

A man with glasses and a mustache, wearing a dark jacket over a blue turtleneck, stands in a museum. Behind him are several large, realistic models of sharks mounted on a dark wall. He is leaning forward slightly, with his hands resting on a dark, textured surface in the foreground.

Eyes on the ocean

Daniel Pauly is sounding the alarm over global fish harvests, but others think he is making too much noise.

BY DANIEL CRESSEY

Off the coast of Morocco, small wooden fishing boats bob in the sea, collecting squid. On the other side of the Atlantic Ocean, powerful cabin cruisers speed out of Nassau, carrying tourists in pursuit of huge mahimahi, wahoo and marlin.

None of these vessels exist — at least in the official tally of marine harvests kept by the Food and Agriculture Organization of the United Nations (FAO). That global database, known as the State of World Fisheries and Aquaculture, or SOFIA, is generally regarded

as the bible of information about marine food resources. But SOFIA includes only information that nations give to the FAO, which is of varying quality and often ignores subsistence fishing, illegal harvesting and the sport trade.

Daniel Pauly is obsessed with those missing fishing vessels and the untold amounts of food that they pull from the oceans. The soft-spoken but intense marine biologist at the University of British Columbia in Vancouver, Canada, seeks to bring them out of the shadows. Over the course of a long career that has been equal parts

BRETT BEADLE

celebrated and controversial, he has set himself the huge task of working out what he calls the “true catch” of the world’s fisheries. He hopes that such figures will help countries — especially in the developing world — to take control of their resources and feed their people.

Now he is reaching the culmination of the project. Towards the end of this year, his team will publish a global atlas of all its data, revealing for the first time its estimate of the actual annual harvest from the world’s fisheries. Preliminary publications indicate that the figures will be at least 50% above the FAO numbers for developed countries, and much higher for the developing world. The data, Pauly says, paint a bleak picture of the state of the oceans.

Although official FAO numbers suggest that catches have been roughly stable in recent years, Pauly’s work indicates that the global catch is falling. The debate is not just academic. Declining catches could mean that fisheries in many countries are being over-exploited, says Pauly. “That is the scary part.”

TRUE-CATCH DETECTIVE

Growing up in landlocked Switzerland, Pauly did not seem destined to spend his life thinking about oceans. But at university, he started studying fisheries science with the aim of working in developing countries — and escaping from Europe, where he felt he was always reminded of his biracial background (his father is African American). “I wanted to get to a place where they wouldn’t question so much,” he says.

After earning a PhD in Germany, he worked in Asia on fisheries-management issues. In 1999, he ended up on the western seaboard of North America, as head of the Sea Around Us Project, which is dedicated to studying fisheries and their influence on ecosystems. The effort is a collaboration of the University of British Columbia and the Pew Environmental Group.

Created, led and shaped by Pauly, this programme crystallized around a series of questions. How many fish are caught around the world? What species are they? And how can this catch be changed to ensure that fisheries are sustainable and to prevent damage to the oceans? “This always was on the horizon, this basic question: how much is really caught in the world?” says Pauly.

When he started, Pauly relied heavily on the FAO numbers. “I for years have done analysis of the FAO data. And I thought they are like all numbers that you can get — they have their up and downs, and overall this balances out,” he says. But over time, as he pored through the data and obsessed over their nuances, he realized how many important factors were missing. “That got me scared, because I realized that it was not an exception but the rule.”

He describes his growing disenchantment with the FAO statistics as a “gradual falling out of love”.

Pauly says that the problem boils down to the fact that “people, when they don’t know, they

put zero”. Fishery officials report that they do not catch any of a particular species, or they do not have any small-scale subsistence fishing — people in small boats providing for their families. “But these zeroes that are soft zeroes — reflecting uncertainty — become hard zeroes.”

This led him to his next realization — that someone had to undertake the mammoth task of fixing this problem, and “recreating the statistics of the world from the bottom up”.

“Wherever I turn, data are missing.”

In 1998, Pauly wrote an article¹ suggesting a way to do that. He proposed that researchers could reconstruct catch data by hunting through old government files, harbour masters’ records, aerial photographs and interviews with fishers, along with published scientific reports.

This approach relies on the understanding that fishing is a social activity, says Pauly. “It throws shadows on the society in which it operates”. Fishing influences the restaurants and markets at which fishers sell their products, and the boat-builders and fuel suppliers who allow them to work. “It is not possible to have a fishery and have no data about that fishery,” he says.

The Sea Around Us group uses these shadows to find the fisheries hidden from the FAO. It has worked country by country to piece together a comprehensive database of what it thinks is the true catch.

Pauly’s group published its first taste of this approach in 2006, in a report on the United States’ islands in the western Pacific². The Sea Around Us had been contracted by the fisheries-management council in the region to analyse the local catch.

Pauly’s colleague Dirk Zeller, a fisheries researcher at the University of British Columbia, and his team used a six-part approach that later became standard for the global effort. First, the group gathered existing catch reports dating back to 1950. Then it identified the gaps in these data — time periods with missing information, species that should have been in the statistics but were not, and types of fishing that were likely to have occurred but were absent from the FAO data, such as local people fishing to feed themselves rather than to sell.

