CHAPTER 5

The Global Status of Fisheries

a long tale of scientists, opinions, and papers written and refuted, all in the pursuit of the same truth

Gloom and Doom

All Fisheries Will Be Collapsed By 2048!

So said the front pages of The New York Times and the Washington Post, even the BBC evening news covered it on November 3, 2006. Front-page headlines about fisheries are rarer than hen’s teeth, unless of course it is really bad news. And so it seemed to reporters covering a Science magazine paper by Boris Worm and thirteen others, stating that, if current trends continue, all commercially exploited fish stocks would collapse by 2048.

Was it true? Not exactly, and certainly not regarding a total collapse by all. In the fisheries world, the decline of fisheries was hardly hot-off-the-press news, but it had long been a concern. There had been reams of scientific papers and coverage by popular media about it for at least a decade. Don Ludwig, Carl Walters, and I had published an article in 1993, also in Science, warning that fisheries managers need to act before stocks are in trouble, and that waiting for scientific certainty about fish stocks was a prescription for increased overfishing. I am quite proud of this paper: it is my most cited one, and it too was covered by The New York Times, even with a picture of the three of us. Needless to say, we did not make the front page, but were relegated to the back.

When Canada closed the Newfoundland cod fishery in 1992, the story of global fish stock collapse received its greatest boost. Cod had been the backbone of Newfoundland’s economy for 500 years. In the 1960s, foreign fleets had plundered the stock, but they were evicted by the 200-mile zone declaration in 1977. Canada controlled the fishery now, and its managers were supposed to rebuild it. It obviously did not work out that way. The closure in 1992 was a terrible blow to the fishermen, but it was hoped that it would take only a year or two for the stock to recover and they could go fishing again; 25 years later, there are signs of rebuilding but not enough yet to allow any significant fishery.
Cod is the poster child of fisheries mismanagement, and Mark Kurlansky is its biographer. In *Cod: A Biography of the Fish That Changed the World,* he tells us how important cod was to the social fabric and economic strength of Newfoundland, Iceland, and the State of Massachusetts. In the 1600s, one could “walk across the backs” of cod, they were so plentiful. Then came the long, slow decline in the 1990s, not only in Newfoundland but all around the North Atlantic.

There had been trouble elsewhere too: in my lifetime, the California sardine collapsed in the 1950s, the Peruvian anchoveta in 1970, and the North Sea herring in the late 1970s. While none of this was a secret in the fisheries community, only the iconic Newfoundland cod attracted global media attention.

Speaking of icons, let us talk about tuna, specifically about the magnificent, silvery, torpedo-shaped, and oh so tasty and widely hunted bluefin tuna. If ever there was a media star, it is the lightning fast, predatory bluefin.

In 2003, Ransom Myers and Boris Worm estimated in *Rapid Worldwide Depletion of Predator Fish Communities* that “the large predatory fish biomass today is only about 10% of pre-industrial levels.” This paper got a lot of publicity, and it implanted in the public mind that most of the large fish of the oceans are gone, a topic that has been hotly discussed ever since. Atlantic bluefin tuna is not only on the International Union for the Conservation of Nature red list as endangered, but is also on every consumer guide’s equally red do-not-eat list. Pacific bluefin tuna is listed as vulnerable, and the southern bluefin tuna of the Indian Ocean as critically endangered. All of them are in the spotlight of conservation organizations and the public interest. The star and example of all that is wrong with fisheries in *The End of the Line,* Charles Glover’s 2004 book and subsequent documentary, is none other than our icon, the Atlantic bluefin tuna.

So it was no real surprise that the claim of a demise of all fish by 2048 would reinforce the general public’s opinion that fishing was draining the ocean of fish.

I have to admit that the boldness of the claim shocked many of us who work in fisheries. After all, I had spent almost all my career working on fish stocks in the Pacific Ocean. I started in Western Canada, and then moved on to work on Pacific tuna, then to fisheries in Australia, the Western United States, Alaska, and New Zealand. Few of the fisheries I knew well were destined for collapse. On the contrary, most were managed so well they would be rather healthier in 2048. Uneasy in my mind, I dug into the data analysis and got worried.

What was the definition of *collapse* in this paper? For Worm’s group, a collapse happened if the catch in any year was less than 10 percent of the highest catch observed. The data came from reported landings by country and type of fish, compiled by FAO for roughly 20,000 country/fish type combinations. Plotting the collapsed stocks against time, they found a downward trend with about 30 percent of stocks collapsed in 2006. Projecting forward, the curve would reach 100 percent in 2048.

What do we mean by *fish stock?* A stock describes the fish in any particular region that belong to the same species. In theory, each stock should be a breeding unit that is geographically separated from the same species in other areas. In real life, the
boundaries of stocks are often drawn quite arbitrarily based on national boundaries or geographic features. The stocks in the Worm 2006 paper were drawn by country and species or species group.

