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Reinterpreting the State of Fisheries and their Management

Ray Hilborn

School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, Washington 98195, USA

Abstract

A series of recent high-profile papers in *Science* and *Nature* have led readers to believe that most fisheries worldwide are overexploited and that current fisheries management practices have universally failed. In reality, current fisheries management is working well to achieve the legislated objective of MSY in some countries but is failing in others. Here, I present three interpretations about the status of fisheries management that are widely accepted and for each consider an alternative interpretation of the data. I propose that, rather than abandoning current approaches to fisheries management, we should expand the use of the management tools used in fisheries that currently achieve biological and economic sustainability.

Key words: fisheries; crisis; management; biological; economic; sustainability.

Perceptions of the Fisheries Crisis

Since the 1990s, many papers have appeared in *Science* and *Nature* describing the decline of fisheries worldwide (Ludwig and others 1993; Casey and Myers 1998; Pauly 1998; Jackson and others 2001; Myers and Worm 2003; Baum and others 2003) and projecting their total collapse (Worm and others 2006). For scientists interested in marine conservation, this has led to a commonly expressed world view that often emerges in introductions to papers dealing with fisheries and ocean matters. For example, '' … fishing in the ocean is no longer sustainable. Worldwide, we have failed to manage the ocean's fisheries—in a few decades, there may be no fisheries left to manage'' (Marra 2005).

Here, I describe these interpretations as a set of tenets regarding fisheries management that now appear to be widely accepted, and present the key papers that have established each tenet along with the policy implications. For each tenet I suggest a reinterpretation or alternative tenet, present evidence that supports it and discuss the appropriate public policy should the alternative tenet be accepted. As in many issues of public policy there are alternative interpretations of the total body of data but the alternative interpretations have not appeared in the general ecological literature. Rather than concluding that fisheries management has failed and new solutions are needed, I propose that we look to where fisheries management is ecologically and socially sustainable and emulate the forms of fisheries management used in those places. I suggest that, beginning in the 1990s, new approaches to fisheries management have been implemented and have proved successful in several places, and it is these new methods that should be followed. The key elements in these methods are elimination of the competitive nature of fisheries, aligning incentives for fishing fleets with societal objectives and effective implementation of formally defined harvest rules (Hilborn and others 2005; Beddington and others 2007). Box 1 illustrates the basic theory of single species management and surplus production.

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**Corresponding author; e-mail:* rayh@u.washington.edu

Tenet I

Most of the World's Fisheries are Overexploited and, if the Current Trend Continues, all Major Fisheries Will Collapse

Worm and others (2006) defined ''collapsed'' as fish stocks with current catch that is less than 10% of the largest historical catch. Using this definition, they calculated the proportion of the world's fisheries that were collapsed for each year since 1950, and determined that, in 2003, 29% of the world's fish stocks were collapsed. The authors projected that, by 2048, 100% of all stocks would be so. Jackson and others (2001) argued that overfishing had nearly extirpated the original larger fish fauna of coastal ecosystems, ranging from sharks and rays in Caribbean reef systems to cod in coastal Maine.

The policy implication that follows holds that governments and management agencies worldwide are unable to prevent stock collapse by the use of existing catch and effort restrictions. The new solution proposed as essential to sustainability are networks of areas that are permanently closed to fishing (Marine Protected Areas or MPAs) (Allison and others 1998).