To fill in the missing data, the team combed through the scientific literature and interviewed local experts, ranging from scientists to

fishermen and fisherwomen. The researchers built anchor points using all the hard data, and then interpolated between these anchor points to estimate the missing figures. This helped them to tally up a total catch for the whole time period.

For the island of American Samoa, their hard data points included a local statistical digest and official statistics published by the Western Pacific Fisheries Information Network. The team also used published estimates of how much fish was caught per capita each year, and combined them with census data to yield a total catch estimate.

When Zeller added up the numbers, the total estimated catch between 1950 and 2002 was 17 times the reported statistics. “That opened up a Pandora’s box,” he says. “If entities associated with the US have trouble with that, what about the rest of the world?”

Since then, Zeller and the Sea Around Us team have been applying versions of the same methodology elsewhere. In 2014, for example, they calculated that the true catch in Portugal was 36% higher than the officially reported fish landings³, and the difference in Panama reached 40% (ref. 4). One thing is constant, says Zeller: “Wherever I turn, data are missing.”

THE GAP NARROWS

The biggest differences between FAO and Sea Around Us numbers are in the past. Pauly says that for recent years, the two sets of figures are edging closer — a trend that can be seen in Senegal. The reconstruction there was headed by Dyhia Belhabib with the Sea Around Us, who has led work all along the West African coast.

Belhabib estimates that at times in the past 40 years, the true catch for Senegal was 4 times higher than the official data show, whereas in the past decade, the gap has shrunk (see ‘Something fishy’). Still, her analysis⁵ suggests that illegal, unregulated and unreported fishing took US\$300 million of fish from Senegal’s waters in recent years. “We did not expect it to be this much. I thought in Senegal there was better monitoring.”

There are signs that the Sea Around Us work is having an impact. In 2014, Senegal’s fishing ministry seized a Russian vessel and accused it of fishing in Senegalese waters illegally. The government successfully extracted a fine of more than \$1 million from the ship’s owners. And in press conferences afterwards, the ministry cited the \$300 million unregulated-fishing figure from the Sea Around Us.

Two years ago, says Belhabib, “I would say we’re the outsiders, we’re the black sheep.” But after the group worked with governments in West Africa, she says, “I feel it’s changing.”

The Sea Around Us Project now has an agreement in place with the Ministerial Conference on Fisheries Cooperation Among African States Bordering the Atlantic Ocean (ATLAFCO). One aim of the collaboration is to help African nations to develop their own capacity to

reconstruct catches. It is also encouraging member nations to publish their data in peer-reviewed journals.

Not everyone has been so positive about this work. A group of researchers in France and Senegal has questioned a number of the assumptions used in Belhabib's analysis. The team argued⁶ that the Sea Around Us work ignores crucial differences between types of fishing, in one case taking data on fish discarded during shrimp harvesting and inappropriately applying the same discard rates to fin-fishing operations. The reconstruction produced huge overestimates and "may lead to inadequate management advice", the authors conclude.

Belhabib, Pauly and their colleagues rebut these criticisms⁷, maintaining that their estimates are sound. In the case of the discard rates, they say that they did not base their estimates on data from shrimp harvests — and that the rates for the two are roughly similar anyway.

But criticisms go beyond Senegal: China has been another flash point. Pauly's group published estimates⁸ that the annual catch by the Chinese fishing fleet around the globe averaged 4.6 million tonnes per year in 2000–11 — more than 10 times the FAO number (see *Nature* 496, 18; 2013).

The FAO said that these numbers are much too high. Sachiko Tsuji, a senior fisheries statistician at the FAO in Rome, says that the problem comes down to the methodology used by Pauly's group. "In many cases their reconstructions are based on extremely small samples," says Tsuji. Others echo that concern, saying that the Sea Around Us extrapolates from limited samples and sometimes unreliable numbers, which can produce huge overestimates. Pauly's group triggers strong feelings among some at the FAO, who believe that their work is being unfairly targeted, says Tsuji. "I personally do not think so, but that is the current relationship between FAO and the Sea Around Us."

Tsuji also points out that the FAO can only report official statistics that are supplied by UN member states. It addresses aspects such as illegal fishing in special reports. For example, it collaborated with the World Bank to produce the 2008 report *The Sunken Billions*, which acknowledged both the problems of illegal fishing and the fact that some fishing was unreported in the agency's official statistics. But the FAO is not allowed to modify the statistics reported by member nations to include such details in the official catch statistics.