My uneasiness rose when I looked in detail at stocks listed as collapsed on the West Coast of the United States and in New Zealand, fisheries I know well. I made a list of the collapses and sent it to colleagues who were very familiar with the fish stocks in question. One of them was David Gilbert, from NIWA, a New Zealand government fisheries laboratory, and he wrote in an email to me:

This leaves 69 stocks of which 10 have “collapsed” by Worm’s criterion. But the collapsed stocks are almost all cases where landings have been partially separated into a collapsed and another group. Of the 10 “collapsed” stocks the only genuine candidate is the dredge oyster which has been decimated by a bonamia parasite epidemic. Worm’s analysis is therefore completely fatuous.

The problem here is a matter of lumpers and splitters. In the 1950s, many species were lumped together with their related species, but later, when data collection improved, these lumped groups were split into individual species so the lumped group had almost no reported catch. But in Worm’s analysis, these lumped groups were still considered collapsed.

On the US West Coast, Alec McCall of the US National Marine Fisheries Service identified the same problem and added another category, the false collapse. When Mexico declared its 200-mile limit, US boats were no longer allowed to fish there. The data, however, go back to pre-200-mile days. Consequently, the species US boats had fished for suddenly showed up as zero in catch reports from the United States—and became the false collapses in the Worm Group paper.

Several critiques by fisheries scientists, including mine, were subsequently published in Science, and a few weeks later, Boris Worm and I were invited to discuss the issue on NPR, the National Public Radio in the United States. Boris and I did not know each other, but I knew he was born and educated in Germany as a marine ecologist and then moved to Halifax in Canada. That meant he worked on the fisheries of the North Atlantic that were widely overfished at the time. It became obvious during the NPR discussion that Boris and I could talk to each other as scientists. Many emails followed to understand why we had such different perspectives.

Was it because of where we worked? Boris worked on the poorly managed North Atlantic fisheries, I work on the much more sustainable fisheries of the Pacific. Or was it because we differed on what fisheries are about? I, and most scientists who work in fisheries management, consider fisheries a way to produce food, and we accept that fishing will change ecosystems. Boris, a marine ecologist, would more likely think of fisheries as a threat to marine ecosystems. Where I see a necessary change in the ecosystem to produce food, marine ecologists might see degradation. Then again, might it be where our data on fish stocks come from? Marine ecologists tend to work close to shore, in places that can be reached with small boats. Fisheries scientists like me rely on large government research vessels because the major fisheries
A Closer Look

The projection to 2048 is obviously highly uncertain, but the data did show a clear trend in an increasing proportion of stocks being classified as collapsed. However, when we look at the abundance data for the assessed stocks of the world in the RAM Legacy Stock Assessment Database, we see the trend in the proportion of stocks collapsed (open circles)—a much lower fraction of stocks were collapsed—and the trend leveled off in the 1990s and has declined slightly since then. The RAM Legacy database does not have data for the major fisheries of South East Asia, and we expect stock collapse to be common in that region. The open circles show why those of us working in fisheries management were skeptical of the claim that all fish stocks would be collapsed by 2048. In the places where most of us worked (places with abundance estimates), the trend in collapse was not increasing, and the fraction of stocks collapsed was not as high as reported in the 2006 paper.

**Figure 5.1** This figure shows the proportion of taxa classified as collapsed in the Worm 2006 paper from 1950 to 2003 (the solid dots), and the projection from that paper that suggested all stocks would be collapsed by 2048 (the solid line). The open circles are the fraction of stocks collapsed in the RAM Legacy Stock Assessment Database.
are out in the open ocean. In general, the coastal zones show much heavier impacts from nearshore fisheries and human-made effects.

How could we overcome our differences? A grant from the National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara, California, allowed us to assemble a group of roughly twenty scientists who would meet three times over 2 years to attempt to understand what was really going on in world fisheries. We agreed at the outset that we needed to look at data on the abundance of fish stocks, not reported catch data. Abundance data come from research surveys that estimate trends by using either fishing gear in a scientifically designed pattern or acoustic methods (sonar). Acoustics are usually combined with some fishing to identify the species, measure each fish’s length and take out its ear bones to determine its age. Fishing gear is generally used for bottom-dwelling fish, and acoustics are used for fish that swim in midwater.

Scientific surveys should cover the entire range of the stock, including areas where fish are rare. Even though it irritates fishermen when research vessels spend time and money sampling where they do not find fish, a survey worth its effort and money must sample beyond the range of a stock to give us a true idea of abundance.

When all available data from research surveys and landed catches are taken together, the heavy lifting starts. It is time for fisheries scientists to work on stock assessments. Without them, any manager trying to set limits is flying blind. With them, she or he is given eyes to estimate the all-important trends in abundance. Our NCEAS group looked at stock assessments of six major fish stocks. Each one told us about estimates of historical abundance, the reported catch, and the recruitment, that is, the number of fish born that survive to be counted and enter the fishery.

Meet the North Sea Herring, a Fine Example of Overfishing Followed by Rebuilding That Deserves a Graph to Tell Its Story

Herring, like sardines, are small pelagic fish of great aggregations. Pelagic fish swim in the water column, neither on top nor on the bottom, and many of them are boom-and-bust fish that often cycle wildly.