Alternative Tenet

Fisheries Management is Working in Some Places and Failing in Others

The effectiveness of fisheries management worldwide differs considerably, but I suggest that the overall situation is not as dire as Tenet I suggests (Mace 2004; Garcia and Grainger 2005; Hilborn and others 2005; Beddington and others 2007; Hilborn 2007a). For example, in the USA, the proportion of overfished stocks declined from 33% in 2001 to 26% in 2005. In 1999, the National Marine Fisheries Service estimated that sustainable yield in the USA would only increase by 20% if all overfished stocks were rebuilt (NMFS 1999). Worldwide (FAO 2005), using abundance data (or, in some cases, catch data evaluated with local knowledge, Figure 1), the proportion of major fish stocks that are overfished has been stable in the range of 20–30% from 1990 until the present. The accelerating decline seen in the catch-based Worm and others (2006) method is both inconsistent with abundance-based data used in the USA and by the United Nations Food and Agriculture Organization (FAO), and has been broadly criticized (Branch 2007; Hilborn 2007b; Holker and others 2007; Jaenike 2007; Longhurst 2007; Murawski and others 2007; Wilberg and Miller 2007). Using the same method, one would predict that most of the American fisheries in the Bering Sea have collapsed (Figure 2). Yet abundance-based analyses for this region show only two species are overfished (NMFS 2005). Many of the major Alaskan fisheries have been certified as sustainably managed by the Marine Stewardship Council (http://www.msc.org/), and Alaska stands out as an area of generally successful management. In the USA generally, as well in other countries, including Iceland, New Zealand and Australia, management systems are working to achieve fisheries sustainably (Cunningham and

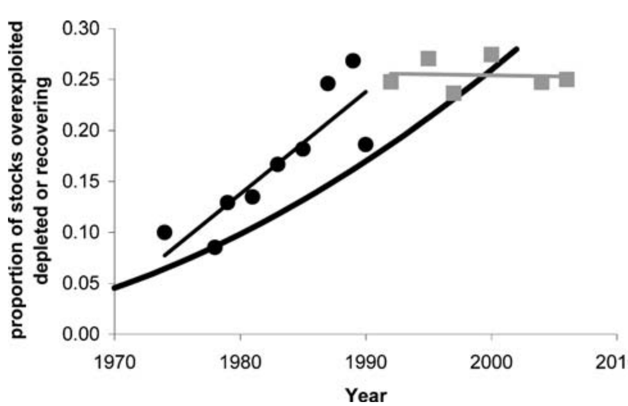

Figure 1. Trends in the proportion of world fisheries classified by FAO as overexploited, depleted or recovering. Data supplied by FAO and originally appear in FAO (2005). I have broken the data into a period of increase (up to 1990, in *black circles*) and stability (after 1990, *grey squares*). FAO has produced its estimates at irregular intervals. The *thick black line* is the estimate by Worm and others (2006) of the proportion of fish stocks worldwide that are collapsed, and shows an accelerating trend. Both Worm and others (2006) and FAO estimate current levels in the range of 25–30%, although the FAO analysis suggests stability whereas the analysis by Worm and others suggests rapid acceleration of stock depletion.

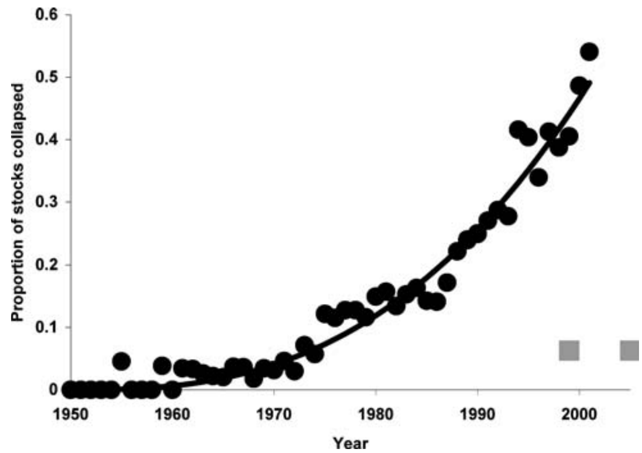

Figure 2. Percentage of Eastern Bering Sea fish stocks classified as collapsed (landings <10% of their historical maximum) using the method of Worm and others (2006). Data supplied by Dr. T. Essington and is from the same data base used by Worm and others (2006). Stocks with less than 1,000 *t* total catch excluded. This analysis estimates that currently more than 50% of the stocks in the region have collapsed, whereas abundance-based analysis (*grey squares*) shows only 2 out of 32 stocks were overfished in 1999 NMFS (1999) and 2005 (NMFS 2005). This ecosystem is widely regarded as one of the best managed fishing systems in the world. The specific problem with this analysis by Worm and others (2006) is that for over half of the stocks in the data-base, there are no regular catch statistics and most collapses are artifacts of how catches are estimated.

