

Fisheries

# Decline of Pacific tuna populations exaggerated?

Arising from: R. A. Myers & B. Worm *Nature* 423, 280–283 (2003)

Tuna have been the target of large-scale industrial fisheries in the Pacific Ocean and elsewhere since the 1950s. In their analysis of Japanese longline-fishery catch-per-unit-effort (CPUE) data, Myers and Worm<sup>1</sup> conclude that the community (species-aggregated) biomass of large pelagic fish, mainly tunas, was reduced by 80% during the first 15 years of exploitation and is now at 10% of pre-industrial levels. We show here that an assumption critical to this conclusion — namely, that Japanese longline CPUE acts as an accurate index of community biomass — is invalid. Our results indicate that biomass decline and fishing impacts are much less severe than is claimed by Myers and Worm<sup>1</sup>.

Interpretation of the species-aggregated CPUE as an index of community biomass rests on the assumption that catchability (a coefficient specifying the proportionality between CPUE and abundance) is constant across species and over time. The former is unrealistic because, among other things, the species have different depth distributions and hence different vulnerability to longline gear<sup>2</sup>. The evolution of tuna longline fisheries in all oceans<sup>3</sup> has seen changes in fishing strategies (and hence catchability) as different species have been targeted. In the early 1960s, Japanese longliners changed from targeting albacore (*Thunnus alalunga*) and yellowfin (*T. albacares*) for the canned-tuna market to bigeye (*T. obesus*) and yellowfin tuna for the Japanese sashimi market<sup>3</sup>. Japanese longline CPUE for albacore declined rapidly not because of declining albacore abundance, but because of this change in species targeting. By contrast, Taiwanese longliners have consistently targeted albacore in subequatorial waters of all oceans, and their CPUE provides a better index of albacore abundance. These results show that CPUE has declined by 50% over 40 years in the South Pacific, but they do not replicate the rapid and much larger decline in CPUE in the 1960s evident in the Japanese data (Fig. 1a).

The Myers and Worm analysis<sup>1</sup> excludes data from the equatorial Pacific, where the highest catches are taken and which is the core habitat for tropical tunas. When these data are included, yellowfin-tuna CPUE in the western Pacific is seen to decline by 70% over 50 years, during which time annual catches by longline and other methods increase from insignificant levels in the early 1950s to more than 400,000 tonnes by the late 1990s (Fig. 1b). By contrast, the CPUE for bigeye tuna has been stable for over 40 years, despite continuously increasing catch (Fig. 1c). Changes in fishing strategies

designed to target the deeper-swimming and higher-value bigeye tuna occurred during the 1970s (ref. 3), making it unlikely that CPUE accurately reflects changes in abundance for either species unless it is adjusted to account for the shift in targeting<sup>4</sup>. Unadjusted Japanese longline CPUE tends to overestimate abundance decline for yellowfin tuna and underestimate abundance decline for bigeye tuna.

Stock assessments rely on a range of data in addition to CPUE, including catch, size composition, tagging and biological data. When stock-assessment models<sup>5,6</sup> that consider all the available data are applied to Pacific tunas, fishery-induced declines in abundance during the 1950s and 1960s of the magnitude proposed by Myers and Worm<sup>1</sup> are found to be extremely unlikely<sup>7–12</sup>. Moreover, where declines do occur, they are not, as claimed by Myers and Worm, due exclusively to fishing. It is impossible, for example, under conventional population-dynamics theory to attribute the pre-1970 decline in yellowfin CPUE to fishing at a time when the total catches were less than one-tenth of today's catches. In summary, the trends in catches and CPUE (Fig. 1) and the results of stock-assessment modelling show that the basic assumption of Myers and Worm that CPUE is proportional to

abundance is incorrect and inconsistent with any known population-dynamics effect.

Fisheries management cannot be based solely on examination of CPUE trends. In our opinion, management advice for Pacific tunas based on the conclusions of Myers and Worm<sup>1</sup> would be misleading. For example, current stock assessments indicate that bigeye is probably overexploited<sup>8,12</sup>, that yellowfin is fully exploited<sup>7,11</sup> and that southern albacore is lightly exploited<sup>10</sup>; management priorities inferred from these assessments would be reversed if assessments were based only on examination of Japanese longline CPUE. Also, the implication that all CPUE and abundance decline is fishery induced ignores the impact of environmentally induced recruitment variation<sup>13–15</sup>. For fisheries management to be effective, it is critical to discriminate between the effects on pelagic fish populations of environmental factors and fishing.