During WWII, the North Sea herring had been left pretty much alone, but by 1946, fishing started again. In the mid-1960s, just under 1.2 million tons were caught, yet the stock did not look all that good. Warning lights went up, stock and catch tumbled, and, in the late 1970s, there was no fishing at all. The herring recovered, and eventually there were some very good fishing years followed by a downturn in the 1990s when the herring were below the target and catches reduced. Presently, under EU management, stock and catch are kept on an even keel. Managing cyclical stocks is a never-ending challenge to smooth out the boom and bust.
A Closer Look

This graph shows the spawning population size (tons of mature fish) for the North Sea herring stock from 1947 to 2015 as solid dots. The open circles show the catch. After WWII the stock was very large, and about 700,000 tons were caught annually. However, the stock declined from over 5 million tons to only about 500,000 tons. Catch declined accordingly, and the fishery was effectively closed for several years in the late 1970s.

Figure 5.2  The horizontal solid line shows the current management target for the spawning population size (1.5 million tons), and the horizontal gray line is the management limit—if the spawning population size falls below this level (800,000) tons, the fishery will be closed. Since the late 1980s, the stock has been near or above the management target. Data from www.ramllegacy.org.

Maybe it Isn’t all Gloom and Doom

Once we had assembled the data on trends in abundance from surveys and stock assessments, we published Rebuilding Global Fisheries\(^4\) in *Science* in 2009. What we had found was that on average, our data showed no downward trend either in the survey data or in the stock assessment data.

More importantly, we found that in different regions, trends differed wildly. In Alaska and New Zealand, widespread overfishing never happened, and trends were stable. Elsewhere, including Iceland, Norway, and the US East Coast, many stocks
were rebuilding after having been overfished. But there were still areas like the Gulf of Thailand that were overfished, and stocks declined. We concluded:

In five of one zero well-studied ecosystems, the average exploitation rate has recently declined and for seven systems is now at or below the rate predicted to achieve maximum sustainable yield. Yet 63% of assessed fish stocks worldwide still require rebuilding, and even lower exploitation rates are needed to reverse the collapse of vulnerable species.

We found something to meet everyone’s expectation; yes, there were areas where stocks were declining, and yes, there were areas where stocks had not been overfished, or were increasing after overfishing.

Our NCEAS group was very excited about the results, and many in the fisheries management and conservation community were pleased to see the consensus reached between the supposed warring factions. Even Science weighed in with Détente in the fisheries war,⁵ and wrote that after a controversial projection that wild-caught fish would disappear, top researchers buried the hatchet to examine the status of fisheries—and what to do about it. Boris was convinced of more page-one press coverage. I was skeptical—all fish gone by 2048 is front-page news; some

**Figure 5.3** The average trend in abundance (solid dots) and surveys (open circles) from the 2009 paper by Worm and others. We found no overall downward trend.
fisheries doing well is not. There was a wager for a bottle of champagne. It was The New York Times, page 23, and I drank the champagne. More symbolically, Boris promised a seafood banquet on December 31, 2047, now confident that there would be fish to serve. I hope that my younger colleagues or I can hold him to that promise, because that day will be my hundredth birthday!

The two key results of our NCEAS work were the recognition by the marine ecology community (well, more than a few anyway) that many fisheries increased and were sustainably managed, and the development of a database of fisheries stock assessments.

We continue to update and expand this database and named it the RAM Legacy database in honor of Ransom (Ram) Myers, a colleague who developed the first large-scale database on fish assessments in the 1990s, but, sadly, died in 2007, just as we began our working group. In 2009, the database contained assessments of 166 stocks representing about 20 percent of global catch. Even though we called our paper Rebuilding Global Fisheries, we stretched the definition of global quite a bit because most of our data came from countries wealthy enough not only to conduct scientific research on fisheries but also make it public.

The RAM Legacy database is in the public domain (www.ramlegacy.org), managed at the University of Washington, and it has expanded to over 1,200 fish stocks that represent a little over 50 percent of global fish landings. It covers the fisheries of the United States, Canada, Norway, Iceland, the European Commission, Peru, Chile, Argentina, high seas tuna fisheries, New Zealand, and Japan, as well as most of the major fisheries of South Africa and Australia. Still missing are the key areas of large catches in South and South East Asia.

We can now speak with more authority about the status of fisheries in large parts of the world, always aware that we are still missing most Asian, African and Latin American fisheries with the exception of Peru, Chile, Argentina, South Africa, and North West Africa. While we do know quite a bit about those stocks, our knowledge does not come from scientific stock assessments.

What Have We Learned from All This Compilation of Data? Let Us See the Details

The RAM Legacy database⁶ tells us that there are increases in abundance in Atlantic Ocean tunas, on the Canadian West Coast, in the European Union Atlantic fisheries, in Norway, Iceland, and New Zealand, and in all regions of the United States. In Canadian East Coast fisheries and Japan, increases in abundance proceed at rather glacial speeds. South America and the Mediterranean, alas, are suffering declines of low abundance without recovery in sight. Indian Ocean and Pacific tuna fisheries did decline but have not yet fallen below the target abundance. In general, stocks that were overfished in 2006 could increase if fishing pressure were reduced.