Bostock 2005; Grafton and others 2006). In these countries, management agencies are achieving the legislated objective of fisheries management, that is, to maximize sustainable yield. However, in other parts of the world, such as Europe, the lessons of the past have not yet been absorbed and agencies are still unable to reduce catch as necessary when abundance declines. In other places, such as much of Asia and Africa and some international waters, institutions do not exist to achieve biological sustainability (Hilborn and others 2003; Hilborn 2007a).

There is no doubt that many fish stocks and marine mammals were depleted prior to 1950 (Jackson and others 2001; Hilborn and others 2003), when modern fish statistics began, and the depletion of these stocks represents a significant loss of biodiversity. However, stocks depleted before 1950 cannot represent any major level of potential production on a world-wide basis because the total removals before 1950 were small. For instance, cod in the North Sea reached their highest recorded abundance during the 1960s (Cushing 1982), and were higher in abundance during the early 1990s than they had been in 1905–1909 (Rijnsdorp and others 1996).

The primary policy implication of this alternative tenet is that methods to achieve sustainable fisheries are available and have been applied in some places. By eliminating the competitive nature of fisheries in a ''race-to-fish'' and reducing incentives for fleet expansion, overfishing can be avoided or eliminated. Many (Hilborn and others 2003; Grafton and others 2006; Beddington and others 2007) identify the root problem as excess fishing capacity generated by the race-to-fish and have difficulty accepting MPAs as an essential solution to fisheries management because MPAs simply shift effort elsewhere and are treating symptoms (overfishing) rather than addressing the root cause (Norse and others 2003). Beddington and others (2007) also identify specific biomass targets as an key ingredient in fisheries successes in industrialized fisheries.

Tenet II

The Species at the Top of the Food Chain in Marine Ecosystems have been Depleted to Low Abundance, and Fishing Fleets Worldwide have been Forced to Move to Less Valuable Fish Lower Down the Food chain

This tenet is that all the big fish are gone. Myers and Worm (2003) argue that most of the large pelagic species of the ocean (tunas and billfish) were depleted to between 10 and 20% of their original biomass by 1980. For example, the catch-per-hook of tuna and billfish in the tropical and temperate Pacific Ocean declined from ten fish per 100 hooks before 1960 to less than two fish per 100 hooks by 1980. Pauly and others (1998) showed that the mean trophic level of fish in the catch in most of the world's major marine ecosystems has declined and suggest this indicates a ''fishing down the food chain'' consisting of depletion of large high trophic level fish (such as tuna), with fleets moving onto smaller fish (such as herring) at lower trophic levels.

This tenet and others also implies that existing management has not sustained fisheries on the target stocks, and again the authors argue MPAs are the needed solution. ''It is likely that continuation of present trends will lead to widespread fisheries collapses … we suggest that in the next decades fisheries management will have to emphasize the rebuilding of fish populations embedded within functional food webs, within large ''no-take'' marine protected areas'' (Pauly and others 1998).

Alternative Tenet

The Large Fish of Many Marine Ecosystems Remain in Many Places Highly Productive, and the Change in Mean Trophic Level more Commonly Reflects Increased Catch Of Lower Trophic Level Fish, not Declining Catch of High Trophic Level Fish

