationally acclaimed expert who compiled these data. Unfortunately, despite intense effort, we were not able to obtain the Antarctic raw data. With respect to the Japanese longline fisheries: we have discussed our results with almost every major scientist who has worked on these data, including numerous individuals at the major management bodies. The acknowledgements list a selection of those scientists who have provided especially valuable input. Thus, we strongly disagree with the notion that we have written this paper lightly, or treated the data sets uncritically. Of course, we do acknowledge that there is uncertainty associated with any one data set. Our chosen method of analysis, however, accounts for this uncertainty (a) by sharing information among data sets (in the mixed model) and (b) by providing error estimates for the parameters that describe the observed declines.

Referee 3

This reviewer is very supportive of the paper, emphasizing its novelty and highlighting innovative features. We followed all suggestions for improvement, such as:

- Replacing the term industrial fishing with industrialized fishing, as suggested.
- Inserting “exploitation” on page 3
- Improving the quality of the supplementary plots
- Improving the discussion of compensation due to release from predation.

References

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