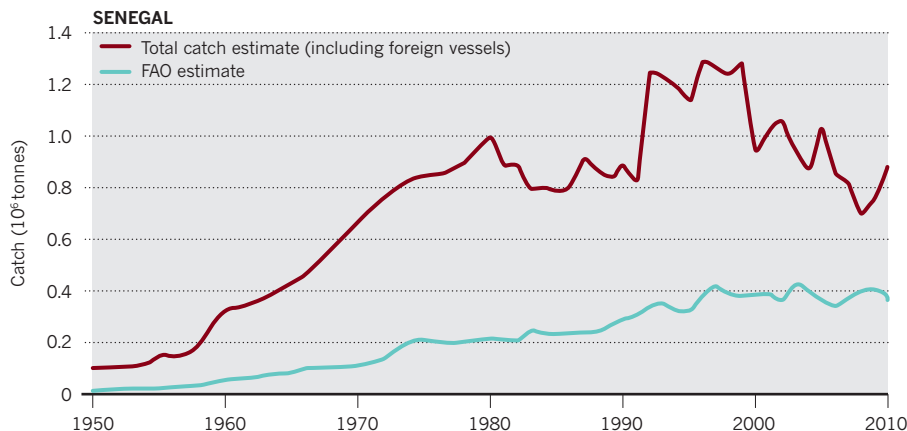
CATCH CONFLICT

Pauly has received a plethora of awards for his work, but he has also made enemies. Never afraid to ruffle feathers, he is outspoken about ocean conservation and willing to point fingers at the huge multinational companies that control much of the world's fishing industry.

Part of his motivation for seeking the true catch of developing nations is to allow such countries to take control of their own

Something fishy

Nations provide the Food and Agriculture Organization of the United Nations (FAO) with data on the total amount of fish caught each year, but those numbers leave out many factors, such as illegal fishing. Total fish-catch estimates from the Sea Around Us Project are often much higher than the FAO estimates.



resources. He says that much of the criticism comes from people who think that he has climbed into bed with environmental non-governmental organizations, which fisheries scientists have tended to shy away from.

Pauly's strident warnings over declining fish populations have landed him in fierce fights⁹, particularly with Ray Hilborn of the University of Washington in Seattle, one of the world's leading fisheries researchers. Hilborn has little faith in the numbers produced by the Sea Around Us. "They end up just using someone's opinion," he says. "I think they're just pissing in the wind."

Trevor Branch, another fisheries scientist at the University of Washington, is more accommodating. Catch data, he says, are "essential", and the reconstructions by Zeller and Pauly are "incredibly valuable". But Branch argues that it is not possible to use catch data alone to assess the status of a fishery, in the absence of information about the actual abundance of a given species in the ocean. For example, catches in a given area may have declined because people simply stopped fishing there, rather than because the number of fish has fallen.

Pauly argues that catch figures are the only source of information on many species of fish. Data on actual abundance are expensive and time-consuming to collect, so catch figures have to be used to assess the status of species.

The dispute has divided much of the fisheries community. But no one denies Pauly's influence. Boris Worm, a fisheries researcher at Dalhousie University in Halifax, Canada, is one of the few to have authored papers with both Hilborn and members of the Sea Around Us. He has estimated global mortality for sharks¹⁰, using data from the Sea Around Us Project and other sources; his work suggests that the global shark catch is three or four times what FAO records suggest.

Asked which numbers he uses to estimate how many fish are actually being caught, Worm answers almost before the question

is finished: "Daniel Pauly."

Despite all the controversies, Pauly seems unfazed. In fact, his manner gives the impression that nothing much fazes him. His life has taken him around the world, and left him with a certainty about what he is doing and why.

He sees much of the dispute about the health of the oceans as boiling down to the fact that the traditional heavyweights in fisheries science are from the developed world, which has enjoyed relatively effective management and assiduous record keeping. The picture is different in the developing world, where Pauly's attention has long been focused. Getting a handle on fishing in these regions requires going beyond the official data, he says.

Yet even as it focuses on developing nations, the Sea Around Us Project has tried to take a broad perspective. Fisheries science is often, by necessity, highly localized. Researchers can spend years unpicking the factors that control the numbers of Maine lobster, or sprat in the Baltic Sea. Many researchers still insist that this is how fisheries science has to work. But Pauly's research has forced people to take a global view — to paint a full picture of the health of the oceans.

"You need to take yourself out of that local perspective," says Belhabib. "It requires a lot of guts to do that. It took Daniel Pauly to do that." ■

Daniel Cressey writes for *Nature* from London.

1. Pauly, D. *EC Fish. Coop. Bull.* **11**, 4–10 (1998).
2. Zeller, D., Booth, S., Craig, P. & Pauly, D. *Coral Reefs* **25**, 144–152 (2006).
3. Leitão, F., Baptista, V., Zeller, D. & Erzini, K. *Fish. Res.* **155**, 33–50 (2014).
4. Harper, S., Guzmán, H. M., Zylich, K. & Zeller, D. *Mar. Fish. Rev.* **76**, 51–65 (2014).
5. Belhabib, D., Koutob, V., Sall, A., Lam, V. W. Y. & Pauly, D. *Fish. Res.* **151**, 1–11 (2014).
6. Chaboud, C. *et al. Fish. Res.* **164**, 322–324 (2015).
7. Belhabib, D. *et al. Fish. Res.* **164**, 325–328 (2015).
8. Pauly, D. *et al. Fish. Fish.* **15**, 474–488 (2014).
9. Pauly, D., Hilborn, R. & Branch, T. A. *Nature* **494**, 303–306 (2013).
10. Worm, B. *et al. Mar. Policy* **40**, 194–204 (2013).