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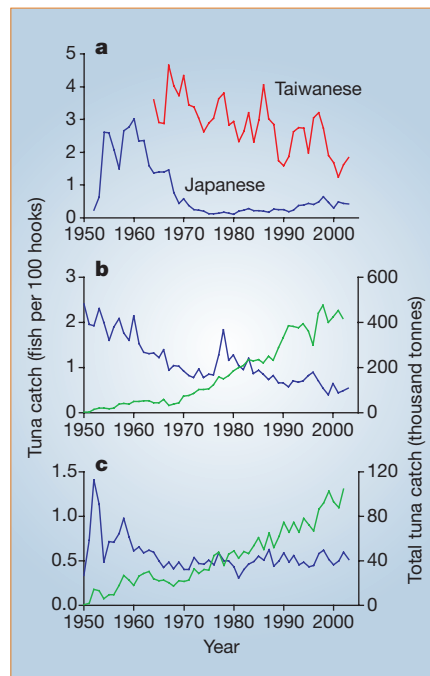
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**Figure 1** Tuna catch per unit effort (CPUE) in the Pacific Ocean. **a**, Albacore tuna CPUE by Taiwanese (red) and Japanese (blue) longliners in the Pacific Ocean, south of the Equator. **b**, Yellowfin and **c**, bigeye tuna CPUE by Japanese longliners (blue) and catch by all fleets (green) in the western Pacific Ocean (west of 150° W, south of 20° N).

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*Myers and Worm reply* — Hampton and colleagues<sup>1</sup> challenge one aspect of our report on global declines in predatory fish communities<sup>2</sup>. They posit that Japanese longline catch per unit effort (CPUE) may be a biased abundance estimator for albacore, bigeye and yellowfin tuna (*Thunnus alalunga*, *T. obesus* and *T. albacares*) in the tropical Pacific, one of the 13 regions we considered. The appropriate use of CPUE data is an important technical issue with substantial policy implications. We have therefore made every effort to check and correct the data for potential bias and to validate them against independent survey data. The results of our analyses<sup>3–7</sup> indicate that our main conclusions are still justified. We note that Hampton *et al.* also use uncorrected CPUE data, assuming that CPUE is proportional to abundance (see ref. 8, for example). As yet, they have not demonstrated a mechanism that could explain why the assumption of proportionality should break down.

We agree that changes in targeting, particularly the increase in the depth of hooks, have altered catchability; however, when the effects of depth are estimated<sup>3</sup>, the combined CPUE shows declines greater than those we estimated originally<sup>2</sup>. Other recent analyses of gear changes suggest that newer gear is twice as effective as older gear<sup>9</sup>, potentially obscuring continuing declines in stock abundance from CPUE data.

Hampton *et al.* discuss two cases. First,

they note that Taiwanese longline CPUE for albacore does not match the Japanese data (decline of about 50% compared with about 90%). However, the Taiwanese data may be misleading as they commenced a decade after the Japanese data and so fail to capture the start of industrialized fishing. Intense albacore fisheries were well developed in this region before the Taiwanese data were collected and had large effects on this species<sup>10</sup>. Thus, less of the decline is seen in the later data (the ‘shifting baseline’ syndrome<sup>11</sup>). The same issue applies to the tropical Pacific, where populations were exploited previously — those areas were therefore excluded from our analysis.

Second, the authors observe that for Pacific yellowfin and bigeye the initial decline in longline CPUE occurred under moderate fishing effort, whereas CPUE remained low and stable under later regimes of high fishing effort. We explained this pattern by an increase in fish productivity, caused by the decline of large predators. Both ecosystem models<sup>12,13</sup> and survey data<sup>5</sup> support this mechanism.

We note further that CPUE is measured in units of numbers of fish large enough to be harvested by longline hooks, which are very size-selective. Initially, there was an accumulated biomass of large fish. Thus, CPUE was very high, but dropped rapidly as those susceptible individuals were removed. CPUE declined as the fishery became completely dependent upon new fish recruiting to the population. Thus, related shifts in size distribution, CPUE and fishing effort may lead to rapid depletion of large individuals, even at relatively low initial fishing effort.

This simple mechanism is consistent with

the large (2–4-fold) reduction in the average size of large predatory fish, as seen from research survey data<sup>5</sup>. The same surveys revealed an 89% decline of large pelagic biomass in the tropical Pacific<sup>5</sup> that precisely matched our global estimate<sup>2</sup>. Hampton *et al.* imply that environmental effects are partly to blame for these changes. Although environmental factors can drive year-to-year variation<sup>8,14</sup>, they cannot explain long-term, worldwide declines, particularly as these coincide with the onset of industrialized fishing<sup>5,15</sup>.

We welcome the incentive from Hampton *et al.* to refine and critically evaluate abundance estimates derived from CPUE data. However, in following their call, either by correcting for potential biases or by analysing independent data sets, we find that our estimates of decline remain conservative.

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