Although most species of large fish of the world have been reduced in abundance owing to fishing, in many major fisheries the large fish species remain at or above levels that produce optimal yield. The difference in view is whether the large fish are widely depleted, or simply fished down to levels that produce MSY. In refutation to Myers and Worm (2003), Sibert and others (2006) showed that the major large pelagics of the Pacific Ocean (skipjack, yellowfin, bigeye and albacore tuna and Pacific blue shark) remain at or above target levels for maximum sustained yield. Rather than having collapsed by 1980, as Myers and Worm suggested, Sibert and others (2006) showed these stocks are currently at or over the scientifically specified desired levels. Although most cod stocks in the N. Atlantic are badly overfished, the record is not uniformly discouraging. The two largest cod stocks in Europe, in Iceland and Norway, are highly productive and far from collapsed (Brander 2007). Several papers have criticized the methods used in Myers and Worm. Walters (2003), Hampton and others (2005) and Polacheck (2006) argue that the declines estimated by Myers and Worm are greatly exaggerated because they naively used catch per hook as an index of abundance in a fishery that had changed behavior (time, place and depth of fishing) dramatically between 1950 and 1980. Most national and international fisheries legislation mandates fishing to maximize the sustainable harvest, which, in turn, means fishing stocks down to somewhere between 20 and 40% of their unfished biomass (Hilborn and Walters 1992). Thus, declines in abundance as the fishery develops are an inevitable consequence of achieving sustainable yield, but are often seen as signs of serious concern by those interested primarily in abundance.

Essington and others (2006) show that the declining mean trophic level of fish caught reported by Pauly and others (1998) is generally not due to collapse of the higher trophic levels. For two thirds of marine ecosystems, the catch (in biomass) from high trophic levels is still increasing but the catch of lower trophic levels is increasing even faster. Rather than being on the brink of running out of fish, the higher trophic levels, in most marine ecosystems, remain productive (Essington and others 2006). Of course, in the other third of marine ecosystems, catch of the high trophic levels is declining and there is no doubt that some of these ecosystems are overfished, as in the Gulf of Thailand (Stobutzki and others 2006). This alternative tenet also leads us to ask why stocks in some areas are doing better than in other areas.

Part of the conflict in perceptions of the status of fisheries and marine ecosystems comes from a focus on abundance as opposed to sustainable yield. Fish stocks might be at relatively low abundance, indicating failed management to some, while still producing at or near MSY, indicating success to others. The case of orange roughy in New Zealand illustrates this distinction. Orange roughy is commonly used by conservation groups as an icon of poor fisheries management and collapsed stocks (http://www.ens-newswire.com/ens/may2004/2004-05-31-03.asp). Hilborn and others (2006) showed that New Zealand orange roughy (*Hoplostethus atlanticus*) stocks are, on average, in the biomass range that produces MSY (Figure 3), and the loss from overfishing a few small stocks is only 8% of the potential yield. Hilborn and others argued that most New Zealand orange roughy fisheries could be cited as an example of successful, rather than failed, management. One could view the rapid decline in abundance as the fishery developed as a catastrophic collapse or, alternatively, as the planned development of a new fishery leading to near legislated outcomes.

There are, however, many places where larger, more valuable fish have been overfished and depleted, as in many reef ecosystems (Jackson and others 2001) and cod in the N. Atlantic. Some

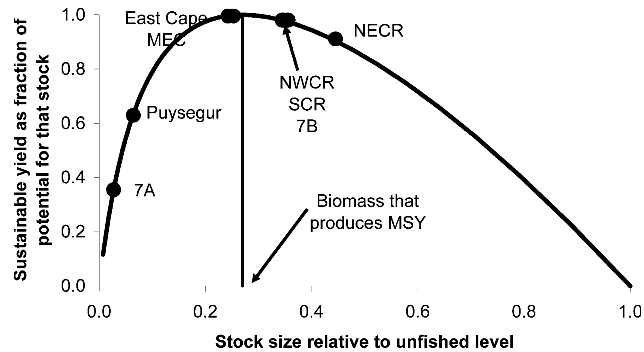

Figure 3. Status of orange roughy (*Hoplostethus atlanticus*) stocks in New Zealand. The *Y* axis is the sustainable yield relative to the maximum sustainable yield for that stock. The *dots* represent the status of individual stocks and the *solid line* represents the expected sustainable yield at that stock size using the assumptions of the models used for management advice. MSY would be achieved at 27% of unfished stock biomass and the *vertical line* indicates this level. Individual New Zealand stocks are labeled. Two of the stocks (Puysegur and 7A) are overfished, producing less than maximum potential yield, leading to a loss of 8% of the total potential yield from the system (see Hilborn and others 2006 for details). The Northeast Chatham Rise (NECR) stock is at a level well above BMSY. The Northwest Chatham Rise (NWCR), South Chatham Rise (SCR) and 7B stocks are slightly above BMSY. The East Cape and mid East Coast (MEC) stocks are at BMSY. From the perspective of sustainable yield, these stocks in aggregate are performing at 92% of maximum with the only loss in potential yield coming from the Puysegur and 7A stocks. However, all stocks are at much lower abundance than they were before fishing began, and those who equate declines in abundance to poor management cite these fisheries as poorly managed. Puysegur and 7A are at very low abundance, raising concerns for all parties and fishing has been closed. Reproduced with permission from Hilborn and others (2006).