Now onto the numbers. Overall fish stock abundance in the areas where we have data increased by 12 percent between 2000 and 2012, and the proportion of stocks
A Closer Look

Figure 5.4 The amount of catch from different countries in the world (size of circle) and the amount of catch from assessed stocks in the RAM Legacy Stock Assessment Database (shaded region). South and Southeast Asia from India to Indonesia to China and Taiwan are the major fisheries of the world without scientific assessments.
considered overfished decreased slightly from 23 percent to 21 percent. There are big regional differences in both status and trend. In 2000, the stocks of eight of eighteen regions were on average above biomass at maximum sustainable yield (BMSY), and in all other areas, stocks have, on average, increased except for South America, the Mediterranean, and West Africa. In the most recent years, the median stock status for the Mediterranean, South America, the Northwest Pacific, the US East Coast, South Africa, and the Canada East Coast is below BMSY.

Even if it should by now be pretty obvious, let us say it again, stop fishing so hard, and stocks will rebuild.

Whatever Happened to the Icons of Fisheries Failure, Cod, Tuna, Toothfish, and Orange Roughy?

Let us begin with what I call the Oh-my-God-what-have-we-done? chart of North Atlantic cod abundance that starts with the Portuguese fishing for cod far away from home and the times when the New Englanders fancied that you could walk across the cod’s backs dry shod. What happened after that is what happens when everyone thinks that a resource is without limit.

Modern stock assessments for cod began in 1970 at an abundance of 8 million metric tons for all the major cod stocks (see Figure 5.5). The decline began in 1980 and became dire, particularly for Newfoundland, in the 1990s. Total overall abundance bottomed out in 2000 at 3 million metric tons, and it was time to reduce or stop fishing altogether. Contrary to much scare mongering, cod had not disappeared everywhere, but it decidedly needed a breather from harvesting. Recovery started and accelerated in 2005, driven by the very large Northeast Arctic stock found primarily in Northern Norway and European Russia. Icelandic cod too started to increase strongly. With new management under the EU, fishing has been generally good. The Western Atlantic stocks, on the other hand, did not do all that well. Recovery was painfully slow or did not happen at all. Even after fishing was closed, the Newfoundland stock did not budge for over a decade. Abundance started to inch up in 2005, and it is now estimated at 350,000 tons, still a very far cry from the millions of tons in the 1950s.

“What, You Eat Tuna? I Thought They Were All Extinct.” Reproach from a Friend When My Wife Ordered Tuna Belly Sushi

Our media star, the bluefin tuna, became notorious in 2013, when Kiyoshi Kimura, the owner of a Japanese sushi restaurant chain, paid $1.76 million for one 489-pound Pacific bluefin. The year before, Kimura had paid $736,000 for a single fish.
With that kind of publicity, it was no wonder that ocean conservationists rallied around the bluefin to prevent its likely extinction. Would it not pay fishermen to go to the end of the earth to catch the very last one?

It would not, because Mr. Kimura’s almost annual crazy bid at the tuna auction is a publicity stunt to keep his restaurant patrons wondering if they are eating a piece of the most expensive fish in the world. And if he can convince them that they are, that will be the best piece of sushi they ever ate. The real price of bluefin tuna is much more mundane. While Mr. Kimura spent $3,600 per pound for his 2013 prize tuna, the next bidder probably got his bluefin at the same auction in Tokyo for the average price of $17 per pound.

In 2003, Myers and Worm concluded that 90 percent of the large predatory fish⁷—our tuna would be one of them—were gone by 1980. I have a soft spot for tuna because I worked on them from 1985 to 1987 at the South Pacific Commission (SPC) in New Caledonia, an international agency that does the science for the tuna

---

Figure 5.5  The total abundance of Atlantic cod from 1970 to 2012. Total abundance is now at about the same level it was in 1970, but many individual cod stocks remain in poor condition.
resources of the countries of the Western Pacific, and my skeptical scientific hackles rose right away.

The Western Pacific is the mother lode of tuna and home turf of the small world of tuna scientists with whom I had become connected. I knew immediately that Myers and Worm could not be right. They had used the catch per hook of the Japanese longline fleet as an index of the abundance of different species, and in most cases, the catch per hook had declined rapidly and dramatically. But everyone who worked on tuna knew that there were hot spots for tuna where they were easily caught, which drove up the catch per hook initially, but the hot spots soon turned into regular fishing grounds with regular catches. However, over the entire range of tuna, the catch per hook had not declined nearly so much.

