



**Twenty Years of the *Sea Around Us*:
Marine Fisheries Research to Serve Civil Society
1999 – 2019**



| 2000



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Sea Around Us

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Executive Summary

This report presents an account of the activities of the *Sea Around Us*, an initiative devoted to documenting and disseminating information on the impacts of fisheries on marine ecosystems and to the proposal of policies to mitigate these impacts.

The *Sea Around Us* began its activities at the Fisheries Centre (now the Institute for the Oceans and Fisheries, IOF) of the University of British Columbia (UBC), Vancouver, Canada, in July 1999 and now has ‘branches’ at the University of Western Australia, Perth, Australia, and at Quantitative Aquatics, a small non-governmental organization based in Los Baños, Philippines.

This report focuses on the scientific achievements of the *Sea Around Us* during its 20 years of existence, but also emphasizes the key role it plays in supplying high-quality catch data (by country, ecosystem, species, gear, end use, etc.) and catch-derived indicators of ecosystem status to a wide range of researchers, educators, governments, NGO staffers, as well as to the public at large.

These data are increasingly used to answer policy-relevant questions ranging from fisheries management to issues of (sea)food security in developing countries, and from climate change issues to the spatial expansion of slavery at sea.

This report was compiled for initial distribution at the celebration of the 20-year anniversary of the *Sea Around Us*, held at UBC on June 28, 2019.

We hope that this event, which assembles a wide range of *Sea Around Us* partners, notably marine scientists and representatives of civil society, will assist in defining our course for the next decade.

Foreword

It is with great pleasure and an element of bewildered joy that I write this Foreword for the 20-Year Anniversary report that documents the journey and achievements of the *Sea Around Us* and celebrates its team – past and current.

The element of bewildered joy exists because on one level, I struggle to understand how this team has achieved so much. As one of my colleagues commented in anticipation of this event: “I really hope nobody tries to use this as a benchmark for what the rest of us should accomplish in 20 years...”

Key achievements of the *Sea Around Us* are documented herein, year by year, so I will not repeat them in this Foreword. As I was at risk of penning a hagiography celebrating Daniel Pauly’s vision - which he would hate because he is all about team - I have instead some observations on how a globally transformative initiative like the *Sea Around Us* has been built.

- **Recognize** that civil society is the bulwark against unfettered ocean exploitation – the *Sea Around Us* ensures our societies are equipped with the knowledge to demand a return to flourishing oceans;
- **Reject** the status-quo but neither let perfect get in the way of better (a slight paraphrase on Voltaire) – the *Sea Around Us* demonstrates, for example, that you can reconstruct fish catches even with imperfect data – and then improve them;
- **Share** – the *Sea Around Us* open access policy means knowledge grows exponentially, beyond what a single team can achieve;
- **Globalize** – the *Sea Around Us* ensures that cherry-picked case studies can be considered in the global context, avoiding the distortions that selective analysis can generate;
- **Communicate with resonance** – the *Sea Around Us* has built on the mainstreaming of important ecological concepts, translated into intuitive and accessible language such as “shifting baselines” as applied by Daniel Pauly to fisheries, and the coining of terms such as “fishing down the foodweb”;
- **Publish publish publish** – the *Sea Around Us* not only ensures its work is published in peer-reviewed journals, but the decision to create a (now extensive) series of high quality reports puts the work quickly front-and-centre;
- **Challenge power and industry capture with evidence** – the *Sea Around Us* speaks a quiet truth that underpins its contributions to civil society and reframes our understanding of our oceans.

Whilst some of the above may seem obvious, the *Sea Around Us*, as documented in the following pages, is a rare global example of the success of these principles.

In response to the implied query in the opening quotation on benchmarks, Daniel simply replied “great team and good resourcing.” So I use this Foreword to also acknowledge Drs Maria Lourdes ‘Deng’ Palomares and Dirk Zeller who have travelled this journey with Daniel for decades. I am deeply impressed also with the students and research assistants from every corner of the planet that bring their local understanding to contribute, country-by-country to global assessments. The other key building block to the *Sea Around Us* was the vision that the partnership between Dr. Rainer Froese and Daniel yielded in establishing FishBase. FishBase is not the focus here, but its relevance to the *Sea Around Us* cannot be overestimated.

Returning to my temporarily-aborted hagiography, this report is also a celebration of Daniel’s vision, discipline, creativity, stubbornness, horrific work ethic, values and attachment to history. That this initiative’s name pays tribute to Rachel Carson’s novel of the same title encapsulates the challenges we face in the Anthropocene:

“It is a curious situation that the sea, from which life first arose should now be threatened by the activities of one form of that life. But the sea, though changed in a sinister way, will continue to exist; the threat is rather to life itself.”

– Rachel Carson (1951) *The Sea Around Us*

We continue to work towards reducing ocean threats, 60+ years since Rachel Carson’s prescient words. In the Anthropocene and in light of the recently released by the United Nation’s report Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, the value of the *Sea Around Us* is immeasurable.

And this is exactly why the *Sea Around Us* matters.

Professor Jessica Meeuwig
University of Western Australia, Perth



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Introduction

This report is the fourth multi-year summary of the *Sea Around Us*' activities, the other three having covered the years 1999-2004, 1999-2009 and 1999-2014.

The first of these reports¹ emphasized the methodological steps we used to structure our work, the results we obtained and the work of individual members of the team.

The second report² emphasized the multidisciplinary nature of our work through 'layers' representing (1) the ocean's physical and jurisdictional boundaries; (2) marine primary and secondary productivity, i.e., phyto- and zooplankton; (3) the oceans' diversity of large invertebrates, fishes, reptiles, seabirds and marine mammals; (4) the catch and effort of marine fisheries; (5) the economics of these fisheries; and (6) the syntheses of all these data, as required for policy formulation and outreach.

The 2014 report³ may be seen as a shorter, early version of the *Global Atlas of Marine Fisheries* we published in 2016⁴. It served also as final report of the *Sea Around Us* to The Pew Charitable Trusts, whose generous support ended that year.

This fourth *Sea Around Us* report is chronological, presenting accounts for the two half years (July to December 1999 and January to June 2019) of its existence, and for the 19 years in-between. Each of these accounts is structured around a specifically selected article published by the *Sea Around Us* in that year, or a conference or other event, jointly with a figure illustrating the article or event in question. Also, for each of the 21 time periods, a 'box' is provided documenting another aspect of the work and/or impact of the *Sea Around Us*.

Jointly, these 21 accounts and the last appendix, provide the reader a general idea of the amount and range of the work performed by the *Sea Around Us* in the last two decades and beyond. For more complete accounts, see the earlier *Sea Around Us* progress reports and our newsletter at www.searoundus.org/publications/ as well as our blog at <http://www.searoundus.org/about/>.

1) Sea Around Us. 2005. *Sea Around Us Project: A five-year retrospective 1999 to 2004*. Sea Around Us, Fisheries Centre, University of British Columbia, 56 p.

2) Sea Around Us. 2009. *Sea Around Us Project: A ten-year retrospective 1999 to 2009*. Sea Around Us, Fisheries Centre, University of British Columbia, 57 p.

3) Pauly, D. and D. Zeller (eds.). 2014. *So long, and thanks for all the fish: The Sea Around Us 1999-2014 - A fifteen-year retrospective*. Sea Around Us, Fisheries Centre, University of British Columbia, 171 p.

4) Pauly, D and D. Zeller (eds.). 2016. *Global Atlas of Marine Fisheries: A critical appraisal of catches and ecosystem impacts*. Island Press, Washington, D.C. xvii + 486 p.

1999: A promising start

In 1997, The Pew Charitable Trusts (PCT) invited a small number of marine scientists to its Philadelphia headquarters and asked them what the PCT should do to address the declining “health” of the ocean¹.

All but one of the invited scientists contested the very concept of “ocean health” and proposed instead new sophisticated data acquisition programs to overcome a perceived ‘lack of data.’ Daniel Pauly positioned himself as the last of the invitees and argued that ocean health could be described as a strong departure from a reconstructed pristine state and that a huge amount of data already existed to assess ocean health, notably the global fisheries statistics published annually since 1950 by the Food and Agriculture Organization of the United Nations (FAO). His arguments carried the day, and he was invited to prepare a proposal for a project to be funded by the PCT². That project, named after Rachel Carson’s book *The Sea Around Us*, began in July 1999 (Figure 1).

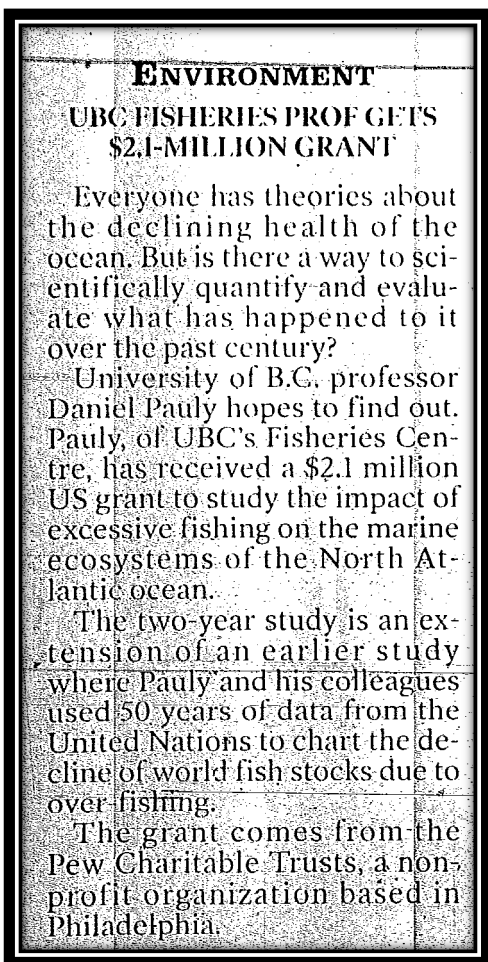


Figure 1. The first of many media ‘hits’ about the *Sea Around Us*, announcing its start and goal in the *Vancouver Sun* newspaper.

The main goals of the *Sea Around Us* were later defined more precisely in the form of six questions posed by Dr. Joshua Reichert, then the head of the PCT's Environment Program:

1. What are the total fisheries catches from the ecosystems, including reported and unreported landings and discards at sea?
2. What are the biological impacts of these withdrawals of biomass for the remaining life in the ecosystems?
3. What would be the likely biological and economic impacts of continuing current fishing trends?
4. What were the former states of these ecosystems before the expansion of large-scale commercial fisheries?
5. How do the present ecosystems rate on a scale from "healthy" to "unhealthy"?
6. What specific policy changes and management measures should be implemented to avoid continued worsening of the present situation and improve the North Atlantic ecosystem's "health"?

We soon provided answers to these questions for the North Atlantic³. This 20-year report documents how the *Sea Around Us* responded to these and related questions for the world as a whole.

Box 1: The first issue of the '*Sea Around Us* Project Newsletter' was launched, as a 2-page document in November/December 1999 under the editorship of Ms. Nancy Baron, a Canadian nature journalist later known for helping scientists to communicate with the media, as documented in her book *Escape from the Ivory Tower*. The *Sea Around Us* newsletter, under various editors, ran until October 2014 when Daniel Pauly, the Principal Investigator of the *Sea Around Us*, wrote a final editorial in issue No. 83. A searchable file with all back issues jointly documenting the first 18 years of the *Sea Around Us*' activities is available at www.searoundus.org/newsletters/. We now communicate mainly through blogposts on our website, and through social media, i.e., Twitter, Facebook, Instagram, and YouTube.

1) Malakoff, D. 2002. Science helps Pew push ocean agenda. *Science* 296: 459.

2) Malakoff, D. 2002. Going to the edge to protect the sea. *Science* 296: 458-461.

3) Pauly, D. and J. Maclean. 2003. *In a Perfect Ocean: fisheries and ecosystem in the North Atlantic*. Island Press, Washington, D.C.

2000: First the North Atlantic

The first two years of the *Sea Around Us* were devoted to the North Atlantic, mainly because long-time series of data on important environmental factors were available which documented changes in its various ecosystems, including declines of fish biomass. One way these declines could be highlighted was by arraying all the Ecopath (food web) models available at the time, and mapping the biomasses they incorporated onto a grid of half degree latitude and longitude cells. Then, using a General Linear Model, the decline of predatory North Atlantic fish (i.e., of trophic levels > 3.5) could be inferred over a period of 100 years (Figure 2).

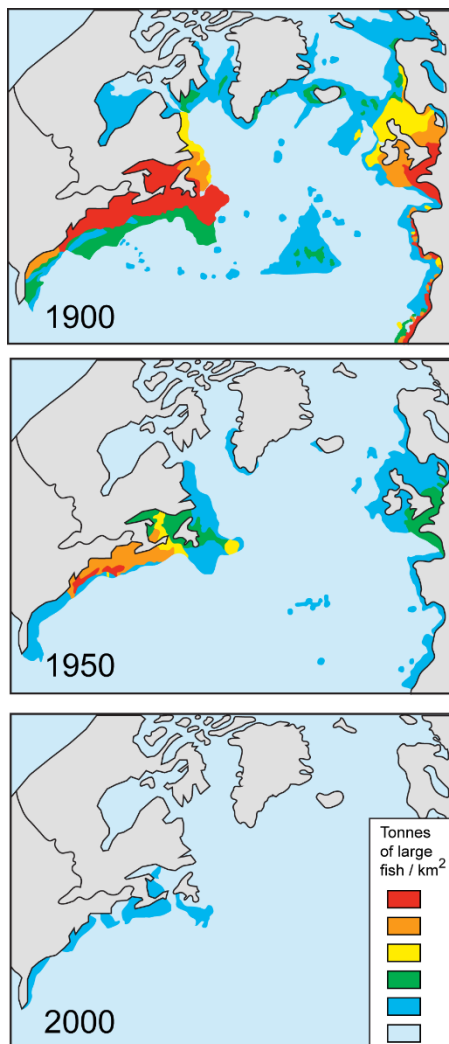


Figure 2. Decline of the biomass of large, high-trophic level (TL > 3.5) fish in the North Atlantic, as assessed from 28 spatialized Ecopath food-web models covering periods ranging from 1880 to 1998¹. These maps, which were also reproduced in *The New York Times*, do not imply that large fish have completely disappeared, but ‘only’ that they have declined by a factor of about 10.

This work, led by Dr. Villy Christensen, then a member of the *Sea Around Us* team, eventually led to a much-cited paper¹, and was later reproduced for West Africa² and Southeast Asia³, where similar declines occurred.

The *Sea Around Us* and its collaborators developed additional methods to document the worldwide decline of larger, high-trophic level fish^{4,5}, but the strong declines that were documented remained controversial, at least in the eyes of a minority of fish stock assessment experts. This is the reason, ultimately, why the *Sea Around Us* evolved to perform species- and stock- specific ‘stock assessments,’ as emphasized in the accounts for 2018 and 2019.

Box 2: A book titled *In a Perfect Ocean*⁶ summarizes the work done by the *Sea Around Us* in its first two years. It concentrated on the North Atlantic Ocean and documented the history of its exploitation, the decline of its fisheries and how its previous abundance could be restored.

-
- 1) Christensen, V., S. Guénette, J.J. Heymans, C.J. Walters, R. Watson, D. Zeller and D. Pauly. 2003. Hundred year decline of North Atlantic predatory fishes. *Fish and Fisheries* 4(1): 1-24.
 - 2) Christensen, V., P. Amorim, I. Diallo, T. Diouf, S. Guénette, J.J. Heymans, A. Mendy, M.M. Ould Taleb Ould Sidi, M.L.D. Palomares, B. Samb, K.A. Stobberup, J.M. Vakily, M. Vasconcellos, R. Watson and D. Pauly. 2004. Trends in fish biomass off Northwest Africa, 1960-2000. p. 377-386 + Plate VI. In: P. Chavance, M. Ba, D. Gascuel, M. Vakily and D. Pauly (eds.) *Pêcheries maritimes, écosystèmes et sociétés en Afrique de l'Ouest : un demi-siècle de changement*. Collection des rapports de recherche halieutique ACP-UE 15.
 - 3) Christensen, V., L. Garces, G.T. Silvestre and D. Pauly. 2003. Fisheries impact on the South China Sea Large Marine Ecosystem: A preliminary analysis using spatially-explicit methodology. p. 51-62 In: Silvestre, G.T., L.R. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C.Z. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) *Assessment, management and future directions for coastal fisheries in Asian countries*. WorldFish Center Conference Proceedings 67.
 - 4) Tremblay-Boyer, L., D. Gascuel, R. Watson, V. Christensen and D. Pauly. 2011. Modelling the effects of fishing on the biomass of the world's oceans from 1950 to 2006. *Marine Ecology Progress Series*, 442: 169-185.
 - 5) Kleisner, K., H. Mansour and D. Pauly. 2014. Region-based MTI: resolving geographic expansion in the Marine Trophic Index. *Marine Ecology Progress Series*, 512: 185-199.
 - 6) Pauly, D. and J. Maclean. 2003. *In a Perfect Ocean: fisheries and ecosystem in the North Atlantic*. Island Press, Washington, D.C.

2001: China's coastal fisheries

The year 2001 is the one that put the *Sea Around Us* on the map.

In 2001, we published a paper documenting that the world's fisheries catches were not increasing, as FAO still proclaimed at the time, based on the data reported to them by China. In fact, the world's fisheries catches were declining. This decline had been masked by exaggerated reports of steadily increasing domestic marine fisheries catches by China in the 1980s and early 1990s that ended up being so high that the Chinese government decreed a “zero growth policy.” We studied the history of Chinese fisheries¹ and also applied a newly developed method for mapping fisheries catches to compare catches per km² in Chinese waters and other parts of the world ocean. This clearly showed that Chinese catches were over-reported² (Figure 3A).

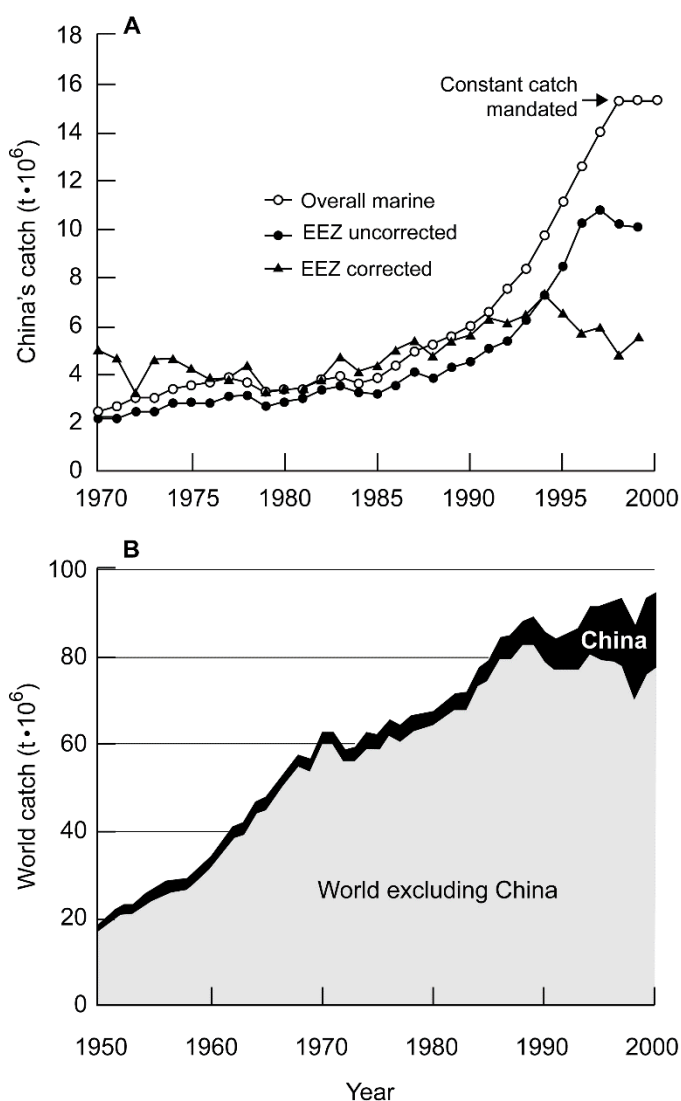


Figure 3. Two ways to deal with over-reporting of fisheries catches by China. A: By computing likely alternative values²; B: By presenting world fisheries catch statistics with and without China, as FAO did for several years, starting in 2002³.

The paper documenting this over-reporting was a bombshell, with FAO, the Chinese government, and the media (notably *The Economist*) engaging in acrimonious debates, from which we wisely abstained.