jurisdictions have learned the lessons of the past, whereas others have not.

The policy implication of alternative tenet II is that single-species management, when successfully implemented, works well for target stocks, and if we can maintain stocks at levels that produce near MSY, the productivity of ecosystems will not be threatened. However, the lessons of successful fisheries also show that ecosystem-based management (Pikitch and others 2004) has an important role, especially in avoiding by-catch of non-target species such as marine mammals, birds and reptiles (Murawski and others 2007).

Tenet III

Fishing Methods, Particularly Bottom Trawling, are Destroying Increasingly Large Areas of the Ocean, And Reducing Their Productive Capacity

Watling and Norse (1998) argued that bottom trawling is analogous to forest clear cutting, and that the ocean area clear-cut each year is comparable to the entire Amazonian rain forest. The impact of bottom gear on benthic ecosystems has been the subject of numerous review articles (Barnes and Thomas 2005), summarized by the NRC (2002).

The policy implication of this tenet is that we need to ban bottom-contact fishing gear and move to other fishing methods, such as pots and hook-and-line, which have less impact on benthic ecosystems. However, even pots and hook-and-line may have adverse impacts on bottom flora and fauna. Non-governmental organizations have repeatedly called for such a ban and, in response, increasing areas of the ocean are being declared trawl-free zones.

Alternative Tenet

The Impact of Bottom Trawls and Dredges is Highly Variable by Habitat and, in Some Areas, Might be Neutral, and Most of the Area Trawled in any Year was Trawled the Year Before

Certainly, bottom trawling dramatically reduces the diversity of some kinds of habitat, particularly corals, but in other habitats, such as mud and sand bottoms, the impact on ecosystem structure and function is much less (Collie and others 2000; Kaiser and others 2006; Simpson and Watling 2006). NRC (2002) showed that the area trawled in one year had usually been trawled the year before, hence Watling and Norse's assertion that it is like clear cutting the Amazonian forest each year is inaccurate. Almost the entire bottom in areas such as the North Sea and Gulf of Mexico are trawled several times each year, and any benthic features sensitive to trawling, such as corals, have long since been impacted. In trawl fisheries on complex bottom mixtures of hard and soft structures, such as California, Oregon, Washington and British Columbia, each vessel trawls the same set of ''shots'' year after year (Branch and others 2005) amounting to 10% of the total bottom. These shots avoid major hard bottom features.

Perhaps the most interesting element of the debate on the effect of trawling is whether trawling modifies productivity of marine ecosystems for the target species. The unstated implication of Tenet III is that trawl-induced changes have detrimental effects on production of desired species. However, neither the NRC report (2002), nor any other papers I could find address this question. Because heavily trawled systems, such as the North Sea and Gulf of Mexico and Georges Bank, remain very productive, their productive capacity for target species cannot have been dramatically reduced by trawling. For instance, in the Georges Bank, scallop, lobster and haddock all are at or near historical highs in abundance or yield (Hart and Rago 2006; Murawski and others 2007) despite a century of intense trawling.

The policy implication of this alternative tenet is that we should move to ocean zoning, where trawling is permitted only in some areas. This is already the case in many places such as Alaska, but the prevailing culture has been to allow trawling everywhere unless explicitly excluded. It is accepted that trawling modifies sensitive bottom habitats. Recognizing that there are highly sensitive habitats, it would seem prudent a priori to prohibit bottom contact gear in such areas.