The tuna scientists were not amused by Myers and Worm. My favorite critique came from Carl Walters at the University of British Columbia with the title Folly and Fantasy in the Analysis of Spatial Catch Rate Data.⁸ The journal Nature that had published Myers and Worm, took 2 years to publish an extended critique, and not until 2005, did it accept John Hampton’s (SPC) article Decline of Pacific Tuna Populations Exaggerated?⁹ As usual, disaster got the publicity, and the good news limping in way behind was barely noticed.

At the time of his paper’s publication, I did call Ram Myers, an old friend and collaborator, and said, “Ram, this is impossible, if these stocks were depleted to 10% of the original abundance by 1980, how is it that global catch of these species increased three fold from 1980 to 2000.” It seemed pretty persuasive that stocks could not have been depleted by small catches and still produced so much more catch in subsequent years.

The definitive status of tunas was published in 2011 in the Proceedings of the National Academy of Sciences by a group from Simon Fraser University in Canada led by Maria José Juan-Jorda.¹⁰ Armed with the tuna assessments from international research groups like the SPC, they showed that globally tuna stocks had declined by 60 percent from 1954 to 2006. By 1980, the decline had only been 20 percent and not the 80 percent Myers and Worm claimed. An initial decline of 60 percent may strike a non-fishery reader as terrible, but it is precisely by how much we want a fished population to go down to get the best possible long-term sustainable yield. Most tuna stocks are now at or above the target levels.

But What about Our Media Star and Icon of Mismanagement, the Atlantic Bluefin?

There is no doubt that Atlantic bluefin was legally and illegally overfished. The key fishing countries, Japan, Spain, and France, eventually buckled to intense pressure from environmental NGOs, and by 2010, it seems that they stopped most illegal catches and considerably reduced overall harvest. In response, the abundance of bluefin in the large Eastern Atlantic population has increased nicely.
Patagonian Toothfish and Orange Roughy: Everyone Knows They Are Overfished

The other two notorious examples of unsustainable management are the Patagonian toothfish, also known as Chilean sea bass, from the Antarctic and sub-Antarctic Islands, and orange roughy from New Zealand.

Toothfish fishing began in earnest in the 1980s, and it was immediately embraced by the white-tablecloth establishments as an attractive flaky whitefish with high fat content. Just as quickly, it also appeared on the red list of most environmental NGOs because of extensive illegal fishing, bycatch of seabirds, and worries whether fish that live 60 to 70 years could even be managed in a sustainable way.

But the critics were proved wrong. The gold standard of fisheries certification is the London-based Marine Stewardship Council (MSC), an NGO founded initially by the World Wildlife Fund and Unilever, a major retailer. MSC certification is important in Northern Europe, where the major retailers will not sell fish without it.

![Figure 5.6](image_url) The estimated trend in abundance of Eastern Atlantic bluefin tuna. While abundance did decline in the 1980s, and there was lots of unreported catch, it was far from going extinct, and it has rebuilt rapidly since the late 2000s. It remains classified by IUCN as “endangered.”
Getting certified is not easy. Many boxes need to be ticked in an elaborate evaluation of the management system and the health of both the fish stock and the ecosystem. A letter to me from MSC arrived in January 2003. Toothfish from South Georgia Island, a British sub-Antarctic territory, were determined by independent evaluators to meet their standard. Would I serve on an “objections panel?” Several environmental NGOs had filed objections. Via conference calls, our panel met with the proponent of certification, in this case the British Government, and the objectors, several conservation organizations. In the end, we agreed that the fishery met the MSC standard and it was certified. By 2017, six different toothfish fisheries, more than half the global catch, had received MSC certification. In response, MSC certified toothfish are no longer on the red list of the Seafood Watch program of the Monterey Bay Aquarium, the most commonly used seafood guide in the United States. For Greenpeace, though, the toothfish are still swimming on the red list.

Finally, on to the methuselahs of fishes, the orange roughy, who live to 150 years and are caught mostly in the deep waters of New Zealand and, in much smaller quantities, all around the world.

New Zealand orange roughy was a classic gold rush. A relatively small vessel could catch hundreds of thousands of dollars’ worth of it in a single trip. No wonder the fishermen got a bit overenthusiastic and the stock was quickly overfished. At first, roughy graced the linen-tablecloth restaurants, but once science revealed just how badly depleted the fishery was, roughy quickly began to grace everyone’s do-not-buy list. The quotas had been set much too high, and the New Zealand government had no choice but to reduce them and, in some cases, totally close certain areas to orange roughy fishing. And as hoped, as soon as fishing pressure let off, the stocks rebuilt. By 2016, the major roughy fisheries in New Zealand were certified by MSC. The stocks have rebuilt to the sustainable range, and the management system meets the MSC standard. Because of the gold rush character of poor early management and because some of the orange roughy fishing damages seamount habitat, no major environmental NGOs have taken orange roughy off the red list.

What Do We Really Know About the Global Status of Fish Stocks?

To begin with, there is no black and white in fisheries—only shades of gray. The outlook is generally good for fish stocks with scientific assessments and comprehensive management systems in place because abundance is mostly going up. Problem areas, like the Mediterranean, much of Africa, and some of Latin America, persist with either downward trends or poor overall stock abundance. But there are also areas with good average stock status that contain some overfished stocks.