When the furor settled, FAO began, in its reporting of global catch statistics, to present data for China separately from the rest of the world (Figure 3B), which China did not appreciate. China, then, sent a high-level expert to FAO in Rome, who retroactively reduced reported Chinese catch by a few million tonnes. Thus, it gradually became accepted that the world's fisheries catch was at least stagnating if not declining. However, the decline was definitely confirmed in 2016, as documented in our account for that year.

Box 3: Dr. Maria Lourdes ‘Deng’ Palomares joined the *Sea Around Us* in September 2001 as a Research Associate, which followed a long association with the International Center for Living Aquatic Resources Management (ICLARM), where she worked with Daniel Pauly. She later became a Senior Scientist. In 2017, Dr. Palomares became the *Sea Around Us*’ Project Manager, succeeding Dr. Dirk Zeller, who had joined the *Sea Around Us* in 1999 as a postdoctoral fellow and also ascended the ranks. In June 2017, Dirk became a professor of Marine Conservation at the University of Western Australia, where he leads the *Sea Around Us*– *Indian Ocean*, our first external ‘branch.’

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- 1) Pang, L. and D. Pauly. 2001. Part 1 – Chinese marine capture fisheries from 1950 to the late 1990s: the hopes, the plans and the data. p. 1-27. In: R. Watson, L. Pang and D. Pauly. (eds.) *The marine fisheries of China: development and reported catches*. Fisheries Centre Research Reports 9(2).
 - 2) Watson, R. and D. Pauly. 2001. Systematic distortions in world fisheries catch trends. *Nature* 414: 534-536.
 - 3) FAO. 2002. *State of the World Fisheries and Aquaculture (SOFIA) 2002*. FAO, Rome.

2002: A conference in Dakar

Northwest Africa is one of the most productive regions of the world in terms of marine fish. However, its fisheries resources are over-exploited, largely because of foreign fleets, both legal and illegal, extracting very large catches from these waters, which also support well-developed artisanal fisheries.

A common reflex of fisheries scientists faced with complicated issues such as the competition between foreign industrial fleets and local artisanal fleets is to argue that there is “no data” to address the problem in question. However, based on his previous work in the region, Daniel Pauly knew that there were mountains of data in the grey literature about the fisheries of West Africa that remained under-utilized and unanalyzed. He thus proposed a conference that would analyze such data and make them available to fisheries managers. That conference took place in Dakar, Senegal from 24 to 28 June 2002 bringing together a wealth of management-relevant information.

With supplementary funds from the Oak Foundation, the *Sea Around Us*, led by M.L. ‘Deng’ Palomares, prepared the conference by assembling massive amounts of pertinent documents and data¹. These included the haul-per-haul data of a baseline survey, the Guinean Trawling Survey, conducted in 1960, which was thought to be lost. The proceedings of this conference, published in 2004², are still a reference, demonstrating that, yes, there are data and information relevant to the management of West African fisheries – one must only look!

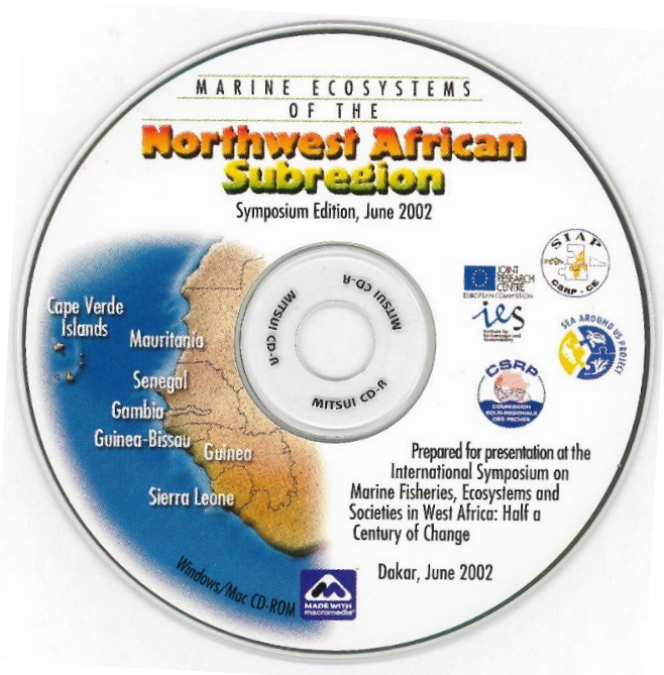


Figure 4. The CD-ROM that, in preparation of the Dakar conference, was loaded with information, publications and data relevant to the marine fisheries of West Africa, and made freely available to the participants by the *Sea Around Us*.

Later that year, the *Sea Around Us* hosted West African scientists in Vancouver and held a workshop to learn how to apply ecosystem-based management tools (Ecopath) to their local situations. Following the workshop, a report of findings later published³.

This work proved useful when the *Sea Around Us* again worked in West Africa to reconstruct the fisheries catches in 22 countries, from Morocco in the north to Namibia in the south, and for which sufficient fisheries catches and related data were assembled that painted a picture of catches in this region differing starkly from official figures⁴.

Box 4: Probably because of earlier notable publications in *Nature* and *Science*, Daniel Pauly was asked by the editor of *Nature* in early 2002 to write a review of global fisheries for a special issue devoted to “The Future of Food.”⁵ Two faculty members of the Fisheries Centre (now Institute for the Oceans and Fisheries), Professors Carl Walters and Tony Pitcher joined the *Sea Around Us* team in co-authoring what became a review which, as of this writing, has been cited nearly 3,000 times.

-
- 1) Palomares, M.L.D., D. Zeller, C. Young, S. Booth and D. Pauly. 2002. A CD-ROM on West-African Ecosystems. Presented at the International Symposium on ‘Marine Fisheries, Ecosystems and Societies in West Africa: half a century of change,’ held in Dakar, Senegal, June 24-28, 2002 [CD-ROM available from the first and last authors].
 - 2) Chavance, P., M. Ba, D. Gascuel, J.M. Vakily and D. Pauly (eds.). 2004. *Pêcheries maritimes, écosystèmes et sociétés en Afrique de l’Ouest : un demi-siècle de changement. Actes du symposium international, Dakar - Sénégal, 24-28 juin 2002*. Office des publications officielles des communautés Européennes, XXXVI, ACP-UE 15, 532 p. + Appendices. [Marine Fisheries, Ecosystems and Society in West Africa: Half a Century of Change. All chapters have abstracts and figure and table legends in French or English [www.ird.fr/osiris/telechargement/Symposium%20SIAP/index.htm]]
 - 3) Palomares, M.L.D. and D. Pauly (eds.). 2004. *West African marine ecosystems: Models and fisheries impacts*. University of British Columbia, Vancouver. 209 p.
 - 4) Belhabib, D., A. Mendy, Y. Subah, N.T. Broh, A.S. Jueseah, N. Nipey, N. Willemse, D. Zeller and D. Pauly. 2015. Fisheries catch under-reporting in The Gambia, Liberia and Namibia and the three Large Marine Ecosystems which they represent. *Environmental Development* 17: 157-174.
 - 5) Pauly, D., V. Christensen, S. Guénette, T.J. Pitcher, U.R. Sumaila, C.J. Walters, R. Watson and D. Zeller. 2002. Towards sustainability in world fisheries. *Nature* 418: 689-695.

2003: The Millennium Ecosystem Assessment

The year 2003 saw the *Sea Around Us* fully engaged in the ‘Millennium Ecosystem Assessment’ (MA), a global initiative called for by the United Nations Secretary-General Kofi Annan in 2000 and involving a multitude of scientists and institutions. The MA was conducted from 2001 to 2005 and was devoted to evaluating the implication for humans of the massive changes inflicted onto the Earth’s ecosystems (see www.millenniumassessment.org).

As a result of our participation, the MA considered two marine realms, a ‘Marine Systems’ chapter, for which Daniel Pauly and Jackie Alder (then a senior member of the *Sea Around Us* team, now at FAO), were Coordinating Lead Authors, and a ‘Coastal’ chapter, in which Jackie had a similar role. These two chapters^{1,2} made extensive use of our newly mapped fisheries catch data and other databases, thus demonstrating their utility for assessments such as the MA.

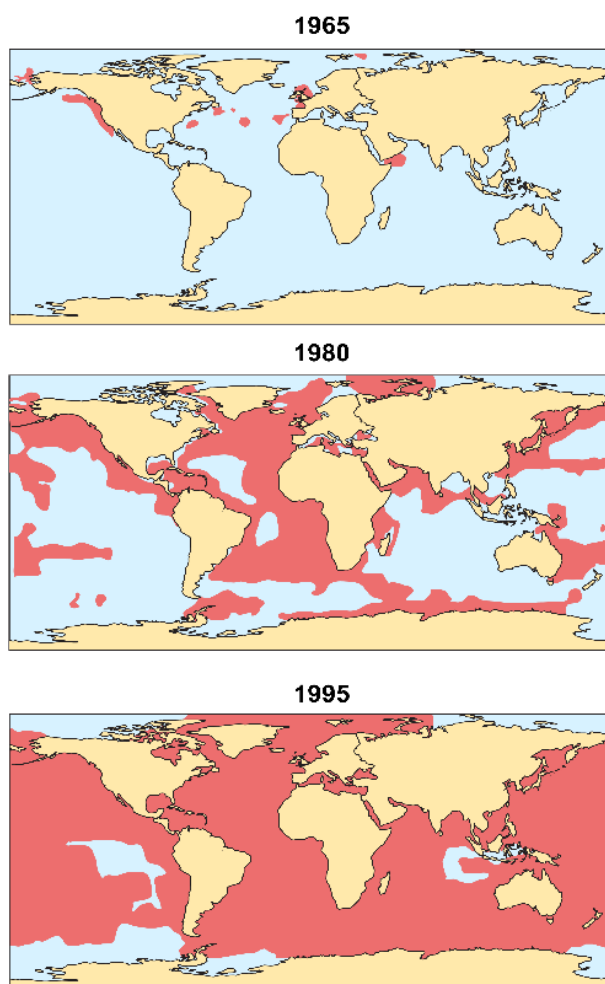


Figure 5. The three panels of this figure are adapted from figure 18.6 in our ‘Marine Systems’ chapter in the Millennium Ecosystem Assessment¹, itself adapted from a PowerPoint animation, in which the about 150,000 half-degree latitude/longitude maritime cells used for spatializing FAO global catch (or more precisely ‘landings’) statistics were switched from yellow to red when the catch therein had peaked. This PowerPoint animation, also frequently included in presentations by former US Vice-President Al Gore, nicely illustrated the geographic expansion of fisheries that took place after WWII, and to which the *Sea Around Us* later devoted lots of attention³.

This positive experience was in line with other experiences of this sort, e.g., with *National Geographic*⁴, the Pew Ocean Commission (2003), the 22nd report of the U.K. Royal Commission on Environmental Pollution (*Turning the Tide*, 2004), WWF's successive assessments of the European Common Fisheries Policy, or more targeted studies, such as the *Sea Around Us*' report to the EU Parliament's Fisheries Committee on the distant-water fleet of China⁵, which later led to a rather impactful paper⁶.

Box 5: In 2003, the *Sea Around Us* published an article in *Science* about the future of fisheries⁷, which, as is the rule for such exercises, projected trends prevailing at the time (e.g., the trend toward fishing in increasingly deeper water⁸). Perhaps more interestingly, we also used pre-formulated scenarios⁹ to compare possible complex and interdependent socioeconomic impacts on fisheries and marine ecosystems, an approach we also used when evaluating possible development paths for mariculture (see account for 2014).

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- 1) Pauly, D., J. Alder, A. Bakun, S. Heileman, K.H.S. Kock, P. Mace, W. Perrin, K.I. Stergiou, U.R. Sumaila, M. Vierros, K.M.F. Freire, Y. Sadovy, V. Christensen, K. Kaschner, M.L.D. Palomares, P. Tyedmers, C. Wabnitz, R. Watson, and B. Worm. 2005. Marine systems. Chapter 18, p. 477-511 In: R. Hassan, R. Scholes and N. Ash (eds.) *Ecosystems and human well-being: Current states and trends, Vol. 1*. Millennium Ecosystem Assessment and Island Press, Washington, D.C.
 - 2) Agardy, T., J. Alder, P. Dayton, S. Curran, A. Kitchingman M. Wilson, A. Catenazzi, J. Restrepo, C. Birkeland, S. Blaber, S. Saifullah, G. Branch, D. Boersma, S. Nixon P. Dugan and C. Vörösmarty. 2005. Coastal systems and coastal communities, p. 513-543 (in same volume as above).
 - 3) Swartz, W., E. Sala, R. Watson and D. Pauly. 2010. The spatial expansion and ecological footprint of fisheries (1950 to present). *PLoS ONE* 5(12) e151433.
 - 4) Watson, R. and D. Pauly. 2001. Global overfishing. p. 163 In: S. Earle (ed.) *National Geographic Atlas of the Ocean: the deep frontier*. National Geographic, Washington, D.C.
 - 5) Blomeyer, R., I. Goulding, D. Pauly, A. Sanz, and K. Stobberup. 2012. *The role of China in World Fisheries*. European Parliament, Directorate General for Internal Policies. Policy Department B: Structural and Cohesion Policies - Fisheries. Brussels, 97 p.
 - 6) Pauly, D., D. Belhabib, R. Blomeyer, W.W.L. Cheung, A. Cisneros-Montemayor, D. Copeland, S. Harper, V.W.Y. Lam, Y. Mai, F. Le Manach, H. Österblom, K.M. Mok, L. van der Meer, A. Sanz, S. Shon, U.R. Sumaila, W. Swartz, R. Watson, Y. Zhai and D. Zeller. 2014. China's distant-water fisheries in the 21st century. *Fish and Fisheries* 15(3): 474-488.
 - 7) Pauly, D., J. Alder, E. Bennett, V. Christensen, P. Tyedmers and R. Watson. 2003. The future for fisheries. *Science* 302: 1359-1361.
 - 8) Morato, T., R. Watson, T.J. Pitcher and D. Pauly. 2006. Fishing down the deep. *Fish and Fisheries* 7(1): 24-34.
 - 9) Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. *Conservation Biology* 17(2): 358-366.

2004: The whales don't eat our fish

A few countries, mainly Japan, Iceland, Faroe Islands and Norway persist in considering whales as a food source for humans. Japan in particular is intent on commercial whaling and, in December 2018, it abandoned all pretenses of whaling for research.

In 2004, in response to a request from the Humane Society of the USA, the *Sea Around Us* agreed to investigate the validity of Japan's claim that the fish that whales consume would become available to fisheries if whales were culled¹. Thus, we mapped the distribution of whales mainly based on the work of then PhD student Kristin Kaschner², combined these with whale numbers³ and diet composition⁴, and compared the results with global maps of the composition of fisheries catches from the *Sea Around Us*.

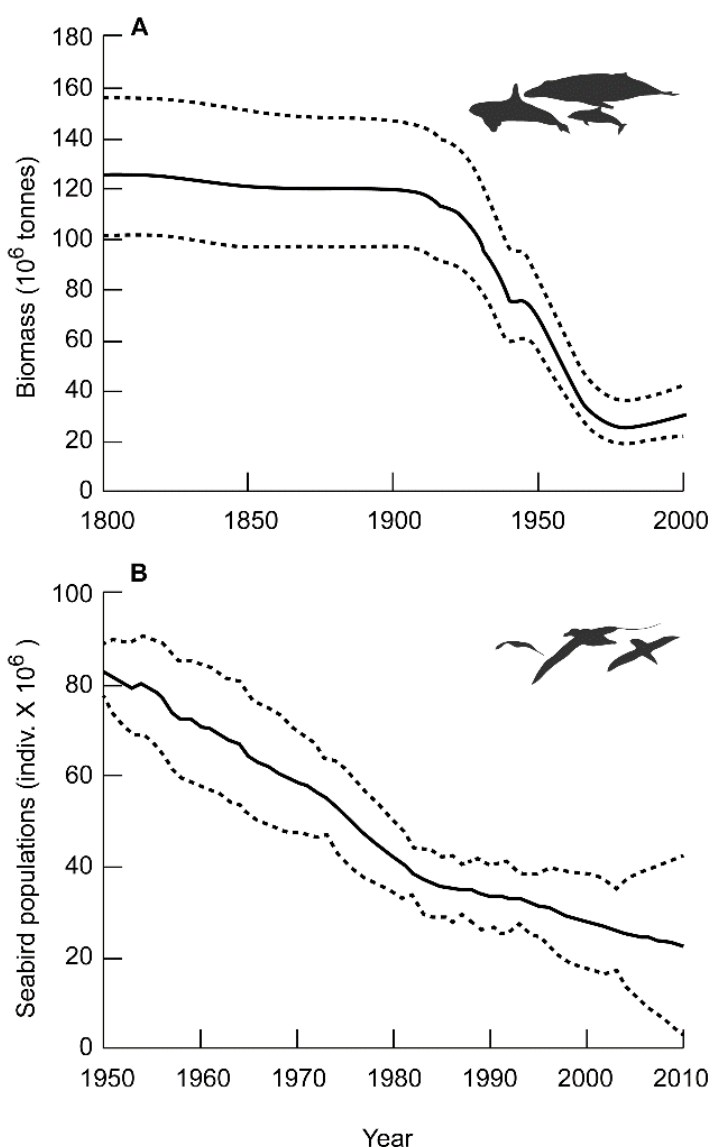


Figure 6. Results of interactions between humans and two groups of marine predators. A: marine mammal biomass, composed of 79 exploited species³; B: number of individuals in 324 species of seabirds^{7,8}.

We found that the fish consumption overlap between whales and fisheries was very small and such that while humans often impact whales, the whales usually do not impact us, and culling them would not increase the world's fisheries catches⁵. Later, detailed studies involving food web modeling published in *Science*⁶ confirmed these findings, which completely refuted the 'whales-eat-our-fish' argument.

Box 6: Given our previous work on marine mammals, it was obvious that we would then move on to seabirds, a group with which fisheries demonstrably compete for fish, especially small 'forage' fish. Initially performed mainly by MSc students of Daniel Pauly (Vasiliki Karpouzi⁷ and Michelle Paleczny⁸), our seabird-fisheries interaction studies gradually involved more groups, recently culminating in an important study⁹ led by David Grémillet, a French seabird ecologist.

The data we acquired on marine mammals and seabirds, along with similar data on other groups, are now part of SeaLifeBase (www.sealifebase.org), which covers marine animals not included in FishBase (www.fishbase.org). Jointly, these two databases, maintained in the Philippines by a small NGO working closely with the *Sea Around Us* (Quantitative Aquatics, see also appendix on the *Sea Around Us* Staff, p. 45), are used to provide the size, trophic levels and other traits that we use for policy-relevant work, e.g., for the estimation of the Marine Trophic Index¹⁰.

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2005: Fueling global fishing fleets

Based on work initiated earlier¹, in 2005 the *Sea Around Us* published one of the first estimates of fuel consumption by the world's fishing fleets and mapped them² (Figure 7).

This result, interesting enough to be featured in the science section of *The New York Times* on December 20, 2005, also was a first estimate of the annual contribution of fisheries to global carbon dioxide emissions (134 million tonnes of CO₂). The CO₂ emissions per tonne of landings were particularly high in trawlers, and among them in shrimp trawlers, which can discard up 80-90% of their catch, mostly consisting of perfectly edible fish³.

