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Comment on "Impacts of Biodiversity Loss on Ocean Ecosystem Services"

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Worm *et al.* (Research Articles, 3 November 2006, p. 787) investigated the importance of biodiversity to marine ecosystem services across temporal and spatial scales. In projecting the extent of future fisheries collapse, we argue that the authors inappropriately extrapolated beyond their available observations and used data on marine reserves and fishery closures that are not representative of global fisheries.

The Worm *et al.* study (1) represents a useful contribution to the discussion of human exploitation of the oceans and the relation between biodiversity and ecosystem services. The conclusion is that high biodiversity in the marine environment is associated with ecosystem stability and resilience, and with the productivity and recovery potential of vital fisheries. However, we note two potential shortcomings of this study. First, we question the validity of projecting future fisheries collapse using the time trend in the depletion of commercial fish stocks. Second, conclusions about the impact of marine reserves and fishery closures are not based on representative samples.

Worm *et al.* (1) modeled the depletion of stocks as a function of time, which they then used to project a 100% collapse for all currently fished taxa by the year 2048. To reach this conclusion, however, the authors extrapolated far beyond the range of the available observations (0 to 30%

collapse between 1950 and 2003). At the same time, they assumed a causal relation between the number of stock collapses and time, when no such relation has been demonstrated. To illustrate the inappropriateness of making such an assumption, we model the increase in the German unemployment rate over time (2) as an exponential relationship ($r = 0.90$; $N = 45$). Extrapolating beyond the range of observations available (0.5 to 9.5% unemployment between 1961 and 2005) projects 100% unemployment by approximately 2056. In both examples, time does not have any real explanatory power. Hence, to extrapolate into the future oversimplifies the issue and ignores any causal relations within the ocean system that are involved in stability, resilience, productivity, and adaptive behavior of fisheries, each of which may change in response to changes in the ecosystem.

Furthermore, Worm *et al.* compared trajectories of fisheries collapses in species-poor and species-rich ecosystems. However, the seemingly arbitrary split into high- and low-diversity systems essentially results in a comparison between tropical and boreal systems rather than a comparison between similar ecosystems with contrasting degrees of biodiversity degradation. Thus, the observed differences may have multiple causes, including delayed fisheries industrialization in some regions. Additionally, a comparison on the basis of percentages of collapsed taxa makes interpretation difficult, since identical numbers of collapses can result in very different percentages.

We agree with Worm *et al.* (1) that the number of overexploited or depleted fish stocks has been increasing over several decades and the United Nations Food and Agriculture Organization (FAO) reports an increase from about 10% in the mid-1970s to around 25% in the early 1990s (3). The FAO data indicate, however, that the increasing trend has stabilized since the early 1990s, whereas the Worm *et al.* data indicate that the increasing trend continues.

Finally, Worm *et al.* examined the utility of marine reserves and fishery closures, concluding that they are beneficial to ecosystem services, including fisheries. However, their supporting online material indicates that of the 122 data sets analyzed, 73 are from coral reefs (mainly tropical), whereas only 11 are from habitats that support groundfish fisheries, and none are from pelagic fisheries. Although we agree that marine protected areas (MPAs) have been shown to be beneficial for many ecosystems, we are unconvinced that the conclusions from this subset are representative of the situation across global fisheries because groundfish and pelagic fisheries are the most important in terms of fisheries production (3). Furthermore, the potential efficacy of MPAs at high latitudes remains uncertain, although such information will be important for fisheries management in Europe, North America, Australia, and New Zealand, where the need for ecosystem-based management has been recognized. A recent study (4) suggests that spatial management strategies (e.g., MPAs) will be less effective at high latitudes if they are constructed at scales similar to reserves in tropical regions, because dispersal potential and gene flow in marine fish increases with latitude.

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