Overfishing is very much in the mind of the beholder. In Table 5.1, we used the US government definition of overfishing that a stock is overfished when the abundance of the stock is less than half of the level that would produce long-term
maximum sustainable yield. The concept of overfishing is very much tied to the objective of fisheries management. It implies that a stock is at a lower abundance than would be consistent with achieving management goals. Almost all national and international legislation is built around the concept of maximum sustainable yield—that is getting the best possible harvest over many generations. I like to look at it differently. Rather than worrying about whether a stock is called overfished, I suggest we look at how much long-term yield would be lost if we continue to manage fish stocks with the current level of fishing pressure. If we fish too hard, yield will be lost because of overfishing—but if we fish too little, yield will be lost because we are not taking advantage of the total potential harvest.

### A Closer Look

<table>
<thead>
<tr>
<th>Stock Type</th>
<th>Percent of stocks overfished</th>
<th>Yield lost from fishing too hard</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Alaska</td>
<td>0%</td>
<td>0.0–0.0%</td>
</tr>
<tr>
<td>US West Coast</td>
<td>6%</td>
<td>0.0–0.0%</td>
</tr>
<tr>
<td>Pacific Ocean tuna</td>
<td>7%</td>
<td>0.5–1.2%</td>
</tr>
<tr>
<td>Indian Ocean tuna</td>
<td>11%</td>
<td>0.0–0.1%</td>
</tr>
<tr>
<td>South Africa</td>
<td>13%</td>
<td>0.4–1.0%</td>
</tr>
<tr>
<td>European Union Atlantic and Baltic</td>
<td>13%</td>
<td>2.0–4.9%</td>
</tr>
<tr>
<td>Australia</td>
<td>14%</td>
<td>8.5–11.6%</td>
</tr>
<tr>
<td>Canada West Coast</td>
<td>17%</td>
<td>0.5–1.0%</td>
</tr>
<tr>
<td>US Southeast and Gulf</td>
<td>18%</td>
<td>0.1–0.3%</td>
</tr>
<tr>
<td>Norway Iceland Faroe Islands</td>
<td>19%</td>
<td>2.4–5.3%</td>
</tr>
<tr>
<td>New Zealand</td>
<td>19%</td>
<td>1.2–2.4%</td>
</tr>
<tr>
<td>Atlantic Ocean tunas</td>
<td>29%</td>
<td>0.8–1.3%</td>
</tr>
<tr>
<td>US East Coast</td>
<td>32%</td>
<td>2.8–6.3%</td>
</tr>
<tr>
<td>Northwest Pacific</td>
<td>38%</td>
<td>1.2–3.6%</td>
</tr>
<tr>
<td>Canada East Coast</td>
<td>39%</td>
<td>2.1–3.6%</td>
</tr>
<tr>
<td>South America</td>
<td>43%</td>
<td>2.3–12.6%</td>
</tr>
<tr>
<td>Mediterranean-Black Sea</td>
<td>48%</td>
<td>20.4–48.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>23%</td>
<td>4.1–8.1%</td>
</tr>
</tbody>
</table>
The table shows that while many stocks (23 percent overall) would be called overfished, relatively little yield is being lost by excess fishing pressure (4.1–8.1 percent). Only in the Mediterranean-Black Sea is the loss from fishing too hard really very significant. How can a region such as Canada’s East Coast have 39 percent of stocks overfished, but only be losing a very small amount of potential yield? This can happen for at least two reasons. The stocks may be at low abundance from too much fishing pressure in the past, as the infamous Northern cod, or the overfished stocks may be small and contribute little lost yield. In calculating the percent overfished, all stocks count the same, whereas in calculating lost yield, big stocks obviously count more than small stocks.

So what causes the differences between regions? It is fishing pressure. Where there are lots of overfished stocks, fishing pressure is or was too high, and where there is a trend for abundance to go up, fishing pressure has been reduced dramatically.

All this analyzing tells us that the so-common narrative about the global decline of fish is wrong for most of the majority of areas with good scientific data. But what about the other half of the world’s fish catch? What happens there?

The Other Half of World Fisheries: Those That Are Not Scientifically Assessed

The picture in South and South East Asia, Africa outside of South Africa, and some of Latin America is not good. We do not have scientific assessment of trends in stock abundance, but we do have a wide range of other data that provide an insight. Perhaps most reliably, we have scientific surveys from some places.

For instance, the Gulf of Thailand has been routinely monitored by scientific surveys for decades. What we see there is severe depletion of the demersal (bottom-dwelling) and pelagic fish stocks, the mainstay of commercial fishing. Surveys, where they exist for bottom trawling, in South and South East Asia typically also show strong declines in abundance.

Fishing pressure in South East Asia is very high. Ordinarily, demersal fish are caught by trawling, dragging a net along the bottom. In many countries, we can measure fishing pressure by how many times a trawl net passes over the same point on the bottom of a country’s continental shelf. Where stocks are healthy, a net on average passes over the same spot about once every 3 to 10 years. In South and South East Asia, that net passes 3 to 10 times per year. Small wonder that stocks are low.