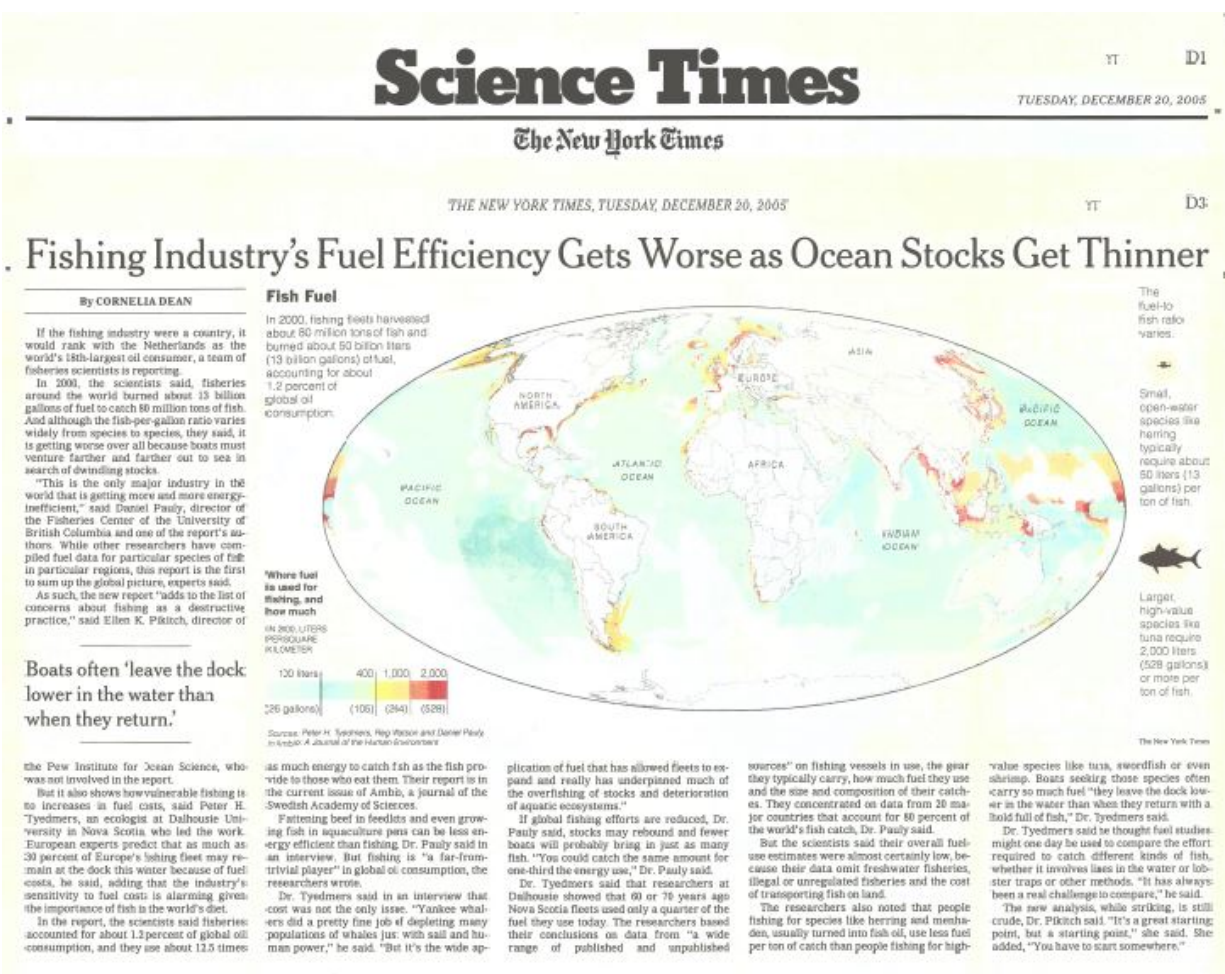


Figure 7. Reproduction of the map of fuel use by global marine fisheries² and the explanatory article that was provided in the *New York Times* section devoted to science of December 20, 2005.

Our global CO₂ emission estimate, which was based on a global catch now known to have been too low, was recently updated by two contributions using different methodologies^{4,5} (see account for 2016). Once the best way to combine the results of these two methodologies is found⁶, we will have a single accurate estimate that can be used by policymakers when they turn to greenhouse gas emissions by fishing vessels.

In fact, given the overcapacity of fisheries and the excessive fishing effort that it implies⁷, this would not only be a good thing for our climate, but also for the fisheries and the fish populations they rely on.

Box 7: In 2005, Daniel Pauly was awarded the International Cosmos Prize from the Expo '90 Foundation in Osaka, “for his excellent research work that contributes to a significant understanding of the relationships among living organisms, the interdependence of life and the global environment.” This major prize, as well as the many awards he received prior and subsequently, along with his publication and citation records, solidified Daniel Pauly’s position as a respected voice for the *Sea Around Us* on issues of ocean conservation and marine policy. It also cemented the reputation and international standing of the *Sea Around Us* and its databases, analyses and products as a reliable source of data-informed science on the impacts of fisheries on the marine ecosystems of the world.

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2006: The harm of fisheries subsidies

Fisheries do not ‘produce’ the fish they catch the way agriculture produces the crop that farmers harvest. Rather, fisheries exploit what natural processes generate freely. Thus, if fisheries cannot keep collecting the bounty that the oceans give them, they have no reason to exist because they surely have overexploited their resource base. However, subsidies, i.e., money transfers from governments, enable fisheries to ignore the clear signals that nature gives them, and to continue fishing depleted stocks.

Our estimate of global subsidies to (marine) fisheries is reliable because it summed country-specific estimates¹ disaggregated by category: capacity-neutral (‘good,’ i.e., payment for management, at-sea safety, and research); capacity-enhancing (‘bad,’ i.e., fuel subsidies, cheap loans for boat purchases, etc.); and ambiguous (‘ugly,’ e.g., decommissioning subsidies).

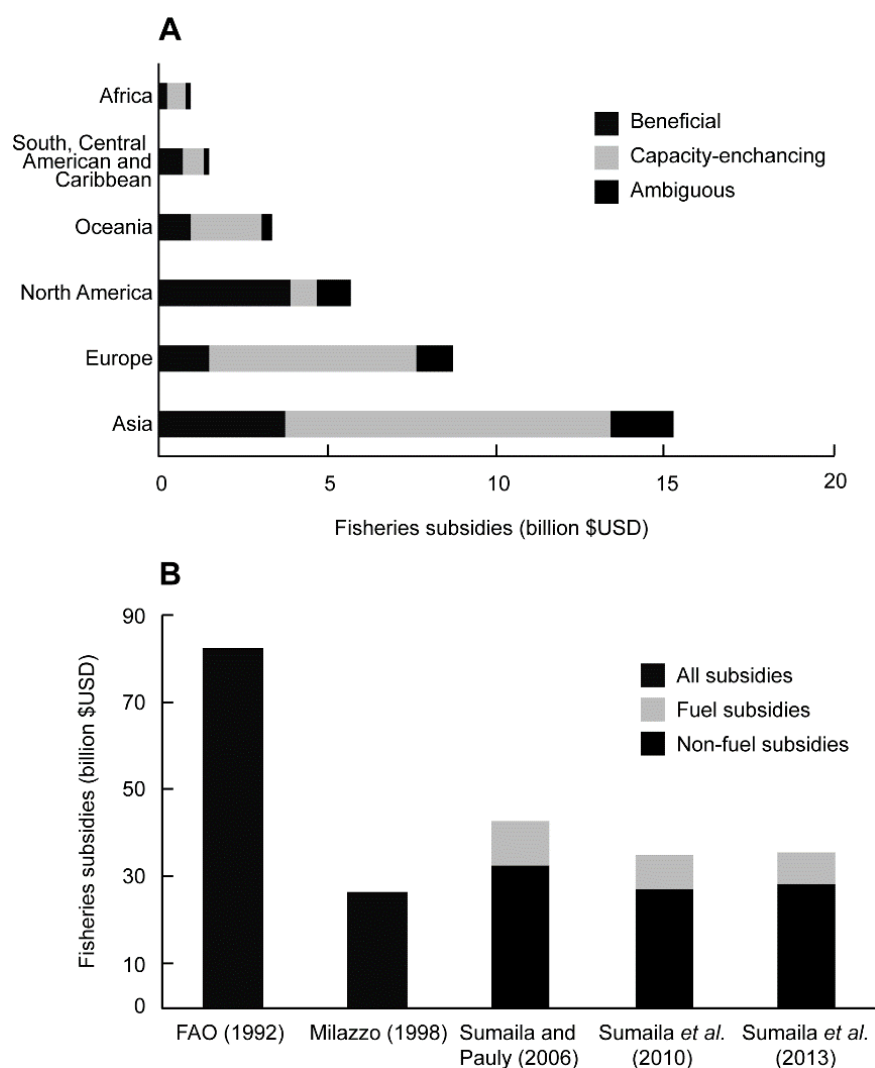


Figure 8. Subsidies to global marine fisheries³. A: Subsidies by region and type. B: Successive global estimates produced by FAO, the World Bank and by U.R. Sumaila and the *Sea Around Us* team, and converted to real 2010 US\$ to enable between-year comparisons.

Our subsidy estimates, available by country at www.seaaroundus.org, were produced through a collaboration between the *Sea Around Us* and the newly formed Fisheries Economic Research Unit of the former Fisheries Centre (now the Institute for the Oceans and Fisheries), led by Professor Rashid Sumaila (formerly a *Sea Around Us* member). As we hoped², these estimates were rapidly picked up by the World Trade Organization (WTO) and by environmental NGOs (notably the WWF and Oceana) and used in various campaigns. This also applied to successive updates of our estimates³.

Box 8: The publication in 1995 of an essay on the ‘shifting baseline’ concept⁴, which describes how ‘old’ data (or ‘anecdotes’) can inform present policies, had many repercussions, one of them being that it reportedly contributed to the emergence of marine historical ecology as an independent sub-discipline^{5,6}. For the *Sea Around Us*, it meant that we chose the earliest possible year (1950, when FAO started issuing global catch data on an annual basis) as starting year for all our catch and derived statistics. We are aware that for some areas, strong fisheries impacts and hence shifted baselines may pre-date our 1950 start year. We also developed other methods for inferences about earlier abundances, notably one that we applied to the Falkland Islands⁷, Raja Ampat in Indonesia⁸ and to dugongs in the Persian Gulf⁹.

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 - 4) Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology and Evolution* 10(10): 430.
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2007: The rise of seafood awareness

The first 30+ years that followed the Second World War was a period of social progress and change throughout the world, which saw the dismantlement of European colonialism in Africa and Asia, far-reaching legislation to protect civil rights and the environment in the USA, the National Health Service in the UK, the *Trente Glorieuses* (30 glorious years) in France, the *Wirtschaftswunder* (economic miracle) in Germany, etc.

In 1980 came the Reagan years in the US and the Thatcher years in the UK, which created, at least in the Western World, the impression that politics and the government had ceased to respond to the needs and aspirations of regular people.

One response to this was that in various western countries, movements emerged that emphasized the power of consumers (as opposed to that of citizens). The Marine Stewardship Council (MSC), which intended to harness the power of consumers to motivate improvements in fisheries management, is an excellent example of this.

Initially, Daniel Pauly and other members of the Fisheries Centre (now IOF) not only supported the creation of the MSC wholeheartedly¹, but were involved in its initial development. In the mid-2000s, however, Jennifer Jacquet, then a PhD student of Daniel Pauly, convinced him that it was time to assess whether the MSC and other consumer-led approaches to fisheries management had been successful.

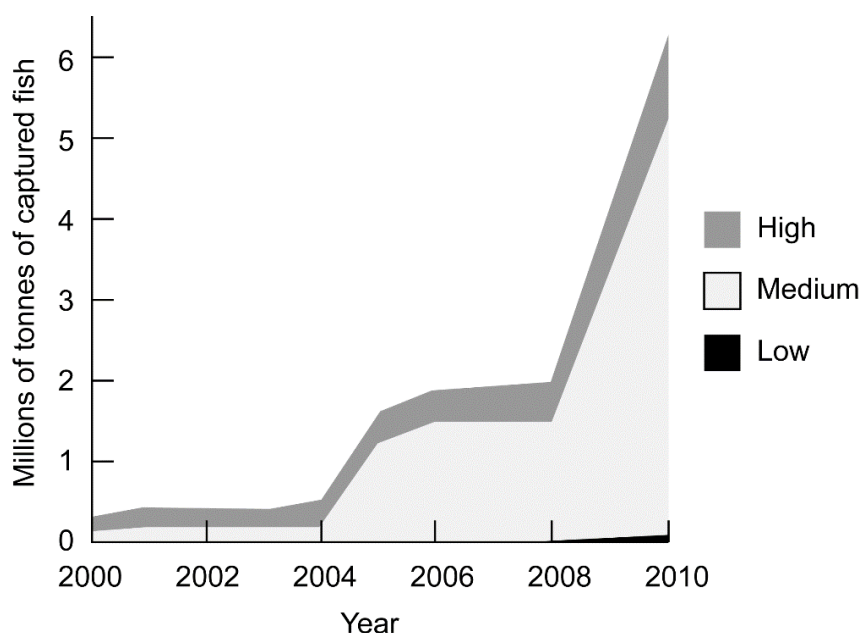


Figure 9. As pointed out in our *Nature* article⁵, from which this figure is adapted, only a minuscule number of MSC-certified fisheries had, in 2010, low environmental impact. Conversely, many were trawl fisheries, which can never be 'low impact' or 'sustainable,' because they modify the marine environment², besides guzzling fuel and creating CO₂ emissions like there is no tomorrow (see account for 2005 and 2018).

This led to various articles^{3,4}, including one in *Nature*⁵. Overall, our conclusion was that these consumer-led approaches, being ‘guilt-based,’ are less successful than ‘shame-based’ approaches, a theme (now) Dr. Jennifer Jacquet, currently an assistant professor at New York University, later explored more fully⁶.

As for the MSC, the *Sea Around Us* no longer supports its activities, as we now view it as fully captured by and dependent on the fishing industry.

Box 9: In 2007, the US National Oceanic and Atmospheric Administration (NOAA) announced the top 10 biggest achievements in the 200 years of its (and its predecessors’) existence. Among those top 10 were the development of the Ecopath modelling approach and software by J.J. Polovina, and its further development by Daniel Pauly, Villy Christensen and Carl Walters⁷, and the Large Marine Ecosystem concept of Ken Sherman and associates, to which the *Sea Around Us* team undoubtedly belongs⁸. Should we mention that we were very pleased by this evaluation?

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2008: Forage fish and fishmeal

In the sea, the equivalent of grass and other terrestrial plants are microscopic algae, the ‘phytoplankton.’ The ‘herbivores,’ the marine equivalent of deer and cows, are tiny ‘zooplankton’ animals, usually smaller than houseflies, and we don’t eat them. They are eaten by small schooling fishes such as sardines, herring, and anchovies, called ‘forage’ fish because they serve as food for larger marine animals, e.g., cod and tuna among fishes, whales among marine mammals, and seabirds such as pelicans and albatrosses.

People in many European countries, for example, Spain, Italy, France and Germany, consume forage fish (sardines, anchovies, herring...) and so do people in Africa, Asia and South America where they are often a staple food item. However, forage fish have another use, that of raw material for the industrial production of fishmeal and fish oils, used not only in the feed of farmed salmon and other carnivorous fish (see account for 2014), but also of pigs and chickens. Fish that could be directly consumed by people is used to feed animals, which are then eaten by other, usually wealthier people. The year 2008 is when the *Sea Around Us* published a first comprehensive study of the food security issue that this represents¹. We also participated in collective efforts to design management systems that would ensure the sustainability of forage fish fisheries².

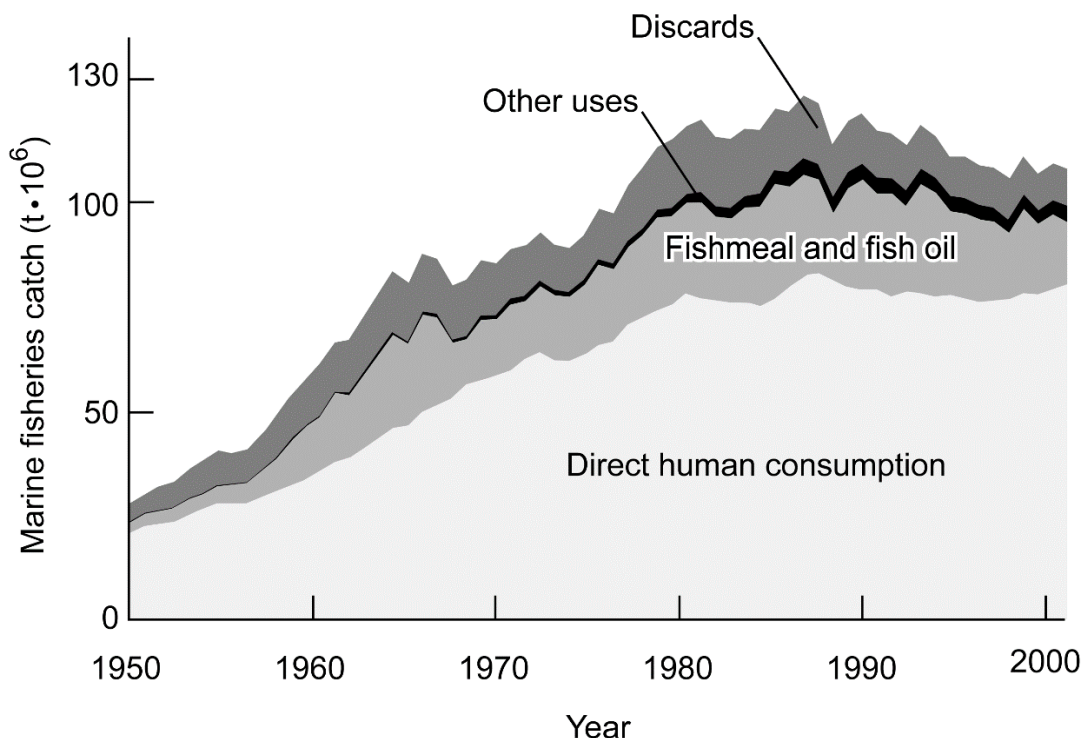


Figure 10. Disposition (i.e., end uses) of the catch of the world’s marine fisheries³ (note the large fraction of the catch that is reduced to fishmeal and fish oil). This graph, soon to be updated beyond 2014, will in the future also include baitfish, and distinguish between fish that are landed dead and fish entering the live-fish trade for food and aquaria.

Later, based mainly on work by Tim Cashion, currently a PhD student of Professor Rashid Sumaila, we established that in the early 2010s, between 15 and 20 million tonnes of fish were annually reduced to fishmeal and fish oil, vs. about 80 million tonnes consumed directly by human³ (Figure 10). Jointly with the re-estimation of the magnitude of another form of waste (discarded bycatch⁴), this should allow for the evaluation of the part that wild-caught fish may play as a source of human food.

Also, the consequence of global warming for fisheries (see accounts for 2009 and 2013) will have to be considered.

Box 10: Marine protected areas (MPAs) are one of the most important tools for maintaining marine biodiversity in the face of an ever-increasing fishing pressure. However, in the early 2000s, it was not known how much of the world ocean surface was protected. Louisa Wood, then a PhD student of Daniel Pauly, single-handedly created a database that she called MPAGlobal, based on files supplied to her by the World Data Monitoring Center (WDMC) that, at the time, did not distinguish between protected areas on land and marine protected areas. Then, she estimated the growth rate of MPA coverage. The result was a sobering 5% per year, which, given a then very low baseline, meant that most of the global MPA targets at that time (e.g., 20% coverage by 2020) would be missed⁵. We like to believe that the widely reproduced graph illustrating this trend helped accelerate the designation of very large marine reserves.

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2009: Oceans warming and tropical fisheries

In early 2007, even before he had defended his PhD thesis, William Cheung became a post-doc with the *Sea Around Us* tasked to work on climate change. The work that he did was outstanding¹ and within two years, he was offered a tenure track position at the University of East Anglia. We lured him back, however, and he continues his close collaboration with the *Sea Around Us* (see also accounts for 2013 and 2017).

William's task with the *Sea Around Us* was to model the well-established observation that increasing ocean temperatures cause the center of the distribution of fish and marine vertebrate populations to move poleward. The basic reason for this is that different species of fish can thrive only within relatively narrow temperature intervals. In other words, fish have a preferred temperature and these preferred temperatures do not change rapidly (or would require thousands of years to change).

Thus, fish exposed to increasing temperatures must move to areas where the temperature is that to which they are adapted. Such temperatures occur in deeper waters, but the main movement is poleward because it is only at higher latitudes that fish find the temperatures that they are adapted to.

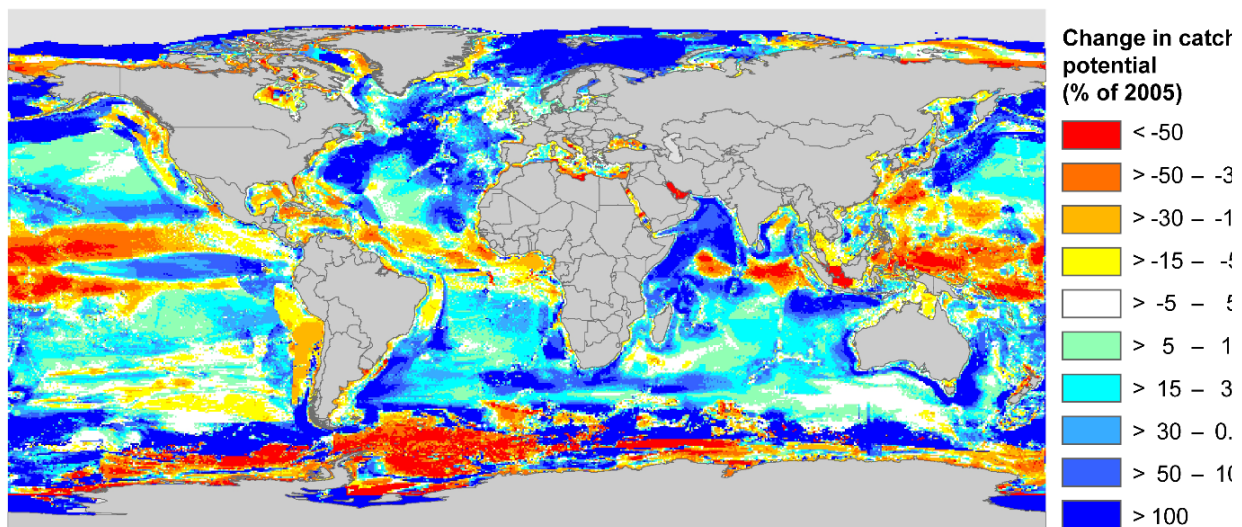


Figure 11. Change to the 2050s in the maximum catch potential of marine fisheries catch, as suggested by a collaborative study that used over 1000 *Sea Around Us* distribution maps of exploited fish and invertebrate species⁴.