Moving Towards Solutions

The views that I put forward here were summarized by Mace (2004) ''I believe that the current perception of the status of marine species and ecosystems is overly alarmist; at best unhelpful and at worst destructive''. The tension between this view and those that hold to the primary tenets described earlier can best be illustrated by the alternative views regarding the solutions to the current crisis. Those who perceive the problem as biological loss of diversity and decreased abundance propose the solutions of MPAs and more ecosystem considerations (Allison and others 1998). Those interested in sustainable harvesting generally see the root problem as excess fishing capacity caused by the race-to-fish in the current governance system and propose solutions of changed governance, incentives and management rules (Hilborn and others 2005; Grafton and others 2006; Beddington and others 2007). My view is that the race-to-fish sets the stage for the failure of agencies to reduce fishing pressure when needed. This may occur because the agencies lack the institutional will or power to reduce fishing pressure, or because the science has failed to identify the need for reductions in fishing (Walters and Maguire 1996).

MPAs, ecosystem approaches and reducing the race-to-fish are compatible, and in the USA recent legislation has mandated both dedicated access and an ecosystem approach. There is increasing recognition within fisheries management agencies that there are a range of benefits to be obtained by maintaining fish stocks at levels higher than would produce MSY. These benefits include higher catch-per-hour fished for commercial fishermen, more stability of catch, and less impact from fishing on all elements of the ecosystem (Hilborn 2007c).

Thus, although there are competing views on the state of fisheries and their ecosystems, and the appropriate policy prescriptions, both views generally share a desire to see lower fishing pressure, higher fish abundance and less impacted ecosystems. The challenge is to determine which tools will best achieve such outcomes.

Box 1: The Theory of Sustainable Exploitation

Experience with exploited fish populations shows that there exists a relationship between fish population size, and the average net increase in biomass (net productivity) that can be taken as sustainable yield similar to that shown in Figure 4A. At high population sizes (stock biomass), the population does not increase owing to competition for resources and there is little net productivity. At low population sizes (low stock biomass), the rate of net productivity is high, but the total net production is low because of the small population size. The peak in net production can occur over a range of possible stock sizes, with Figure 4A showing cases where the peak occurs at 18, 32, 50 and 70% of unfished abundance. Figure 4B shows the empirical data for yelloweye rockfish in California and the MSY occurs at roughly 50% of the unfished stock size.

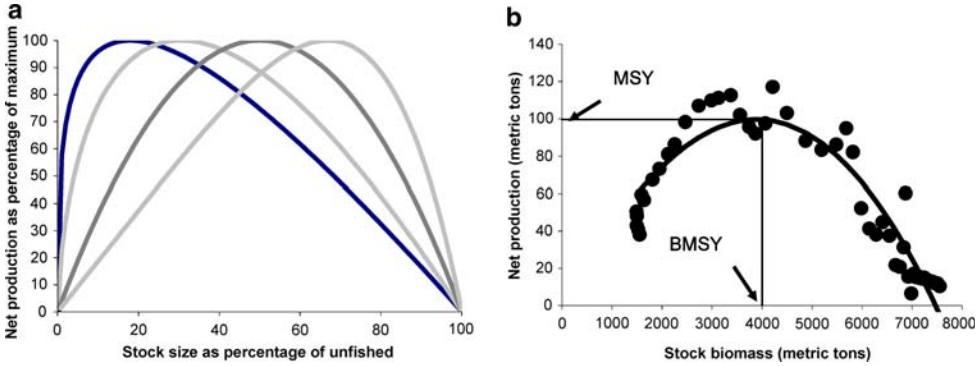

Figure 4. **A** The theoretical relationship between stock size and net production (sustainable yield) for four possible biological relationships. **B** The relationship between stock biomass and net production for yellow-eye rockfish (*Sebastes ruberrimus*) off the west coast of the USA. The *smooth curve* represents a *fit curve* showing average production at each level of stock size. The *vertical line* represents BMSY and the *horizontal line* MSY. Data from http://www.pcouncil.org/groundfish/gfsafe0406/Yeye06_entire_final.pdf

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