We are lucky also to have expert opinion on the status of stocks in this region. My colleague Michael Melnychuk organized a study that asked people who are familiar with fisheries in various countries about the status of stocks in their region. Uniformly, across South and South East Asia, most of Africa, and most of Latin America the answer was that stocks were in poor condition.
Figure 5.7 shows expert opinion on the status of fish stocks for twenty-eight of the most important fishing countries in the world. The dark shaded regions are the economic zones of countries where fish stocks are in poor shape. Of the countries surveyed, the health of stocks in South and Southeast Asian countries, as well as Brazil and Nigeria, were consistently rated as being poor.
The Asian Solution and Fishing Down Food Webs

Can We Really Say That All Those Unassessed Stocks Are Overfished and Declining? Not Really, Sometimes It Depends on Whom You Ask

Tim McClannahan, a participant in the NCEAS meetings, has worked on small-scale coastal fisheries in Kenya for almost 30 years for the Wildlife Conservation Society, formerly known as the Bronx Zoo. He is a marine ecologist who placed himself on one side of the divide between ecologists and fisheries scientists when he said at the first meeting, “where I work, the harder you fish the more you catch.” Anathema had been pronounced. Obviously, for both ecologists and fisheries scientists, logic dictates that when you fish too hard, you overfish and you catch less.

Not so in coastal Kenya. Tim explained when you fish harder and harder in Kenyan coastal fisheries, the long-lived fish that eat the short-lived ones will soon be eliminated. That creates a much simpler ecosystem of a small number of highly productive, predator-free species, whose total yield (in weight) is as high, or maybe higher than it was under less fishing pressure. The downside is that the value of the catch declines. Big, long-lived predatory fish are worth more money per pound. Much of Tim’s work with Kenyan fishermen is trying to convince them to fish less and make more money.

Another participant was Beth Fulton, a research scientist at the Australian Commonwealth Scientific and Industrial Research Organization, and arguably the world’s expert on marine ecosystem modeling. Beth’s reaction to Tim’s story was, “oh, that is what I call the Asian solution.” She meant that in much of Asia fishing pressure was so high that the long-lived predators were gone and the short-lived species happily kept on reproducing and boomed. Something similar happened when Europeans colonized North America. We shot and trapped the top predators, wolves, cougars, and bears, to make life safer for us and our livestock, and at the same time, released deer from predation and turned them into lawn and garden nuisances.

Recently, Cody Szuwalski and co-authors looked at the Asian solution in Chinese fisheries. They agreed with McClannahan that the removal of predators had led to a great expansion of their prey species, what ecologists call a trophic cascade. In this case, they felt that if the Chinese were to apply the single-species management used in the United States and other countries, the results would not at all be for the better.

Single-species management would decrease both catches and revenue by reversing the trophic cascades. Our results suggest that implementing single-species management in currently lightly managed and highly exploited multispecies fisheries (which account for a large fraction of global fish catch) may result in decreases in global catch. Efforts to reform management in these fisheries will need to consider systemwide impacts of changes in management, rather than focusing only on individual species.12
What Szuwalski and his collaborators recommend is what is commonly called *ecosystem-based fisheries management*, but not along the US model that usually includes cautious single-species management. If the Chinese were to rebuild their predatory species to the level that would provide maximum sustainable yield as is mandated by US fisheries law, they would dramatically decrease both the tonnage and value of their catch.

This is a revolutionary suggestion to most marine conservation groups for whom rebuilding all species is a core tenet of their worldview.

It is no revolution for Beth Fulton and the small group of specialists who work on marine ecosystem models. Here we need to digress into some simple ecosystem ecology. We classify marine species by their trophic level: where they are in the food chain. Trophic level 1 is the plants that convert sunlight into carbohydrates. Level 2, zooplankton like krill, eats level 1. Fish generally begin at trophic level 3 and eat level 2. The trophic level of any species is defined by what it eats.

The amount of energy that flows up the food chain is reduced 90 percent at each trophic level. If we want to maximize total energy production, we would harvest as low down on the food chain as possible, which is what we do on land—we mostly eat plants, trophic level 1, and herbivorous livestock, trophic level 2. In contrast, in marine ecosystems, we primarily eat trophic levels 3 to 5, although some invertebrates such as mussels and clams belong to levels 2 to 3. What McClannahan, Szuwalski, and Fulton have shown is that, if we want to get the most food from marine ecosystems, we should harvest low on the food chain.

This has led to one of the more interesting debates about fisheries management in the last decade, called *balanced harvesting*. At present, we are picky, and we like to catch and eat higher-trophic-level species, and the bigger the better. The proponents of balanced harvesting will tell you that it...*distributes a moderate mortality from fishing across the widest possible range of species, stocks, and sizes in an ecosystem*. Beth Fulton calculated that non-selective fishing can produce perhaps 30 percent more yield.