The sophisticated ‘envelope’ model that William Cheung developed, combined with the species-specific distribution maps that the *Sea Around Us* was using to spatialize catch data^{2,3} and predicted temperatures and other modelled ocean attributes from our partners at Princeton University, enabled us to develop predictions of where different species of fish will likely occur decades from now^{4,5}. Also, as the over 1000 fish and invertebrate species included in this model were all commercially exploited, it became possible to map where catches would likely increase, and likely decrease⁶.

In Figure 11, we can see that the tropics will probably experience massive declines in fisheries catches from global warming. This being the first map ever to show the effect of global warming on marine fisheries, it was selected by the Intergovernmental Panel on Climate Change (IPCC) as one of the few included in its ‘Summary for Policy Makers’ for 2014.

Box 11: From the onset, the *Sea Around Us* made extensive use of the information on distribution and life-history of fishes in FishBase (www.fishbase.org) and of other marine animals in SeaLifeBase (www.sealifebase.org). This was facilitated by Daniel Pauly being one of the co-creators of FishBase, and M.L. ‘Deng’ Palomares being a co-creator of SeaLifeBase, and its scientific leader. These two global databases are being maintained by a team of encoders and programmers in the Philippines (see www.q-quatics.org)⁷, who work in close collaboration with the *Sea Around Us* team.

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 - 3) Palomares, M.L.D. W.W.L. Cheung, V.W.Y. Lam and D. Pauly. 2016. The distribution of exploited marine biodiversity, p. 46-58 In: D. Pauly and D. Zeller (eds.) *Global Atlas of Marine Fisheries: A critical appraisal of catches and ecosystem impacts*. Island Press, Washington D.C. xvii + 486 p.
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2010: Are RFMOs failing the High Seas?

A perception prevailing from the 1970s to the 1990s was that fisheries issues were inherently international issues, and that their resolution always entailed lengthy and difficult international negotiations and agreements.

Yet, with entry into force in 1982 of the UN Convention on the Law of the Sea, most fisheries and their resource base ended up fully within the 200-nautical mile Exclusive Economic Zones and therefore fully under national jurisdiction. Thus, for example, the largest fishery stock in the world, the Northern-Central stock of Peruvian anchoveta (*Engraulis ringens*), is fully under Peruvian jurisdiction.

Not so for tuna fisheries and a few other fisheries for highly migratory stocks that straddle several EEZs and range into the high seas, the 60% of the ocean that is *not* under national jurisdiction, and which yields only 5-8% of global catches. These stocks and their fisheries are supposed to be managed by Regional Fisheries Management Organizations (RFMO), of which there are 18, with names such as International Commission for the Conservation of Atlantic Tuna (ICCAT) and the Commission for the Management of Antarctic Resources (CCMLAR).

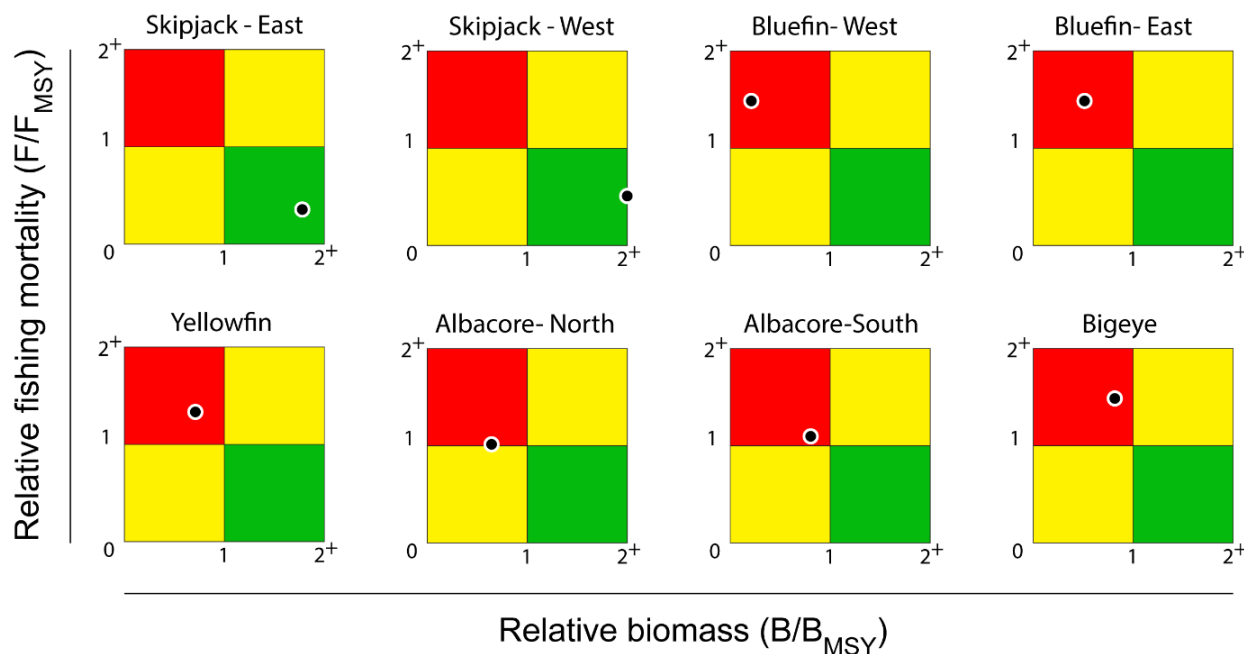


Figure 12. Kobe plots of the eight principal tuna stocks under the management of ICCAT, illustrating that six of these (75%) are subjected to excessive fishing mortality, and have biomasses that are too low³. Similar Kobe plots for the other RFMOs may be found at www.seaaroundus.org.

The *Sea Around Us*, in the person of (now) Dr. Sarika Cullis-Suzuki, then a MSc student of Daniel Pauly, undertook an evaluation of the performance of RFMOs and assessed them in terms of how they keep their own promise of transparency and coverage, and how the resources they are supposed to manage are faring.

The results were disappointing to say the least, with ICCAT being the worst performing, thus confirming a widely held opinion, and CCMLAR being the best¹. Following the presentation of these results before a UN body² and in Europe, the evaluation was repeated with similarly disappointing results³. This provided support for the suggestion that the High Seas should be closed to fishing, a daring idea whose time may have come (see account for 2015).

Box 12: In 2010, two books were published that Daniel Pauly had been writing while on a (half-year) sabbatical in Sète, France between January and March 2009, and in Bremerhaven, Germany between April and June of the same year. The first book⁴ focused on the relationship between fish growth and respiration, and on the response of fish to ocean warming (see accounts for 2009, 2013, and 2017), while the second⁵ consisted of commented reprints of five of his earlier articles in *Nature* and *Science*, of which three were *Sea Around Us* contributions (see account for 2001 and boxes 4 and 5).

1) Cullis-Suzuki, S. and D. Pauly. 2010. Failing the high seas: a global evaluation of regional fisheries management organizations. *Marine Policy* 34(5): 1036-1042.

2) Cullis-Suzuki, S. 2010. The UN Experience. *Sea Around Us Newsletter*, May-June 2010 (59.): 4-5.

3) Cullis-Suzuki, S. and D. Pauly. 2016. Global evaluation of high seas fisheries management, p. 79- 85 In: D. Pauly and D. Zeller (eds.) *Global Atlas of Marine Fisheries: A critical appraisal of catches and ecosystem impacts*. Island Press, Washington D.C. xvii + 486 p.

4) Pauly, D. 2010. Gasping fish and panting squids: Oxygen, temperature and the growth of water-breathing animals. *Excellence in Ecology* (22), International Ecology Institute, Oldendorf/Luhe, Germany, xxviii + 216 p.

5) Pauly, D. 2010. *Five easy pieces: How fishing impacts marine ecosystems*. Island Press, Washington, D.C., xii + 193 p.

2011: Fishing in the High Arctic

The waters off the northern coasts of Canada, Alaska (USA) and Northern Siberia (Russia) constitute an ensemble ('FAO Area 18') from which neither of these three countries nor the FAO report any fisheries catches. Yet, the Inuit in Canada and Alaska and the 'People of the North' in Russia do fish along the Arctic coasts and in the estuaries of the great rivers that empty into the Arctic Sea.

These catches could be reconstructed based on scattered consumption studies^{1,2} and miscellaneous other data³. Granted, the resulting annual catch estimates were tentative and small when compared with the lower-latitude fisheries, as they are overwhelmingly subsistence fisheries. But this is not a good reason to report zero catches from these regions and imply that these activities and the people that perform them can be neglected.

This neglect, however, is the impression one gets when looking at the data at hand, which, in combination with various social indicators, clearly document that the Inuit communities in Alaska and northern Canada and People of the North in Russia do not receive the full benefits that their respective countries afford to their other citizens. This was particularly clear in the case of Canada, in the form of the high catches of char (*Salvelinus alpinus*) then caught by the Inuit to feed their sled dogs (Figure 13).

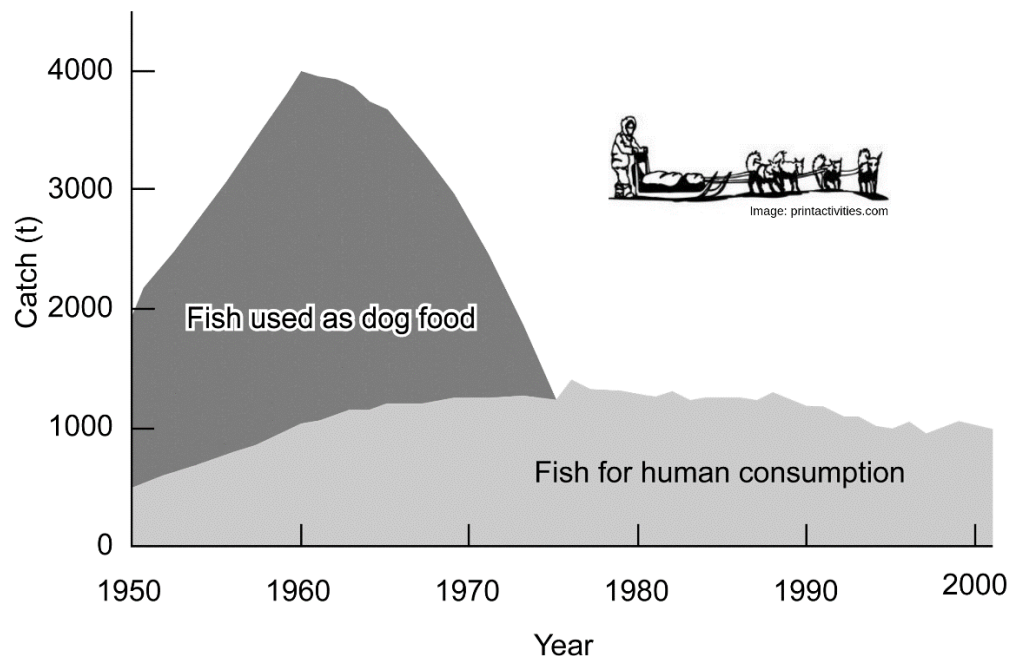


Figure 13. Reconstructed marine fish catch from the Canadian Arctic, distinguishing the component used as food by people from that used as feed for Inuit sled dogs. The latter declined due to a now widely documented dog-killing spree by the Canadian government (see, e.g., <http://bit.ly/globeandmailarticle> and <http://bit.ly/eskimodog>).

These dogs were slaughtered in the 1960s and 1970s by the Royal Canadian Mounted Police to force the Inuit into ‘modern’ settlements that are now riddled by social problems. Another reason that comprehensive marine fisheries catches from the High Arctic should be available is that this is the region of the world where climate change has the most impact and where fisheries, due to global warming, are likely to increase, as the Arctic sea will be invaded by species from lower latitudes (see account for 2009).

Indeed, these are probably the reasons why the peer-reviewed article summarizing our reconstruction of Arctic Sea fisheries catches⁴ elicited such high interest in the Canadian press with articles such as one on CBC News titled “Arctic fishing grossly underreported,”⁵ and in international media, with Reuters publishing a piece titled “Researchers warn Arctic fishing under-reported.”⁶

Box 13: Belize is a lovely country and one where US, Canadian and European marine biologists like to do field work. However, not much of this work, when published, is shared with Belizean scientists and institutions. The impact of this lack of research literature was evident when the Belizean government, in a weak moment, proposed allowing exploratory drilling for oil in the coral reefs that line its coasts (and the pockets of Belizean tourist operators).

To address this problem, the *Sea Around Us* held a conference in Belize, hosted by Oceana and supported by the Oak Foundation⁷. The purpose was to highlight the vast amount of information showing that an oil spill would have devastating consequences for marine biodiversity and for tourism in Belize^{8,9}. Additionally, Dr. M.L. ‘Deng’ Palomares took it upon herself to assemble a huge number of PDFs documenting marine biological research conducted in Belize, and sharing these with the University of Belize.

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- 1) Booth, S. and D. Zeller. 2008. *Marine fisheries catches in Arctic Alaska*. Fisheries Centre Research Reports 16(9), 59 p.
 - 2) Booth, S. and P. Watts. 2007. Canada’s Arctic marine fish catches. p. 3-15. In: D. Zeller and D. Pauly (eds.) *Reconstruction of marine fisheries catches for key countries and regions (1950-2005)*. Fisheries Centre Research Reports 15(2).
 - 3) Pauly, D. and W. Swartz. 2007. Marine fish catches in North Siberia (Russia, FAO Area 18). p. 17-33 In: D. Zeller and D. Pauly (eds.) *Reconstruction of marine fisheries catches for key countries and regions (1950-2005)*. Fisheries Centre Research Reports, 15(2).
 - 4) Zeller, D., S. Booth, E. Pakhomov, W. Swartz and D. Pauly. 2011. Arctic fisheries catches in Russia, USA and Canada: Baselines for neglected ecosystems. *Polar Biology* 34(7): 955-973.
 - 5) CBC News. February 4, 2011. Arctic fishing grossly underreported: report. Available at http://www.seaaroundus.org/OtherWebsites/2011/CBCNews_ArcticFishingGrosslyUnderreportedReport.pdf
 - 6) Dowd, A. February 4, 2011. “Researchers warn Arctic fishing under-reported.” Available at http://www.seaaroundus.org/OtherWebsites/2011/ReutersUK_ResearchersWarnArcticFishingUnderreported.pdf
 - 7) Palomares, M.L.D. and D. Pauly. 2011 (eds.) *Too precious to drill: The marine biodiversity of Belize*. Fisheries Centre Research Reports 19(6), 175 p.
 - 8) Palomares, M.L.D. and D. Pauly. 2011. Documenting the marine biodiversity of Belize in FishBase and SeaLifeBase, p. 78-106 In: M.L.D. Palomares and D. Pauly (eds.) *Too precious to drill: The marine biodiversity of Belize*. Fisheries Centre Research Reports 19(6).
 - 9) Cisneros-Montemayor, A. and U.R. Sumaila. 2011. The economic value and potential threats to marine ecotourism in Belize. In: M.L.D. Palomares and D. Pauly (eds.) *Too precious to drill: The marine biodiversity of Belize*. Fisheries Centre Research Reports 19(6).

2012: Jellyfish are fished and eaten by people

Jellyfish are not fish but they matter because they eat the eggs and larvae of fish; they are a major pain (literally!) for bathers along beaches and they clog the intakes of desalination and other industrial plants requiring large quantities of seawater for cooling.

On the other hand, despite consisting of 98% water, they are important prey in the oceans, especially for turtles, a wide array of fish, and people -yes, some jellyfish species are human food and rather tasty and crunchy, too-.

Thus, it would be nice to know whether or not jellyfish populations are generally increasing or decreasing. The *Sea Around Us*, in the person of (now) Dr. Lucas Brotz, then an MSc student, undertook an evaluation of the academic literature as well as newspapers and other media reporting on jellyfish outbreaks.

The study, which did account for increased encounters with jellyfish (because of increased human population and increased tourism) and found that jellyfish had likely increased in the overwhelming majority of the world's large marine ecosystems¹, had a huge media impact, and very much set Lucas, who later completed a PhD on jellyfish fisheries, on his career path.

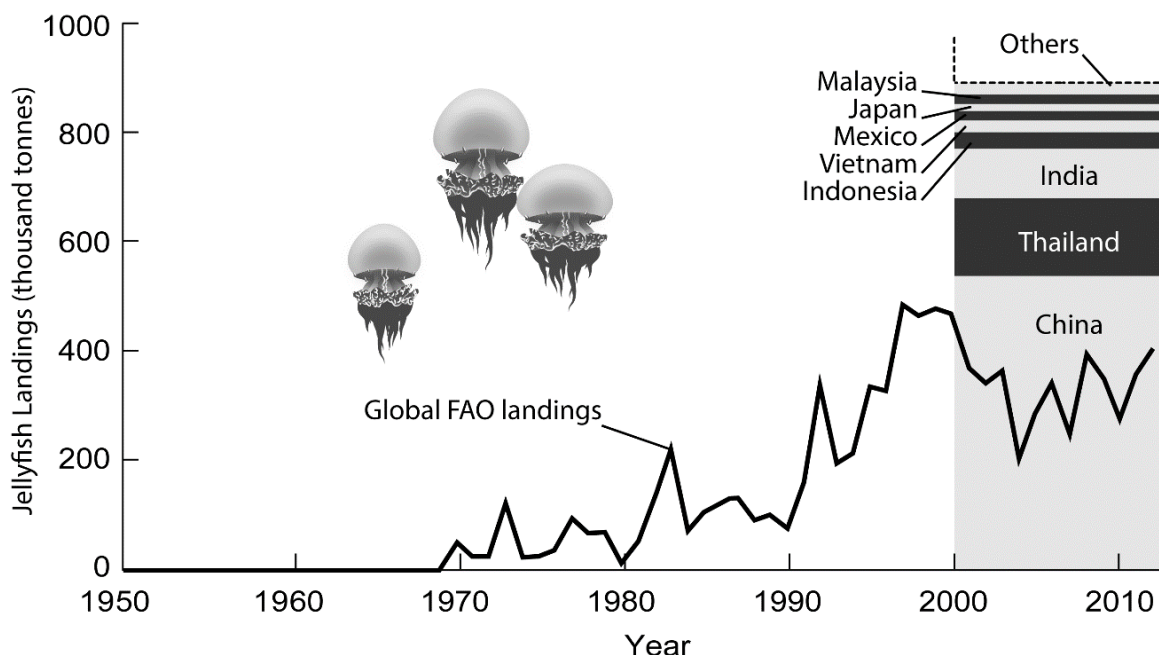


Figure 14. Global landings of jellyfish reported to FAO (solid line) for 1950-2012 and improved estimates of landings for 2000-2013². The schematic representation of jellyfish is inspired by the flame jellyfish (*Rhopilema esculentum*), which is particularly esteemed in China, its main fisheries producer and consumer.

Lucas' contributions established the *Sea Around Us* website as a place to get reliable information on fisheries catch trends of jellyfish². In this, our database is complementing SeaLifeBase (www.sealifebase.org), which, thanks to input from Lucas and others³, has an increasing amount of life history information on jellyfish, including on their growth⁴, previously thought to be very hard to estimate.

In 2016, the design of our website was strongly modified and further improved by a team of professionals from Vulcan Inc., the project implementation arm of the Paul G. Allen Family Foundation, which funded the *Sea Around Us* from mid-2014 to mid-2017. The website and its underlying databases were re-designed to be automatically updated (by us) and to allow for easy downloading of our data (by third parties). Thus, adding a new year of catch data leads to automatic re-computation of a vast number of derived statistics and graphs. Also, all graphs have a download button that allows access to all data used to construct the graphs in question. Furthermore, we also facilitate direct database access via user-derived and customizable R code inquiries.

Box 14: In 2012, the *Sea Around Us*, via Dirk Zeller, Ar'ash Tavakolie and Daniel Pauly, received UBC's Library Innovative Dissemination of Research Award for the quality of our web portal (www.seaaroundus.org). We are proud of this because it confirmed that we were correct in emphasizing the visual impact of as well as open access to the multiple fisheries statistics we make available on the world's fisheries.

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- 1) Brotz, L., W.W.L. Cheung, K. Kleisner, E. Pakhomov and D. Pauly. 2012. Increasing jellyfish populations: trends in Large Marine Ecosystems. *Hydrobiologia* 690(1): 3-20 [Listed in www.f1000.com].
 - 2) Brotz, L. 2016. Jellyfish fisheries: a global assessment p. 110-124 In: D. Pauly and D. Zeller (eds.) *Global Atlas of Marine Fisheries: A critical appraisal of catches and ecosystem impacts*. Island Press, Washington D.C. xvii + 486 p.
 - 3) Pauly, D., W. Graham, S. Libralato, L. Morissette and M.L.D. Palomares. 2009. Jellyfish in ecosystems, online databases and ecosystem models. *Hydrobiologia* 616(1): 67-85.
 - 4) Palomares, M.L.D. and D. Pauly. 2009. The growth of jellyfishes. *Hydrobiologia* 616(1): 11-21.

2013: The ‘mean temperature of the catch’

Upon his return from the University of East Anglia (see account for 2009), William Cheung resuscitated an idea that we had before his departure to the U.K., but did not follow up at that time.

This was the idea that since each fish species has a stable preferred temperature (usually the temperature prevailing where they are most abundant), fish communities and/or the catch extracted from such communities can be characterized by the mean temperature of their catch, or MTC.

This was similar to the logic that led us to the ‘fishing down’ phenomenon, where each species of fish is attributed a trophic level, which then allows trends of mean trophic level to be computed (see www.fishingdown.org). Thanks to William’s effort at accommodating extremely difficult peer review, we published a paper outlining this idea in *Nature*¹.

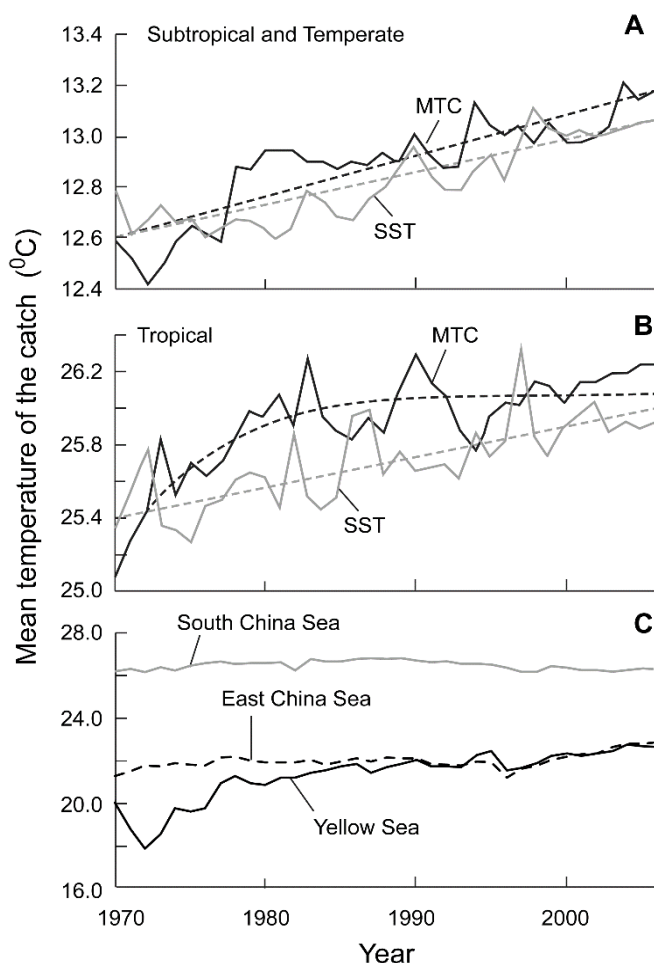


Figure 15. Illustrating the different trends of mean temperature of the catch (MTC) in over 50 subtropical and temperate Large Marine Ecosystems (LMEs) versus the trend in tropical LMEs. Note in A and B that MTC and sea surface temperature (SST) are roughly parallel in the former but divergent in the latter¹. This was confirmed by a more detailed analysis of 3 Chinese LMEs (C) with SST increasing in all 3, but MTC remained constant in the South China Sea (C based on work performed mainly by Ms. Cui Liang, then a visiting PhD student with the *Sea Around Us*, and now with the Chinese Academy of Science in Qingdao, China)².

The MTC concept is now widely used to quantify the effect of ocean warming on national or regional fish catches³, and to demonstrate the effect of ocean warming on fish communities. Figure 15 illustrates this well, along with confirming, as stated in the account for 2009, that the overall effects of ocean warming will be worse in the tropics than in most of the world's other regions, mainly because the fish species that will be leaving the tropics because of excessive temperature will not be replaced by fish from warmer areas (which leads to stagnating MTC).

Moreover, these effects cannot be dismissed as mere extrapolations; rather they demonstrate that ocean warming was detected by fish communities as early as the 1970s, and has since continued to affect them in a manner that is perfectly congruent with the projections in the account for 2009.

Box 15: In 2013, the *Sea Around Us* published a major study and maps on where the deposition of dioxins in marine waters was likely to occur⁴. Dioxins are a family of toxic substances often generated by the burning of plastic. Other works on marine pollution that the *Sea Around Us* did, dealing mainly with the progress of toxic substances through food webs⁵, were summarized in a chapter of the *Sea Around Us Atlas*⁶.

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- 1) Cheung, W.W.L., R. Watson and D. Pauly. 2013. Signature of ocean warming in global fisheries catch. *Nature* 497: 365-368.
 - 2) Liang, C., W. Xian and D. Pauly. 2018. Impacts of ocean warming on China's fisheries catches: An application of "Mean Temperature of the Catch" concept." *Frontiers in Marine Science* 5(26): 1-7.
 - 3) Tsikliras, A.C. and K.I. Stergiou. 2014. Mean temperature of the catch increases quickly in the Mediterranean Sea. *Marine Ecology Progress Series* 515: 281-284.
 - 4) Booth S., J. Hui, Z. Alojado, V.W.Y. Lam, W.W.L. Cheung, D. Zeller, D. Steyn and D. Pauly. 2013. Global deposition of airborne dioxin. *Marine Pollution Bulletin* 75(1-2): 182-186.
 - 5) Booth, S. and Zeller, D. 2005. Mercury, food webs and marine mammals: implications of diet and climate change for human health. *Environmental Health Perspectives* 113(5): 521-526.
 - 6) Booth, S., W.W.L. Cheung, A.P. Coombs-Wallace, V.W.Y. Lam, D. Zeller, V. Christensen and D. Pauly. 2016. Pollutants in the seas around us, p. 152-170 In: D. Pauly and D. Zeller (eds.) *Global Atlas of Marine Fisheries: A critical appraisal of catches and ecosystem impacts*. Island Press, Washington D.C. xvii + 486 p.

2014: Mariculture in the seas around us

Aquaculture in general, and mariculture in particular, are important components of food supply systems, and the *Sea Around Us* is doing its part in documenting this industry, thereby helping to understand it. Thus, based on work initiated by Brooke Campbell, the *Sea Around Us* presented as part of its website, time series of mariculture data for all maritime countries of the world, and by province or state for large countries (www.seaaroundus.org/data/#/mariculture).

This has allowed several in-depth studies and scenario-based projections of the world's mariculture industry^{1,2}. Therein, we emphasized that mariculture, like aquaculture in freshwater, can be seen as consisting of two industries as different from each other as plant agriculture is from cattle ranching and other forms of meat production.

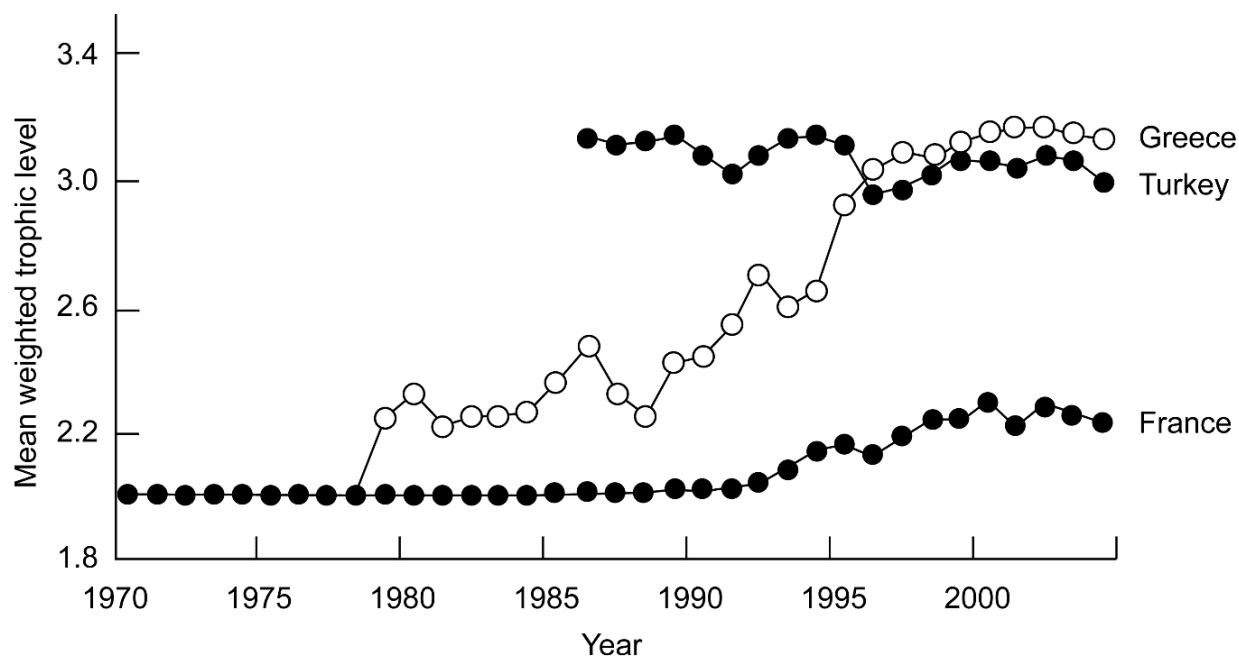


Figure 16. One way to demonstrate the radical difference between the aqua-farming of low-trophic level ('aquaculture A') and that of high-trophic level species ('aquaculture B') is the plotting of time series of the mean weighted trophic level of the aquaculture industry of countries, which will differentiate countries (here: Turkey) 'farming' tuna and other carnivores from, e.g., France, still mainly farming bivalves such as oysters and mussels. This also shows how countries can transit from aquaculture A to B, i.e., France and especially Greece³.

Aquaculture consists of (A) the raising of oysters, mussels, clams and other bivalves that do not need to be fed artificially and of carp, tilapia and other (normally) vegetarian fishes; and (B) the farming of salmon, seabass and other carnivorous fish. Aquaculture A could feed the world, and already adds huge amounts of high-value protein to the human diet. Aquaculture B is preponderant in the Western World³, where it is widely perceived as all there is to ‘aquaculture.’ In fact, this aquaculture B type feedlot operation is a real challenge to the food security of millions of people, notably in West Africa, where (as shown in the account for 2008) small fish previously available to people as food are caught by foreign fleets, ground up and turned into salmon or seabass feed.

Box 16: Dr. Dalal Al-Abdulrazzak, then a PhD student of Daniel Pauly, discovered while working on the fisheries of the Persian Gulf for her thesis, that by using Google Earth she could see and count the fishing weirs which, in that region, are used to catch coastal fishes. She became the first author of a paper⁴ that not only reported on the presence of weirs (including some that were only partly visible), but also estimated the previously neglected and unreported catch made by these weirs. This paper had, in 2014, a humorous follow-up, which can be appreciated by reading our response⁵ to a critique so incompetent (but not cited here) that it was funny.

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- 1) Campbell, B. and D. Pauly. 2013. Mariculture: A global analysis of production trends since 1950. *Marine Policy* 39:94-100.
 - 2) Campbell, B., J. Alder, P. Trujillo and D. Pauly. 2016. A global analysis of mariculture production and its sustainability, 1950-2030, p. 137-151 In: D. Pauly and D. Zeller (eds.) *Global Atlas of Marine Fisheries: A critical appraisal of catches and ecosystem impacts*. Island Press, Washington D.C. xvii + 486 p.
 - 3) Stergiou, K.I., A.C. Tsikliras and D. Pauly. 2009. Farming up the Mediterranean food webs. *Conservation Biology* 23(1): 230-232.
 - 4) Al-Abdulrazzak, D. and D. Pauly. 2013. Managing fisheries from space: Google Earth improves estimates of distant fish catches. *ICES Journal of Marine Science* 71(3): 450–454.
 - 5) Al-Abdulrazzak, D. and D. Pauly. 2014. Ground-truthing the ground-truth: reply to Garibaldi et al.’s comments on: “Managing Fisheries from space: Google Earth improves estimates of distant fish catches”. *ICES Journal of Marine Science* 71: 1927-1931.

2015: Closing the High Seas to fishing?

As outlined in the account for 2010, fisheries in the High Seas jointly generate only 5-8% of the world's marine catch, despite accounting for 60% of the ocean that is not within the Exclusive Economic Zones (EEZ) of maritime countries.

However, the fish targeted are mainly different species of tuna (bluefin, yellowfin, bigeye and skipjack) that are quite valuable and whose capture can therefore justify the deployment of distant-water fleets (especially given that they are all subsidized; see account for 2006).

Only a handful of countries can afford to deploy and subsidize distant-water fleets targeting tuna and thus, these countries enjoy an oligopoly in accessing tuna resources. Moreover, as can be expected, they compete against each other, the result being the deployment of too many vessels and the overfishing of the underlying resources.

Both the inequitable distribution of benefits from the High Seas tuna resources and their competitive exploitation, could be resolved by closing the High Seas to fishing¹. The tuna and other highly migratory fish that are presently caught in the high seas would be caught in the EEZs of various countries bordering the High Seas areas, leading to more equity between countries (Figure 17).

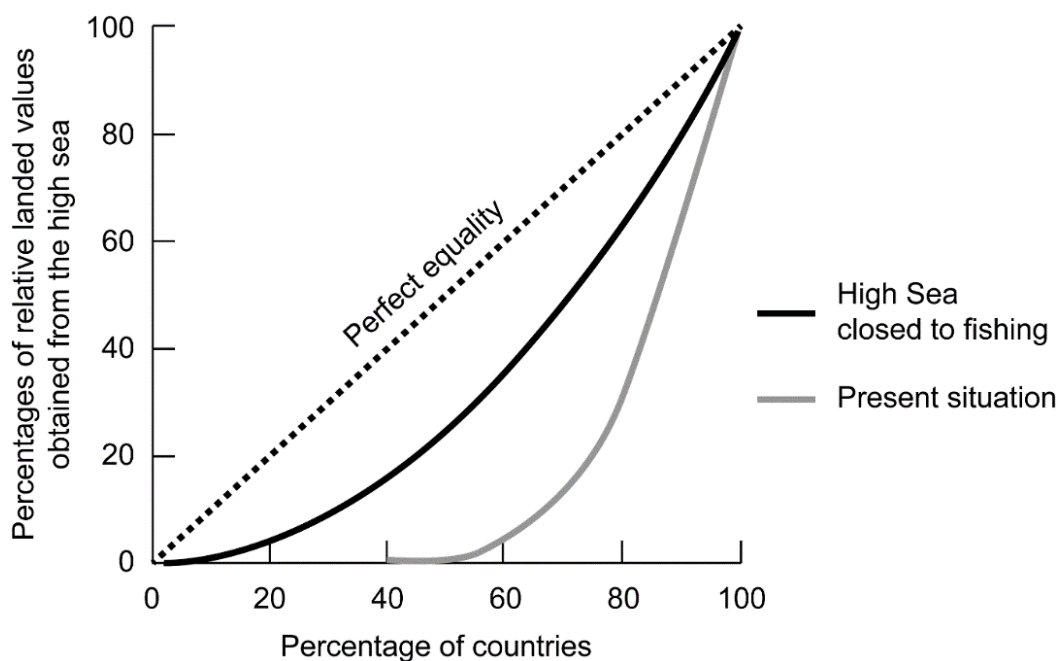


Figure 17. Closing the High Sea to fishing, which would not reduce catches in the long term, would lead to lower fishing costs² and to more equity in the access to tuna resources¹.

Moreover, in the aggregate, more tuna would be caught because the High Seas would act as a giant marine reserve, enabling presently overfished tuna stocks to rebuild while exploiting a ‘spillover’ to be caught within the EEZ.

Many found this suggestion unrealistic. But the 200-nautical mile EEZs that all maritime countries can legally claim was similarly thought to be unrealistic in the 1950s and 1960s, when the idea was first proposed. The *Sea Around Us* is proud to have been part of this proposal, and we look forward to developments on High Seas issues in the coming years.

Box 17: In 2015, we published a compilation of catch reconstructions for the often-neglected sub-Antarctic islands³. Previously, we had published four similar compendia for islands, covering both tropical and temperate islands in all ocean basins, and ranging from the largest, such as Greenland, to the smallest such as Pitcairn Island or Nauru^{4,5,6,7}. Never before had a research group presented the fisheries catches of all island territories of the world. We were the first to do it.

This may lead to advances in ‘nesology,’ the multifaceted disciplines devoted to the study of island economies and culture⁸, but which suffered from access to reliable fishery catch time series from countries’ overseas territories, such as the Galápagos, and also from culturally or economically important islands such as Crete, Sardinia, Sicily or the Balears in the Mediterranean.

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- 1) Sumaila, U.R., V.W.Y. Lam, D. Miller, L. Teh, R. Watson, D. Zeller, W.W.L. Cheung, I. Côté, A. Rogers, C. Roberts, E. Sala and D. Pauly. 2015. Winners and losers in a world where the high seas is closed to fishing. *Scientific Reports* 5: 8481.
 - 2) Sala, E., J. Mayorga, C. Costello, D. Kroodsma, M.L.D. Palomares, D. Pauly, U.R. Sumaila and D. Zeller. 2018. The economics of fishing the high seas. *Science Advances* 4(6): eaat2504.
 - 3) Palomares, M.L.D. and D. Pauly (eds.). 2015. *Marine fisheries catches of Sub-Antarctic islands, 1950-2010*. Fisheries Centre Research Reports 23(1), 45 p.
 - 4) Zeller, D. and S. Harper (eds.). 2009. *Fisheries catch reconstructions: Islands, Part I*. Fisheries Centre Research Reports 17(5), 104 p.
 - 5) Harper, S. and D. Zeller (eds.). 2011. *Fisheries catch reconstructions: Islands, Part II*. Fisheries Centre Research Reports 19(4), 143 p.
 - 6) Harper, S., K. Zylich, L. Boonzaier, F. Le Manach, D. Pauly and D. Zeller (eds.). 2012. *Fisheries catch reconstructions: Islands, Part III*. Fisheries Centre Research Reports 20(5), 134 p.
 - 7) Zylich, K., D. Zeller, M. Ang and D. Pauly (eds.). 2014. *Fisheries catch reconstructions: Islands, Part IV*. Fisheries Centre Research Report 22(2), 157 p.
 - 8) Fischer, S.R. 2012. *Islands: From Atlantis to Zanzibar*. Reaktion Books, London.

2016: Reconstructing the world's marine catch

The first question the *Sea Around Us* was tasked with was what the actual catch of the world's maritime fisheries is (see account for 1999), as opposed to the catch data that FAO receives, harmonizes and disseminates, based on the annual reports submitted by its member countries¹.

Importantly, the data reported by FAO are 'landings' and not 'catches,' because they explicitly omit discarded catches. Also, they cover small-scale fisheries very cursorily, often ignoring artisanal and especially subsistence and recreational fisheries. Additionally, they do not attempt to include illegally caught fish, thus masking the issues with Illegal, Unreported and Unregulated (IUU) fisheries.

After much deliberation on various directions for addressing this question, we developed a methodology for correcting these omissions, at least partially. We called this 'catch reconstruction.' This methodology was first systematically applied to the US territories in the Pacific^{2,3,4} based on two basic principles⁵.