By now you should not be surprised that balanced harvesting was raked under the harrow of criticism by other marine ecosystem ecologists concluding that...*this body of evidence suggests that BH (balanced harvesting) will not help but will hinder the policy changes needed for the rebuilding of ecosystems, healthy fish populations, and sustainable fisheries*.

We forge on to the next controversy. This one is about fishing down food webs. In 1998, Daniel Pauly of the University of British Columbia and his colleagues described it as *a gradual transition in landings from long-lived, high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fish*. It is one of the most famous papers in fisheries ever published and is referred to by other scientists over 4,500 times. The underlying premise is simple: large-bodied valuable fish like bluefin tuna tend to be long lived and at a high trophic level and are the initial targets of developing fisheries. When they are depleted, fishing switches to the less valuable but more abundant species that are lower on the food web until, in the end, we will have jellyfish sandwiches for lunch.
Pauly and co-authors supported this argument by showing that the mean trophic level of fish in the FAO landings database had declined.

**Gentle Reader, Do You Hear the Snap of the Method Trap?**

At first, I never doubted that it was true but I did wonder if it might possibly not be bad. After all, we can produce more food from the ocean by fishing lower on the food chain.

Back to NCEAS once more. Trevor Branch, then a post-doctorate at the University of Washington, took a leading role in the development of the survey database we used in our 2009 paper. He wanted to see if the mean trophic level of the ecosystems was declining in the survey data and he linked the survey abundance data with a database known as FishBase for trophic levels for each species. To everyone’s surprise he not only found that the mean trophic level in surveys did not decline, he also found that neither did the mean trophic level of the landings in the FAO data—it had actually increased in recent decades.¹⁴ The paper that received 4,500 citations from other scientists was simply wrong. In other words, we could replace the jellyfish sandwich with an equally plausible bluefin tuna steak. Even though in some ecosystems the mean trophic level is indeed declining, globally, Pauly’s trend is simply not there.

Then, to hammer some more nails into the coffin of fishing down marine food webs, Suresh Sethi, a PhD student in my lab, looked at the idea that fishing down is caused by fishermen first targeting the large valuable fish. He linked the trophic-level database to a price-per-pound database maintained by Pauly’s The Sea Around Us project and showed that there was absolutely no relationship between price per pound and trophic level.¹⁵ Some of the most valuable species, abalone, scallops, and shrimp, are low down on the food chain, and many high-trophic-level fish like skipjack tuna and sharks are not particularly valuable. Sethi then looked at the history of how fisheries develop over time and what species are caught first. The answer turned out to be pretty simple: abundant fish stocks tend to be targeted first. Fishermen go where the money is.

It is truly difficult to combat the perception that the oceans are being emptied of fish. But there is hope. Villy Christensen, who, like Beth Fulton, is one of the world’s experts on marine ecosystem models, used more than 200 such models, for a study he published in 2014, to estimate how the number of fish in the sea had changed.

Our results predicted that the biomass of predatory fish in the world oceans has declined by two thirds over the last 100 years. . . . Results also showed that the biomass of prey fish has increased over the last 100 years, likely as a consequence of predation release.¹⁶

There it was, the most optimistic assessment of global fisheries ever. We know from basic population dynamics that to get the best possible harvest over the long term, we must bring down fish populations to roughly 30 to 40 percent of their original abundance. Using Christensen’s calculations, on average, we have reached that target for the predatory fish. But if the lower-trophic-level fish have truly increased
and are much, much more abundant than their predators are, then, maybe instead of emptying the oceans of fish, there are actually more tonnages of fish in the ocean now than before industrial fishing began. Now that is a truly revolutionary thought.

To follow this up, I got in touch with Jeppe Kolding, who also works with ecosystem models. He intrigued me the first time we met by stating that Africans using mosquito nets to catch tiny fish was a fine idea. This, of course, is the very opposite of the common narrative that fishing with very fine nets is destructive, and repurposing nets provided by US foundations to protect people from malaria in order to plunder the lakes of Africa is doubly pernicious.

Kolding had been a nurse in hospitals in East Africa. He said that once you have seen children die from malnutrition, you look at the world differently than an ecologist sitting in a University in Denmark or the United States. Small fish are one of the most nutritious foods known, and these very small fish in the African Great Lakes are not overfished. And if they can be caught with mosquito nets, all the better.

On my prodding, Kolding analyzed all the ecosystem models he had and concluded that indeed there were as many or more tons of fish now than there had been before industrial fishing began for temperate fisheries like the United States and Europe that target high-trophic-level fish. In the tropics, on the other hand, where harvest is much less selective, there were undoubtedly fewer fish now.

I hope that, with this chapter, I was successful to convince you, the skeptical reader, that the oceans are not being drained of fish and that in most places where we have good scientific data, fish stocks are doing well and are increasing. For the other half of the world, we may have to readjust our goal. Even though there is convincing evidence that, particularly, the long-lived species are severely depleted in many areas, this altered state does appear to be able to produce the near maximum catches to provide food for people.

FURTHER READING