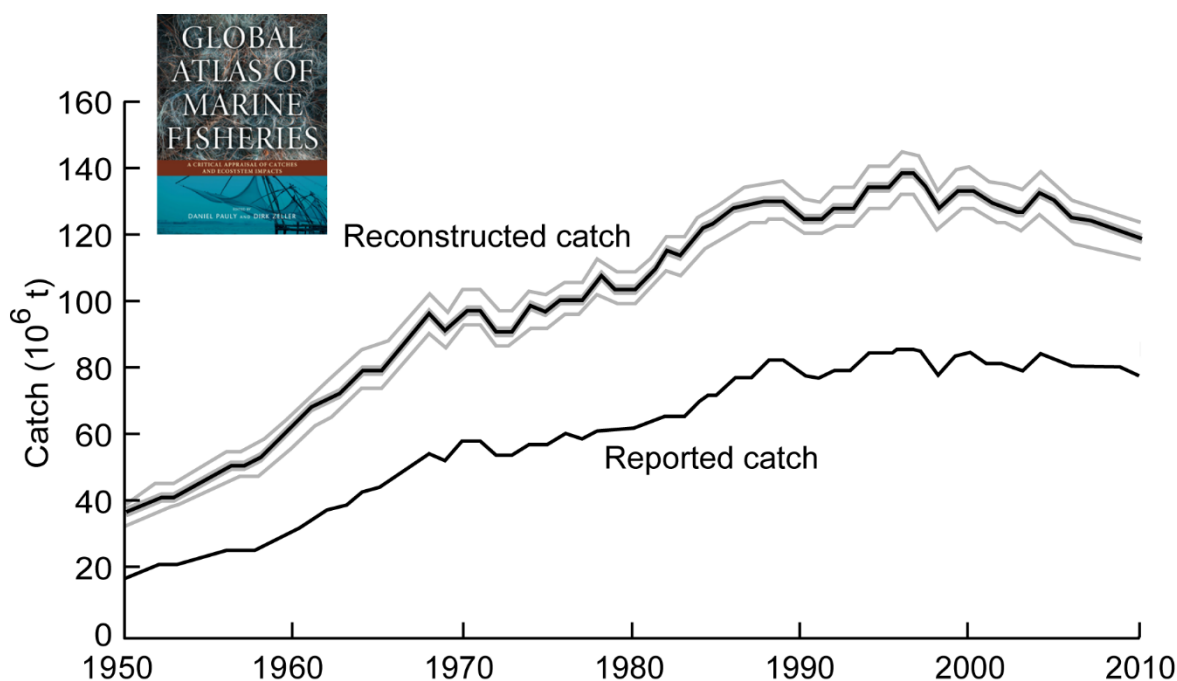


Figure 18. In 2016, we also published a multi-authored *Atlas*⁸, which reviewed the methods and major results of the *Sea Around Us* research activities and the reconstruction project, and presented 273 one-page summaries on the fisheries of the maritime countries of the world, and all their overseas territories.

1. Fisheries are social activities, thus it is not possible for fisheries to exist about which “there are no data”; and
2. It will always be better to estimate the catch of a hitherto undocumented fishery from its “social shadow” (e.g., fish consumption or fish export data, number of persons reporting fishing as their livelihood) than to set its catch at precisely zero, which is what occurs when no other estimate is provided and reported.

Altogether, the *Sea Around Us* initiated over 200 catch reconstructions, covering the Exclusive Economic Zones of all maritime countries, or their overseas territories, for the years 1950 to 2010. The reconstructions are corrected as soon as we become aware of shortcomings and are updated regularly. For example, during our 20th birthday year (2019) they are being updated and improved to the year 2016. These contributions, for which over 100 are now documented in the peer-reviewed literature, involved about 400 co-authors (i.e., about 100 as team members of the *Sea Around Us* and 300 external colleagues from all continents) and formed the basis for the improved and freely available catch database and website of the *Sea Around Us*⁶. These data also provided the foundation for an article in a high impact journal⁷ whose title summarized the main findings of this giant activity: “Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining” (Figure 18).

Box 18: In 2016, we also published a multi-authored *Atlas*⁸ (see insert, Figure 18) which reviewed the methods and major results of the *Sea Around Us* research activities and the reconstruction project, and presented 273 one-page summaries on the fisheries of the maritime countries of the world, and all their overseas territories, with maps expertly drawn by Chris Hoornaert and with nearly 800 other illustrations prepared by Ms. Evelyn Liu (who also drafted or redrafted all illustrations in this report).

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- 1) Garibaldi, L. 2012. The FAO global capture production database: A six-decade effort to catch the trend. *Marine Policy* 36: 760-768.
 - 2) Zeller, D., S. Booth, P. Craig and D. Pauly. 2006. Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. *Coral Reefs* 25(1): 144-152.
 - 3) Zeller, D., S. Booth, G. Davis and D. Pauly. 2007. Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: the last 50 years. *U.S. Fisheries Bulletin* 105: 266-277.
 - 4) Zeller, D., M. Darcy, S. Booth, M.K. Lowe and S.J. Martell. 2008. What about recreational catch? Potential impact on stock assessment for Hawaii's bottomfish fisheries. *Fisheries Research* 91(1): 88-97.
 - 5) Pauly, D. 1998. Rationale for reconstructing catch time series. *EC Fisheries Cooperation Bulletin* 11(2): 4-7.
 - 6) Zeller, D., M.L.D. Palomares, A. Tavakolie, M. Ang, D. Belhabib, W.W.L. Cheung, V.M.Y. Lam, E. Sy, G. Tsui, K. Zylich and D. Pauly. 2016. Still catching attention: *Sea Around Us* reconstructed global catch data, their spatial expression and public accessibility. *Marine Policy* 70: 145-152.
 - 7) Pauly, D. and D. Zeller. 2016. Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications* 7: 10244.
 - 8) Pauly, D. and D. Zeller (eds.). 2016. *Global Atlas of Marine Fisheries: A critical appraisal of catches and ecosystem impacts*. Island Press, Washington, D.C. xvii + 486 p.

2017: Shrinking fish, oxygen and temperature

As part of an influential series of articles on the effect of global warming on fish communities by William Cheung and his associates in the *Sea Around Us* and elsewhere (see accounts for 2009 and 2013), an article was published that explained how higher temperatures, by elevating the oxygen requirements of fish, force them to remain smaller, as is already occurring in various species¹.

This obvious inference was based on the fact that fish gills, as a 2-dimensional surface, cannot grow as fast as their bodies, i.e., the 3-dimensional volumes that gills supply with oxygen. Hence, the larger fish get, the less oxygen they obtain per unit weight (Figure 19). It is thus no surprise that they must remain smaller when exposed to higher temperatures².

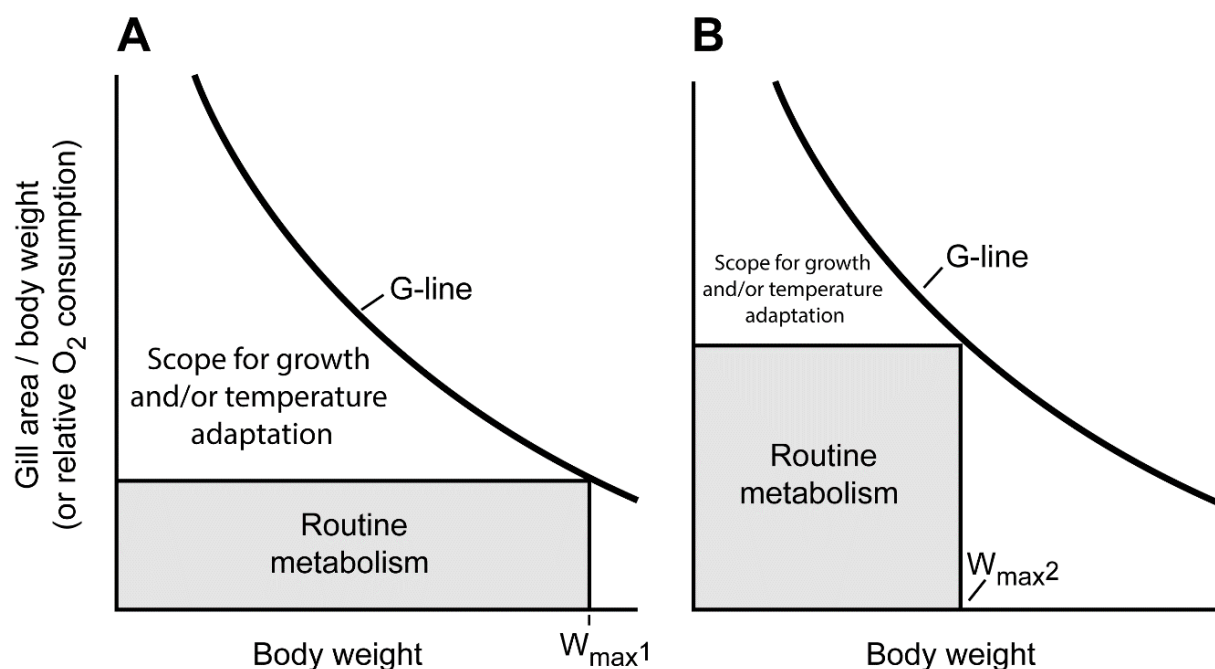


Figure 19. Fish remain smaller in warm than in cold water because their gills (a surface) do not grow as fast as the bodies (a volume) that they supply with oxygen. Thus, gill surface area (where the oxygen uptake occurs) per unit body weight declines until, at maximum weight (W_{max}), relative gill area (and hence oxygen supply) is just sufficient for routine maintenance (shaded area). (A): Fish exposed to a low temperature, which can grow to a large maximum size (W_{max1}). (B): Fish exposed to a high temperature, which increases oxygen requirements, and hence reduces the maximum size that can be reached (W_{max2}).

Yet, this article was contested by a group of fish physiologists, who had previously also attacked one of their colleagues for also writing about fish having problems breathing at high temperatures³. Their criticisms forced us to think more deeply about gills, oxygen and fish growth. This led to the re-expression of earlier work by Daniel Pauly as the Gill-Oxygen-Limitation Theory (GOLT)⁴, which is now attracting increased attention because of the growing worries about the implication of ocean warming and deoxygenation, and similar processes in freshwater bodies.

Box 19: The international dimension of the *Sea Around Us* catch reconstruction work, whose first comprehensive results were published in 2016, was captured in an award-winning documentary by Ms. Alison Barrat. The film is titled *An Ocean Mystery: The Missing Catch* and it premiered at the Smithsonian National Museum of Natural History and on Smithsonian Channel on Earth Day 2017. *The Missing Catch* is now available for free viewing at www.livingoceansfoundation.org/outreach/films/an-ocean-mystery/.

The *Sea Around Us* was also recognized in 2017 through the Oceans Awards in Science being awarded to Daniel Pauly and Dirk Zeller, in recognition of their work and commitment to help address the crisis in our oceans.

-
- 1) Cheung, W.W.L., J.L. Sarmiento, J. Dunne, T.L. Frölicher, V.W.Y. Lam, M.L.D. Palomares, R. Watson and D. Pauly. 2013. Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems. *Nature Climate Change* 3:254-258.
 - 2) Pauly, D. 2010. *Gasping fish and panting squids: Oxygen, temperature and the growth of water-breathing animals*. Excellence in Ecology (22), International Ecology Institute, Oldendorf/Luhe, Germany, xxviii + 216 p.
 - 3) Pörtner, H.-O., and R. Knust. 2007. Climate change affects marine fishes through the oxygen limitation of thermal tolerance. *Science* 315:95 - 97.
 - 4) Pauly, D. and W.W.L. Cheung. 2018. Sound physiological knowledge and principles in modelling shrinking of fishes under climate change. *Global Change Biology* 24:e15–e26.

2018: Assessing ‘all’ fish stocks in the world

If left to their own devices, modern fisheries tend to overfish the resources upon which they depend. Thus, it is necessary to impose limits on fisheries, for example, limits on how much they should catch in a given year, called Total Allowable Catch (TAC) or ‘quotas.’ However, to set quotas, the amount of fish left in the water, its biomass, must be known, and this information is obtained through so-called ‘stock assessments.’

In recent years, formal stock assessments and their methodologies have become enormously complicated and data hungry. This is the reason why formal stock assessments are only undertaken for a minority of the tens of thousands of fish and invertebrate populations that are exploited throughout the world. However, a research partner of the *Sea Around Us*, Dr. Rainer Froese, and his colleagues, have perfected a stock assessment method (CMSY) that requires only catch time series as input, along with easy-to-obtain ancillary quantitative information¹.

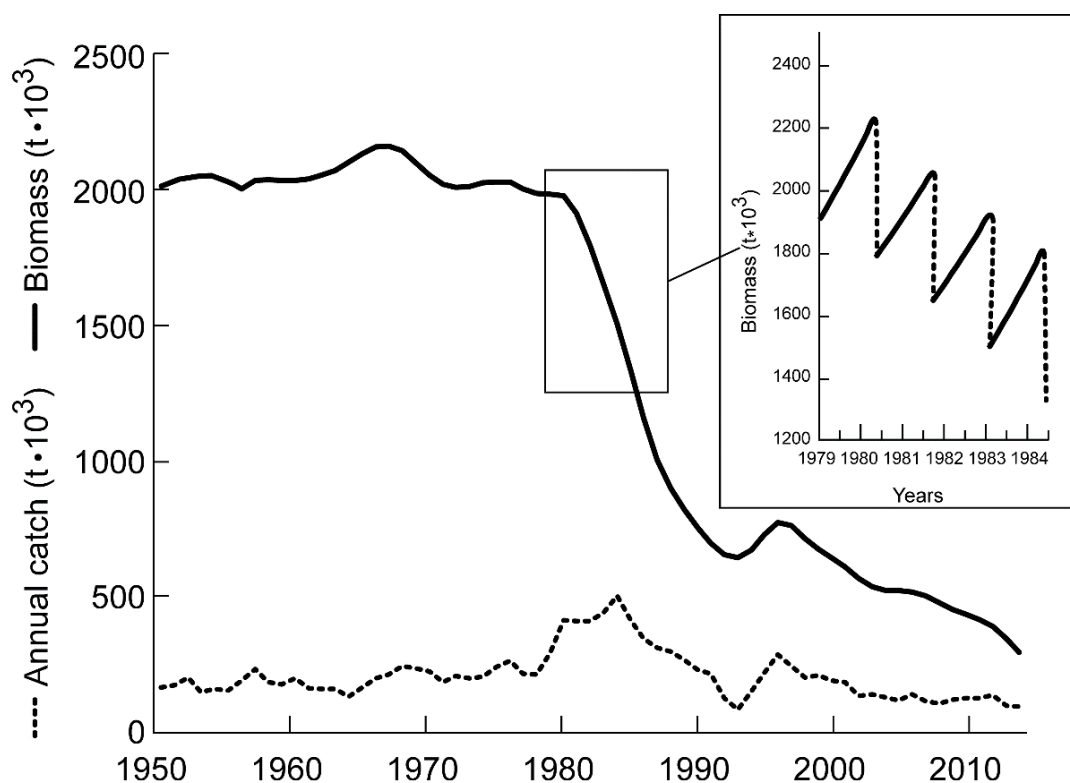


Figure 20. Illustrating the basic principle of the CMSY method: thousands of random but feasible population biomass trajectories are projected from a start year (here 1950), when the biomass is assumed to have been a (generally high) fraction of pre-exploitation carrying capacity (k) which increases via annual growth increments (as a function of population growth rate, r , and B/k) and decreases due to catches (see insert). The biomass trajectory that is retained (along with their associated values of r and k) is one that does not crash the population and best conforms to various constraints.

In 2018, with the support of Oceana, and based on the reconstructed catch time series of the *Sea Around Us*, Dr. M.L. ‘Deng’ Palomares performed over 2000 stock assessments, essentially covering all the most important exploited marine fish and invertebrate species in the world. She was supported in this feat by the *Sea Around Us* research assistants Brittany Derrick, Simon-Luc Noël, Gordon Tsui and Jessika Woroniak, and by Rainer Froese, who came from Germany to work with the group for one month.

This led to the *Sea Around Us* being able to present, for every ‘Marine Ecoregion’ and thus every EEZ of the world, stock assessments of major species occurring and exploited therein² (Figure 20). These assessments, initially presented as PDFs, are scheduled to be incorporated in 2019 into the *Sea Around Us* database and its website as interactive graphs. Thus, these assessments and the data supporting and enabling them can be downloaded and examined, and assessments can be rerun using various assumptions or ‘priors.’

Box 20: In 2018, as a result of another intense effort led by Mr. Tim Cashion (see account for 2008), we published in *Fisheries Research*³ and on our website, the world’s fisheries catch disaggregated by major industrial fishing gears. This disaggregation, available at the level of countries⁴, is also available for Large Marine Ecosystems and other geographies, and thus should enable comparative assessments of the ecosystem impact of fishing, particularly by bottom trawlers.

This work on catch by gear is being complemented with the construction of a global database on fishing effort, as expressed by the cumulative power of the engines in the fishing fleets of maritime countries, ranging from small coastal to large offshore vessels. The database resulting from this work, led by Ms. Krista Greer, will probably be made public at the end of 2019 or in early 2020.

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- 1) Froese, R., N. Demirel, G. Coro, K.M. Kleisner and H. Winker. 2017. Estimating fisheries reference points from catch and resilience. *Fish and Fisheries* 18(3):506-526.
 - 2) Palomares, M.L.D., R. Froese, B. Derrick, S.-L. Noël, G. Tsui, J. Woroniak and D. Pauly. 2018. *A preliminary global assessment of the status of exploited marine fish and invertebrate populations*. A report prepared by the *Sea Around Us* for OCEANA, 64 p.
 - 3) Cashion, T., D. Al-Abdulrazzak, D. Belhabib, B. Derrick, E. Divovich, D. Moutopoulos, S.-L. Noël, M.L.D. Palomares, L. Teh, D. Zeller and D. Pauly. 2018. Reconstructing global marine fishing gear use: Catches and landed values by gear type and sector. *Fisheries Research* 206: 57-64.
 - 4) Cashion, T., D. Al-Abdulrazzak, D. Belhabib, B. Derrick, E. Divovich, D. Moutopoulos, S.-L. Noël, M.L.D. Palomares, L. Teh, D. Zeller and D. Pauly. 2018. *A global fishing gear dataset for integration into the Sea Around Us databases*. Fisheries Centre Research Reports 26(1): 71 p.

2019: How much fish is left in the world's oceans?

In conjunction with trips from Vancouver to Perth to the newly established *Sea Around Us - Indian Ocean* branch under the leadership of Professor Dirk Zeller at the University of Western Australia, a relationship was established with the Minderoo Foundation. The Walk Free Initiative within the Minderoo Foundation regularly produces the 'Global Slavery Index' (GSI; www.globalslaveryindex.org), of which a by-product is a ranked list of all countries in the world based on rigorously derived estimates of the number and vulnerability of people forced to work under conditions of 'modern slavery'.

As demonstrated by Pulitzer Prize-winning journalist Martha Mendoza¹ and others, modern slavery is rampant in industrial fisheries, particularly in High Seas and distant-water fisheries. Indeed, modern slavery is now a preferred method to reduce operating costs in highly competitive fisheries exploiting dwindling resources.

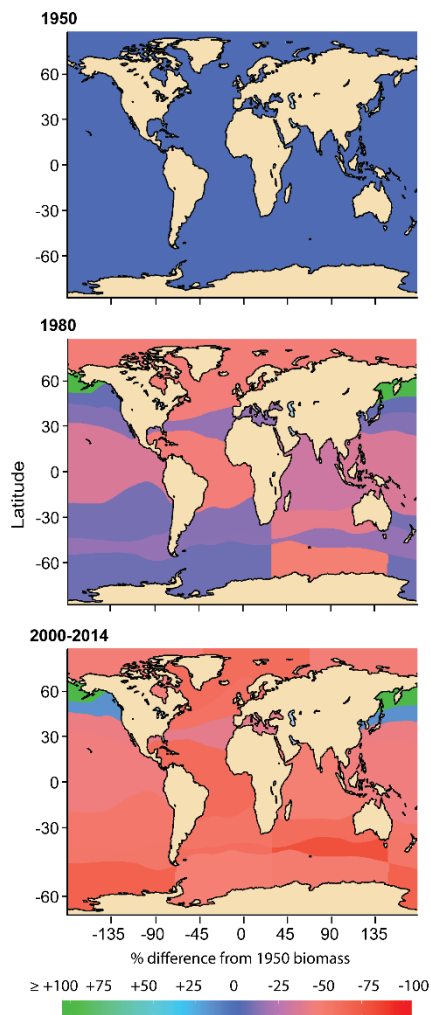


Figure 21. A preliminary estimation of the 'biomass left', based on about 2000 stock assessments by climate zone.

The first steps of the Minderoo-*Sea Around Us* collaboration included two articles: one, based on our mapped catches, established that the distant-water fleets of various countries face increasing economic challenges²; the other identified the factors that can be associated with a propensity for the use of modern slavery on fishing vessels³. Given these positive interactions, an agreement was concluded between the Minderoo Foundation and the *Sea Around Us* to accelerate the updating of reconstructed catch data in 2019. This will enable the CMSY-based stock assessments (see account for 2018) to be updated and used, in 2020, to rank the maritime countries of the world, as is done for the Global Slavery Index, by the estimated amount of fish ‘left’ in their waters.

This initiative, which will complement the deliverables of our other funders (notably, Oak Foundation, David and Lucile Packard Foundation, Bloomberg Philanthropies via Rare, Oceana, Marisla Foundation and Paul M. Angell Family Foundation), will likely shape the future of the *Sea Around Us*, as we expect a massive interest by other groups in reliable estimates of the historic changes of biomass in the sea.

Box 21: For several years, the *Sea Around Us* provided critical comments^{4,5,6} on the bi-annual State of World Fisheries and Aquaculture reports (SOFIA) published by FAO. These comments were not intended as attacks on the crucial work done and services rendered by FAO on behalf of the global community, but rather aimed at pointing out misinterpretations of fishing trends due to the inherent limitations of the incomplete data being reported to FAO by member countries.

This problem dates back to the work done by the *Sea Around Us* on the catches of China (see account for 2001). Thus, we were delighted to notice⁷ in the latest SOFIA what seemed to us as a positive change in perception at FAO. This is a welcome opportunity for the academic scientific community to engage and work with FAO and other international organizations to improve the global accounting and accountability of fisheries. After all, we all want the same thing, namely healthy marine ecosystems with fisheries that can extract sustainable catches in perpetuity to provide livelihoods and food security for the global human populations.

1) See www.ap.org/explore/seafood-from-slaves/index.html#main-section.

2) Tickler, D., J. Meeuwig, D. Pauly, M.L.D. Palomares and D. Zeller. 2018. Far from home: distance patterns of global fishing fleets. *Science Advances* 4: eaar3279.

3) Tickler, D., K. Bryant, F. David, J.A.H. Forrest, E. Gordon, J. Meeuwig, B. Oh, D. Pauly, U.R. Sumaila and D. Zeller. 2018. Modern slavery facilitates overfishing in global fisheries. *Nature Communications* 9: 4643.

4) Pauly, D. and R. Froese. 2012. Comments on FAO's State of Fisheries and Aquaculture, or 'SOFIA 2010'. *Marine Policy* 36: 746-752.

5) Pauly, D. and T. Charles. 2015. Counting on small-scale fisheries. *Science* 347: 242-243.

6) Pauly, D. and D. Zeller. 2017. Comments on FAO's State of World Fisheries and Aquaculture (SOFIA 2016). *Marine Policy* 77: 176-181.

7) Pauly, D. and D. Zeller. 2019. Agreeing with FAO: Comments on SOFIA 2018. *Marine Policy* 100: 332-333.

2020 and beyond: The future of the *Sea Around Us*

The staff of the *Sea Around Us* at UBC is shown on Figure 22 below, and the staff of the *Sea Around Us – Indian Ocean* at UWA is shown on Figure 24, p. 46.

The *Sea Around Us* research and data products they and their predecessors have produced over the last 20 years have been groundbreaking in many ways, especially due to the unique viewpoint we have taken throughout: fisheries as interconnected global systems, with fisheries data deeply embedded in ocean ecosystems.

This is reflected in our globally unique fisheries data that not only span over 60 years for every country in the world, but also account comprehensively for unreported and discarded catches, and is allocated to marine ecosystem space in an ecological realistic manner. These spatialized data products, with integrated parameters that span taxonomy, fishing countries, gears, sectors and the end use of the catch, as well as being linked directly to economic indicators and drivers of fisheries, combined with comprehensive biodiversity, ecosystem and governance information sources, makes for a truly unique global data and information system. And all of it is freely available due to our open data policy via our data portal at www.seaaroundus.org.

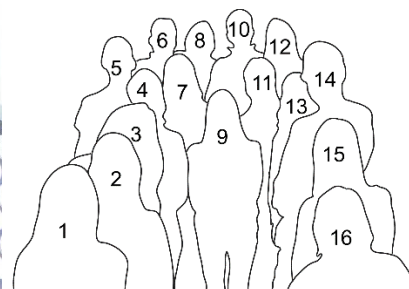


Figure 22. The current *Sea Around Us*/UBC team. 1. Valentina Ruiz Leotaud; 2. Emmalai Page; 3. Myriam Khalfallah; 4. Darcy Dunstan. 5. Simon-Luc Noël; 6. Rennier Hernandez; 7. Krista Greer; 8. Brittany Derrick; 9. Lu Zhai; 10. Nicolas Bailly; 11. Audrey Zhu; 12. Jessika Woroniak; 13. Courtney Brown; 14. Daniel Pauly; 15. Rebecca Schijns; 16. Deng Palomares. The team of *Sea Around Us-Indian Ocean*/UWA is shown on Figure 24, p. 46.

Thus, it is our hope that this resource, updated and augmented by our excellent staff at UBC and UWA will serve the global community, scientists, environmental NGOs, conservation groups, as well as governmental and intergovernmental organizations and agencies as a reliable and well documented data and information source for many years to come.

Box 22: There are people who misunderstand the reconstructed catches of the *Sea Around Us* as fantasies through which they can oppose fisheries statistics assembled by FAO from reports submitted by its member countries. Yet, FAO itself admits their statistics are incomplete; notably, they do not include discarded bycatch (and hence they are ‘landings,’ not catch statistics), and mostly fail to include subsistence and recreational catches.

The *Sea Around Us* catch reconstructions correct for the downward bias that this incompleteness represents, and also refine the geography that FAO uses (consisting, globally, of 19 giant ‘statistical areas’) by considering the distribution range of the species in countries’ reported catches¹. Thus, the *Sea Around Us*’ reconstructed catches should not be construed as less reliable than FAO statistics. In fact, although unofficial, reconstructed catches are less biased against small-scale fisheries and generally more informative than the official catches which reconstructed catches complement².

The quality improvement of reconstructed catches, however, comes at a price: it takes our research teams 8-10 person/year to implement an update. Thus, depending on our funding, we can update reconstructed catches about every 2 years. Given that FAO statistics are released with a lag of 2 years, this means we will usually follow with a 3-4 year lag. Thus, for example, we are (as of this writing in April 2019) updating our reconstructed catches to 2016. However, the lag time also allows taking account of various publications on the fisheries in question, and also to retroactively correct errors pointed out to us by users of our data, or which became visible when analyzed in detail. Thus, the various articles in which we present our reconstructions³ should be viewed as living documents subject to improvements as our knowledge grows.

1) Zeller, D., M.L.D. Palomares, A. Tavakolie, M. Ang, D. Belhabib, W.W.L. Cheung, V.W.Y. Lam, E. Sy, G. Tsui, K. Zylich and D. Pauly. 2016. Still catching attention: *Sea Around Us* reconstructed catch data, their spatial expression and public accessibility. *Marine Policy* 70: 145-152.

2) Pauly, D. and D. Zeller. 2016. Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications* 7: 10244.

3) See the documentation of individual catch reconstructions for countries or their overseas territories at www.seaaroundus.org.

Staff of the *Sea Around Us*, 1999-2019

Over the 20 years of its existence, the *Sea Around Us* employed over 150 people in various capacities, many of which are mentioned (with photos) in past biennial reports of the *Sea Around Us*, reproduced on p. 51 to 64.

Four Project Managers worked with the *Sea Around Us* Principal Investigator, Daniel Pauly, to guide the group: Dr. Nigel Haggan (1999-2004), Dr. Jacquie Alder (2004-2008), Dr. Dirk Zeller (2008-2017) and currently Dr. M.L. ‘Deng’ Palomares.

Many of our publications were led by a succession of post-doctoral fellows, e.g., Drs. Lucas Brotz, Sylvie Guénette, Kristin Kleisner, and Lydia Teh, and by Dr. Pauly’s PhD and MSc students, e.g., Drs. Dalal Al-Abdulrazzak, Dyhia Belhabib, Jennifer Jacquet, Frederic Le Manach, and Dawit Tesfamichael.

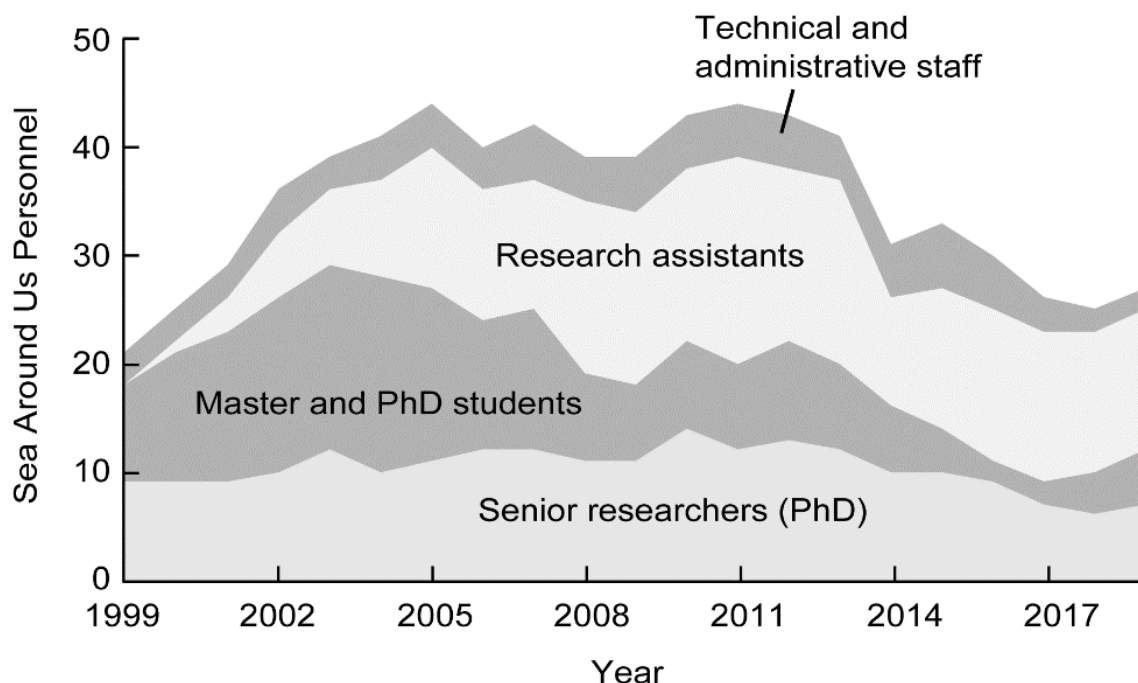


Figure 23. Staff of the *Sea Around Us*, 1999-2019. We have also had dozens of unpaid volunteers or interns in these 20 years. (Detailed numbers, by category are available on our website www.seaaroundus.org).

Also, we have had many volunteers, interns and/or funded foreign graduate students participating in our activities. This involved MSc students from France, e.g., Ms. Lou Frotté and PhD students from China, notably (now) Dr. Cui ‘Elsa’ Liang, currently a close collaborator to the *Sea Around Us*.

However, the bulk of the work of the *Sea Around Us* has been accomplished by research assistants, for example, Ms. Robin Ramdeen, who performed most of the catch reconstructions for countries of the Caribbean; Shawn Booth for the High Arctic; Sarah Harper for extensive island data work; Debbie Shon for North and South Korea; Kyrstn Zyllich for tireless tracking the growing number of catch reconstructions; Esther Divovich and Sarah Popov for Russia, and last but not least the excellent staff we currently have (see Figures 22 and 24).

The work from all these extraordinary people would not have been possible if not supported by programmers, website developers and other technical and support personnel, e.g., Fred Valdez, Adrian Kitchingham, Sherman Lai, Jeroen Steenbeek, Grace Ong, Chris Close, Joe Hui, Ar’ash Tvakolie, Gordon Tsui, and Eric Sy, backed up by Ma. Josephine Barile and Miel Ortiz at Quantitative Aquatics in Los Baños, The Philippines.

A complete list of the persons who have worked in the *Sea Around Us* since mid-1999 is available on our website (www.seaaroundus.org).



Figure 24. A photo of the *Sea Around Us* – *Indian Ocean* staff. Clockwise from top left: Matthew Ansell, James Hehre, Dirk Zeller, Jessica Meeuwig, Gabriel Vianna, Rachel White, Hanna Jabour Christ, Lincoln Hood, and Amy McAlpine. The *Sea Around Us* staff based at UBC is available as Figure 22, p. 43.

Publications of the *Sea Around Us*, 1999-2019

With one of the major goals of the *Sea Around Us* being to “document the impact of fisheries on marine ecosystems, and to propose policies to minimize such impact¹,” strong emphasis has been given to timely publication of the results of our research.

We emphasized articles in peer-reviewed journals (Figure 25), but also published data-rich reports, working papers, books, and book chapters, as well as miscellaneous outlets ranging from magazines to websites.

In the (almost) 20-year period that the *Sea Around Us* contributions have been available, they have gathered over 33,000 citations (according to Google Scholar). Given that publications other than peer-reviewed journal articles usually receive very few citations, this would correspond to about 10 per journal article, which is quite high taking into account that over 40% of all published peer-reviewed articles are never cited and their median lifetime citation rate usually ranges from 1-3².

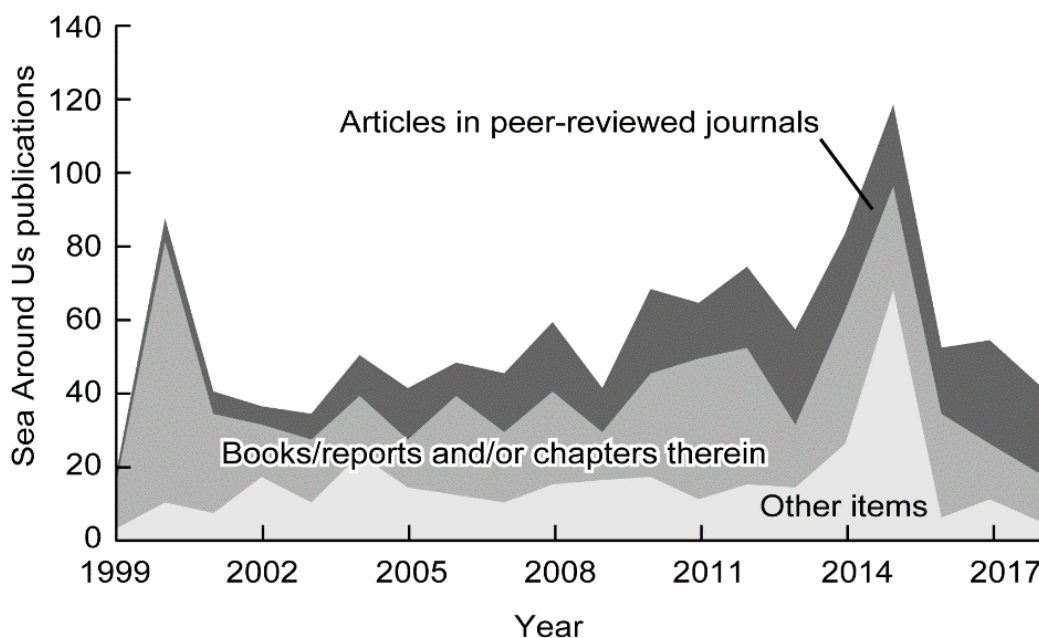


Figure 25. Publications of the *Sea Around Us* 1999-2018. Note the increasing fraction of peer-reviewed articles.

1) Pauly, D. 2007. The *Sea Around Us* Project: Documenting and communicating global fisheries impacts on marine ecosystems. *AMBIO: A Journal of the Human Environment* 34(4): 290-295.

2) See Luc Beaulieu at <https://lucbeaulieu.com/2015/11/19/how-many-citations-are-actually-a-lot-of-citations/>

Outreach of the *Sea Around Us*, 1999-2019

At the *Sea Around Us*, we firmly believe that scientists are accountable to the people that provide their funds, whether they are taxpayers, as is usually the case for those working in academia, or whether they are private organizations or individuals.

This is why throughout our two decades of existence we have made a point of communicating our research with those to whom we are accountable and with the public at large.

In 1999, we launched the *Sea Around Us* Newsletter, of which we produced and printed 83 issues up to October 2014. This publication served as a platform to share our research, events, accomplishments, awards, conference attendances and reflections on fisheries-related current affairs, something that we also did (and still do) through mass media and social media (see box in the 1999 account).

By regularly making ourselves available to the press and, at the same time, by preparing outreach materials to share with journalists whenever there is a relevant development within our project, we have been able to attract attention to our scientific work. In an era where information is superabundant and fake news is a common thing, making the effort to communicate our findings is a must.

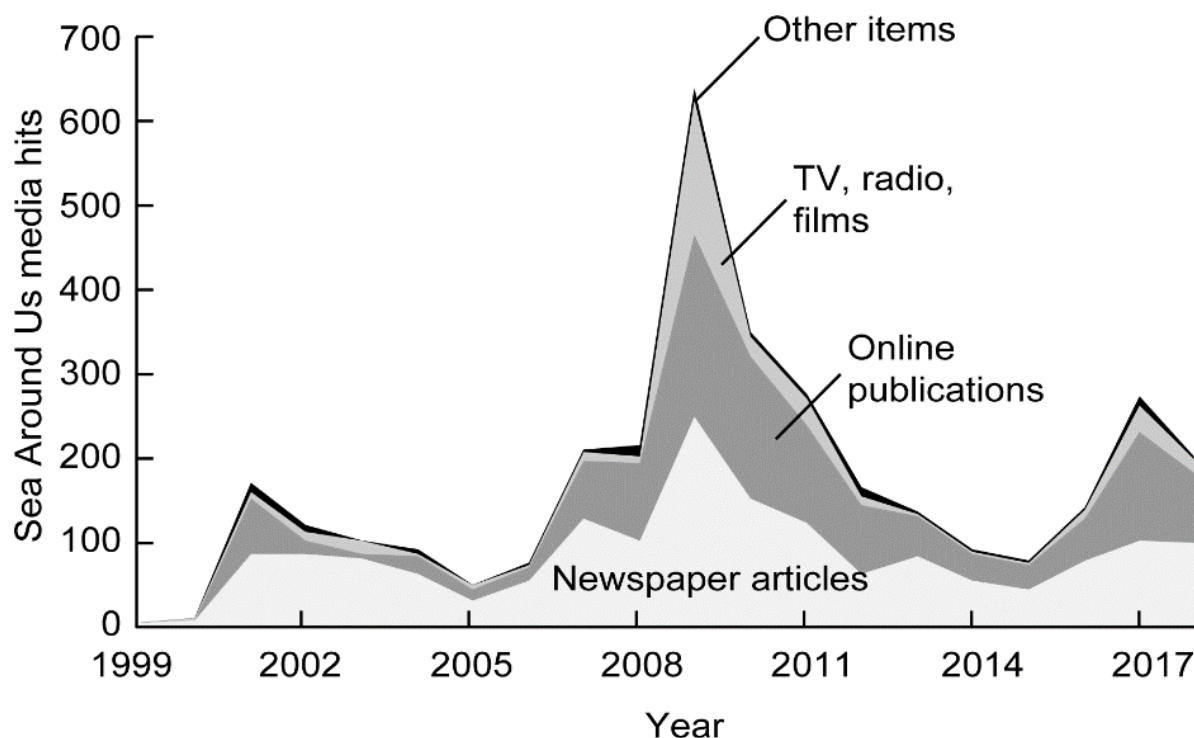


Figure 26. ‘Hits’ received by the *Sea Around Us* and/or its scientists in mass media from 1999 to 2018.

The result of building this reciprocal relationship with the media is reflected on an ever-growing interest in our research. As figure 26 shows, we saw a first peak in interest when we published our “China paper”¹ in 2001. A second peak is shown in 2009, when we had a record of 650 media hits as different studies, such as the one on fish feces helping neutralize CO₂ in the ocean² or the one on how climate change will affect 1,066 commercially important fish and shellfish species³, made it to the press. The latter is, literally, a hot topic that we have been able to deal with for quite a few years, as the 2017 peak, connected to our paper on shrinking fish and global warming⁴, shows.

At the *Sea Around Us*, we also produce our own mass media products based on our research, including blog posts that can be accessed on www.seaaroundus.org, social media posts published on platforms such as Twitter, Facebook and Instagram, and YouTube videos (see figure 27).



Figure 27. Screenshot of an animated video produced by the *Sea Around Us*. The video explains the different types of gears used by large-scale and small-scale fisheries, based on information in a 2018 paper by Cashion *et al*⁵.

- 1) Watson, R. and D. Pauly. 2001. Systematic distortions in world fisheries catch trends. *Nature* 414: 534-536.
- 2) Wilson, R.W., F.J. Millero, J.R. Taylor, P.J. Walsh, V. Christensen, S. Jennings and M. Grosell. 2009. Contribution of fish to the marine inorganic carbon cycle. *Science* 323: 359-362.
- 3) Cheung, W.W.L., C. Close, V.W.Y. Lam, J. Sarmiento, K. Kearney, R. Watson and D. Pauly. 2009. Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* 10: 235-251.
- 4) Pauly, D. and W.W.L. Cheung. 2018. Sound physiological knowledge and principles in modelling shrinking of fishes under climate change. *Global Change Biology* 24:e15–e26.
- 5) Cashion, T., D. Al-Abdurrzak, D. Belhabib, B. Derrick, E. Divovich, D. Moutopoulos, S.-L. Noël, M.L.D. Palomares, L. Teh, D. Zeller and D. Pauly. 2018. Reconstructing global marine fishing gear use: Catches and landed values by gear type and sector. *Fisheries Research* 206: 57-64.

Funding received by the *Sea Around Us*

The funding history of the *Sea Around Us* can be readily split into three phases:

1. The period from mid-1999 to mid-2014, when we were mainly funded by The Pew Charitable Trusts, with additional project-specific funds from other sources, e.g., the Oak Foundation, the BC Ministry of Water, Land and Air Protection, the World Wildlife Fund, the United Nations, the Rockefeller Foundation, the Waterloo Foundation;
2. The period from mid-2014 to mid-2017, when our main funder was the Paul G. Allen Family Foundation, again, with additional funding from other sources, e.g., the MAVA Foundation, the UBC Strategic Excellence Fund, the Marisla Foundation and the Paul M. Angell Family Foundation.
3. The period starting in mid-2017 onwards, with our funding from a variety of sources, notably the David and Lucile Packard Foundation, Bloomberg Philanthropies via Rare, Oceana, Oak Foundation and the Minderoo Foundation.

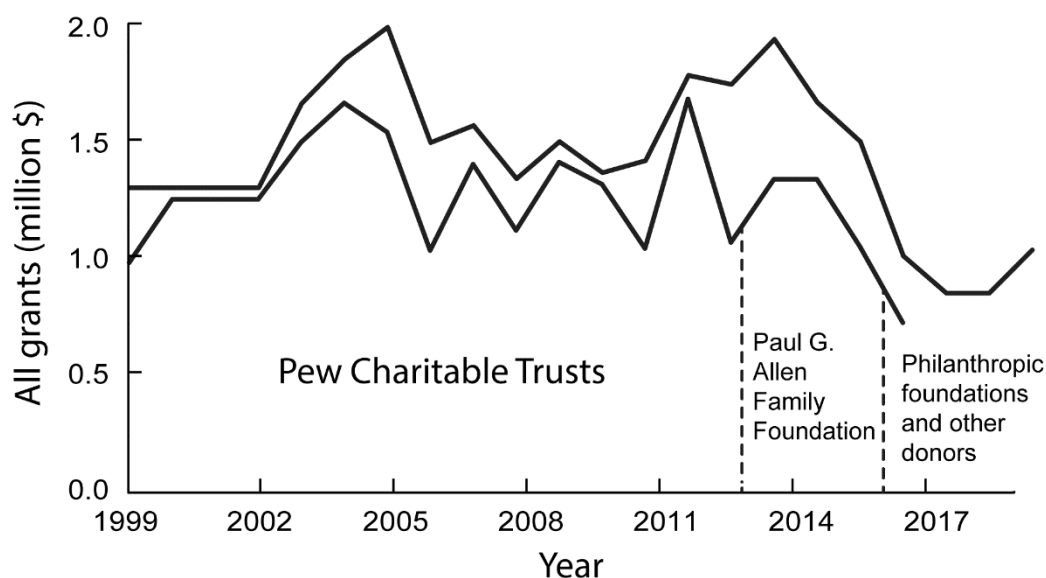


Figure 28. Funds (in nominal Canadian dollars) obtained by the *Sea Around Us* from mid-1999 to 2019, smoothed over a 3-year average to reflect the manner in which these funds were disbursed (which was less variable than the manner in which they were acquired).

We use this opportunity to thank all our donors, big and small, past and present.



The *Sea Around Us* in biennial reports of UBC's Fisheries Centre, 2001-2013

In the following 14 pages, we present copies of the 2-page accounts of the *Sea Around Us* in the biennial reports that UBC's Fisheries Centre (now the Institute for the Oceans and Fisheries, IOF) published for the years 2001-2003, 2004-2005, 2006-2007, 2008-2009, 2010-2011 and 2012-2013.

These biannual reports complement the annual accounts presented as the main part of this report with, among other things, more details on the personnel involved in our work. The references to the contributions cited in these biennial reports are cited following the account for 2012-2013.



2001-2003

Sea Around Us Project



Daniel Pauly
Director

The *Sea Around Us Project (SAUP)* assesses large-scale impacts of fishing on marine ecosystems and finds solutions to the challenges they pose using a variety of tools including ecosystem modeling, mapping, economic and policy analyses and public outreach. Its work extends on our knowledge and understanding of the impacts of fishing on marine environments globally.

Sea Around Us Project's tools for mapping global catches make it possible to look at landings spatially. This work established that China inflated its fish landing statistics with an overall correction of lower global fish landing totals. The findings, published in *Nature* (2001), motivated calls for more reliable fisheries statistics and better management globally.



Villy
Christensen
Researcher

The Project quantifies the ecosystem impacts of fisheries at the ocean-basin level, i.e., at a larger scale than ever attempted before. A map-based approach allows us to draw basin-wide inferences from numerous local observations synthesized from mass-balance food web modeling. We estimate that the biomass of high trophic-level fishes in the seemingly well-regulated North Atlantic declined by an order of magnitude in the last century. The results demonstrate that in the most-studied and most-regulated ocean basin in the world, the decline in fishery catches is associated with increasing fishing. Thus, it is not surprising that fisheries throughout the world, are unsustainable (*Nature*, August 2002). The Project collaborates with Professor Walters on developing the Ecopath with Ecosim (EwE) ecosystem modeling approach. EwE is the world's de facto standard for modeling ecosystem based management of fisheries, with 2500 registered users of the software in 124 countries, over 200 hundred published applications, and some 30 graduate theses in various universities based on the approach. Ecosystem modeling is an integral aspect of the work of the *Sea Around Us*, and we cooperate extensively with colleagues around the world to support the move towards an ecosystem approach to fisheries. The ecosystem modeling work serves as an integrating factor with members of the *Sea Around Us* collaborating with colleagues in all the other units of the Centre on joint projects or thesis work.



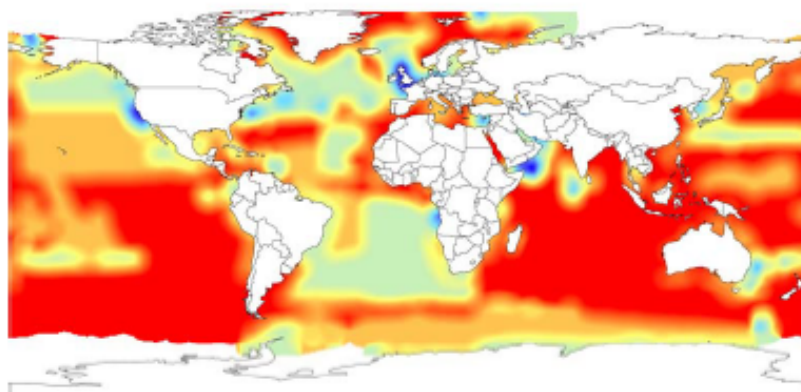
Reg Watson
Researcher



Jackie Alder
Researcher



Maria Lourdes
(Deng)
Palomares
Researcher



Decade with the maximum fish and invertebrate landings.



Assessment of southeast Atlantic fisheries culminated in 2002 in the International Symposium on Marine Fisheries, Ecosystems and Societies in West Africa, under the title "Half a Century of Change." Held in Dakar, Senegal, the gathering produced an unprecedented Consensus Statement (see www.seaaroundus.org/Dakar) summarizing important points of agreement between representatives from Northwest Africa and other countries. It recognized that the strong decline of fishes over recent decades was due to fishing pressure and that a substantial reduction in overall fishing effort is required for the fisheries to be able to continue to exist.

Reconstruction and clarification of catch data from the Caribbean, Central America and South America enabled the *Sea Around Us Project* to investigate the long-term impact of fishing from the southeast Caribbean to Brazil and, using a newly documented set of *Ecopath* models, to study management options (Fisheries Centre Report 11(6) 2003).

Sea Around Us Project is active in the Millennium Ecosystem Assessment (MA). The Marine Condition and Trends chapter is led by Daniel Pauly and Jackie Alder, in collaboration with fisheries scientists from around the world and other *Sea Around Us Project* members. Other significant contributions to the MA include linking socio-economic indicators to coastal habitats and assisting with four narrative scenarios on possible futures in the fisheries sector. This work led to a contribution in *Science* (November 2003). We also hosted the MA's Marine and Coastal Cross-Cutting Workshop in April 2003.

The *Sea Around Us* team has produced numerous data products useful to the world's scientific and conservation communities. Our global fisheries tools can map fisheries catch composition at any place on the ocean, and show what part of the catch in any country's waters is likely taken by foreign fleets. Maps documenting this work, and the distribution of all commercial marine species can be straightforwardly downloaded from our website. Over the last three years the project developed databases of fishing access and agreements, estuaries and high seas. They are the first of their kind and generate collaborative studies with several other organizations (e.g. World Wildlife Fund for Nature and the World Conservation Monitoring Centre). New methods to integrate, analyze and map this mix of information continue to evolve, making *Sea Around Us Project* a world leader in global analysis of marine ecosystems. The *Sea Around Us Project* was initiated and is funded by the Pew Charitable Trusts of Philadelphia.



Russian trawler fishing for silver hake on the Scotian Shelf in the 1980s.



Dirk Zeller
Researcher



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www.seaaroundus.org





2004-2005

Sea Around Us Project



Daniel Pauly
Principal
Investigator

The Sea Around Us Project (SAUP) assesses large-scale impacts of fishing on marine ecosystems and identifies solutions to the challenges they pose using a variety of tools, including ecosystem modeling, mapping, economic and policy analyses and public outreach. Its work extends our understanding of the impacts of fishing on marine ecosystems globally, and contributes to fisheries management policy.



Villy Christensen
Senior
Research
Fellow

The SAUP is increasingly involved in research on marine protected areas (MPAs). Our work on improving the current global database of marine protected areas documents, in quantitative terms, the difficulty governments and conservation groups are facing in meeting the various targets set for establishing a global network of MPAs. The recent development of seamount fisheries has highlighted their potential impacts on high seas biodiversity management, and – again – the need for high seas MPAs. This was confirmed by a report to the Convention on Biological Diversity (CBD), which focused attention on the breadth of biodiversity in the high seas.



Reg Watson
Senior
Research
Fellow

Our collaboration with the CBD also involved turning our earlier work on trends in mean trophic level – which demonstrated widespread ‘fishing down marine food webs’ – into a ‘marine trophic index’ (MTI), now endorsed by the member countries of the CBD as one of eight indicators through which biodiversity will be monitored worldwide.



Jackie Alder
Senior
Research
Fellow

The SAUP's work on the geographic and dietary overlap between fish and marine mammals has helped to dispel the myth that whales and other marine mammals were competing with human food fisheries. Similar work on seabirds also highlighted the limited overlap between fish consumed by seabirds and human food fisheries. On the other hand, an analysis of the deployment of various fishing gears has provided a better picture of the spatial and temporal extents of the impact of gears, such as trawls and long lines on marine ecosystems.

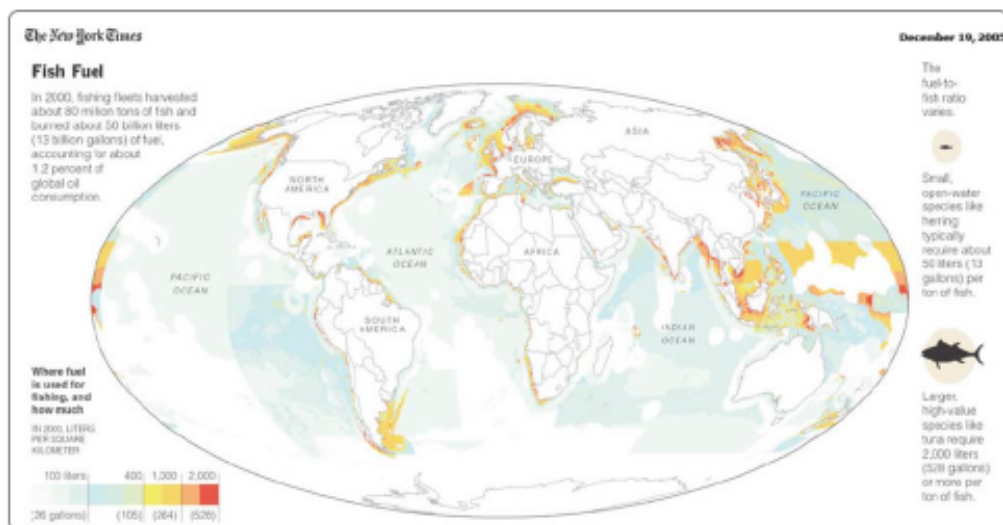


Maria Lourdes
(Deng)
Palomares
Research
Fellow

The SAUP has significantly advanced our understanding of small-scale fisheries in its development of a methodology to estimate small-scale catches based on a variety of information sources. The pilot study of US Flag Island Areas in the Pacific highlighted the large catches of coral reef fish that have gone unreported in the past, and more importantly, their significance to food security and economic development in the community.

A natural extension to the SAUP's core research has been to explore the economic impacts associated with fisheries. To do this on a global scale, a database of ex-vessel prices has been developed and is accessible at the Project website (www.seaaroundus.org). The SAUP has also investigated various aspects of fishing cost, and completed an analysis of fuel consumption by various fishing fleets. This underlined the contribution of fishing vessels, particularly trawlers, to global greenhouse gas emissions, but also their extreme sensitivity to fuel price increases.





Source: The NYT, based on Peter H. Tyedmers, Reg Watson and Daniel Pauly, in *AMBIO: Journal of the Human Environment* (2005).

Many of the outcomes of SAUP's work contributed to policy at the international and national levels. The SAUP led the writing of the Marine Fisheries Chapter for the Conditions and Trend Volume of the Millennium Ecosystems Assessment, as well as contributing to other chapters and volumes, notably through modeling work, based on Ecopath with Ecosim. Members of the SAUP presented the results of their work to various institutions, including the UN in New York, a British 'Royal Commission', and the fisheries agencies of various countries.

The increasingly successful outreach of the SAUP was highlighted in October 2005, when the Project hosted a two-day workshop with over 20 non-government organizations (NGOs) working on marine conservation around the world. The workshop illustrated the breadth and depth of SAUP research, and its potential toward meeting the science-based information needs of these NGOs. Many NGOs are already using a number of the SAUP products accessible on the web, and based on their experiences a number of improvements will be made to our website. Also, we will focus our research in the coming years to even better identify policy solutions to the global crisis of fisheries. This, ultimately, is the only meaningful measure of success for the *Sea Around Us* Project.

www.seaaroundus.org



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2006-2007

Sea Around Us Project



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Professor



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Jackie Alder
Senior
Research
Fellow



Dirk Zeller
Senior
Research
Fellow

The Sea Around Us Project, funded by the Pew Charitable Trusts, Philadelphia, started in mid 1999. Its goal remains to investigate the impacts of fisheries on marine ecosystems and to propose policies to mitigate these impacts.

Although conceived as a global activity, the project first emphasized the data-rich North Atlantic as a testing bed for developing its approaches, which rely on mapping of catch data and indicators of ecosystem health derived from the analysis of extended catch time series data. Initial achievements included mapping the decline, throughout the North Atlantic basin, of high-trophic level fishes from 1900 to the present and the presentation of compelling evidence of change in the functioning of the North Atlantic ecosystems. The Central and South Atlantic were the next basins to be tackled, with emphasis on the distant-water fleet off West Africa. The project then emphasized the North Pacific, Antarctica, and marine mammals and the multiplicity of tropical Indo-Pacific fisheries before our scope became global, with all our major analyses and reports (e.g., on the interactions between marine mammals and fisheries, on fuel consumption by fleets, on subsidies to fisheries) based on global studies.

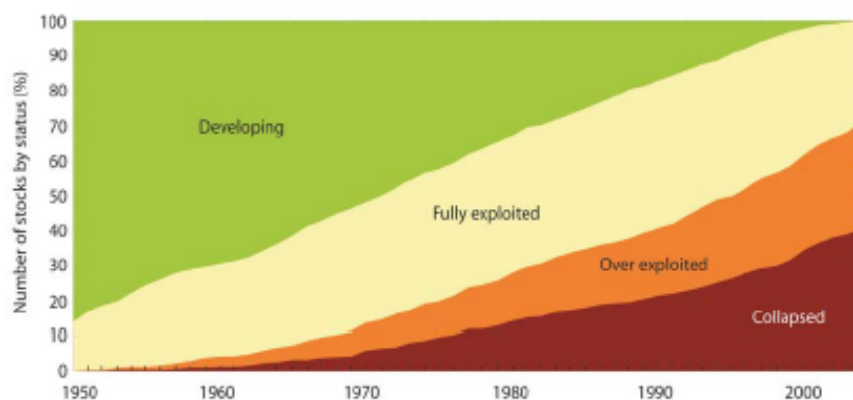
Broadly, our work aims at a reappraisal of fisheries, from the benign activity that many still perceive them to be, to a realization that they have become the driver for massive loss of biodiversity. Moreover, the emphasis on global estimates (rather than local estimates of dubious generality) has allowed the project to contribute to various global initiatives (e.g., developing the Marine Trophic Index for the Convention on Biological Diversity; quantifying marine ecosystem services for the Millennium Ecosystem Assessment; supplying various datasets to UNEP's Fourth Global Environment Outlook; and co-authoring major syntheses by other research groups).

In the 2006 and 2007 period, the *Sea Around Us* Project completed major activities, among others:

- The 'forage fish' project, which demonstrated that the role of anchovies, sardines, etc., presently mostly reduced to fishmeal for intensive food production, must be reconsidered, in view of their role as prey of marine mammals and seabirds, and as much-appreciated food for people in many countries;
- The launching of SeaLifeBase (www.sealifebase.org), a database on the biology and ecology of non-fish marine organisms, funded by the Oak Foundation, and which will complement FishBase (www.fishbase.org) in making information relevant to marine ecosystem modeling available to a wide range of users;
- The evaluation of all catches, from 1950 to the present, by the inshore fisheries of Hawaii and the US Flag territories in the Pacific (Guam, American Samoa, etc), which are much higher than officially reported;
- The related estimation of total catches from the Arctic, and a number of countries throughout the world, which suggests that the FAO statistics systematically underestimate fisheries catches, particularly for small-scale fisheries, thus biasing policy decisions relying on such data (e.g., fishing access agreements);



- An assessment of the status of fisheries and ecosystem 'health' in each of the 64 Large Marine Ecosystems presently recognized in the world (see figure below);
- The estimation of global subsidies to fisheries (together with FERU, see p. 8-9), which are higher than previously assessed, e.g., by the World Bank, and which mainly have a very negative impact on fisheries resources;
- The release of a new, reprogrammed version of Ecopath with Ecosim, in the context of an activity funded by the Lenfest Ocean Program, and which gives a new lease on life to this widespread ecosystem modeling tool, celebrated in 2007 as one of the "Top 10 Achievements" by the US National Marine Fisheries Service.



Status of the fisheries 'stocks' in the 64 Large Marine Ecosystems of the world, showing the steadily increasing number of overfished or collapsed stocks.

Also, we have initiated the revamping of the Project website (www.seaaroundus.org), our main tool for providing maps and other quality information on marine fisheries and ecosystems to a wide range of users.

These results and their dissemination through public lectures and policy briefings, and by staff of non-governmental organizations (our main 'clients') generated, in 2006-2007, a growing media attention for the *Sea Around Us* Project.

Other activities initiated in 2007, which will come to fruition in 2008, include the development of indicators for ranking maritime countries in terms of how well they manage the fisheries and biodiversity in their Exclusive Economic Zones, modeling studies of how dioxin and other pollutants get distributed over the oceans, then move up in marine food webs, and how global warming will affect the distribution of marine resource species.

www.seaaroundus.org



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2008-2009

Sea Around Us Project



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Principal
Investigator



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Research
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Shawn Booth
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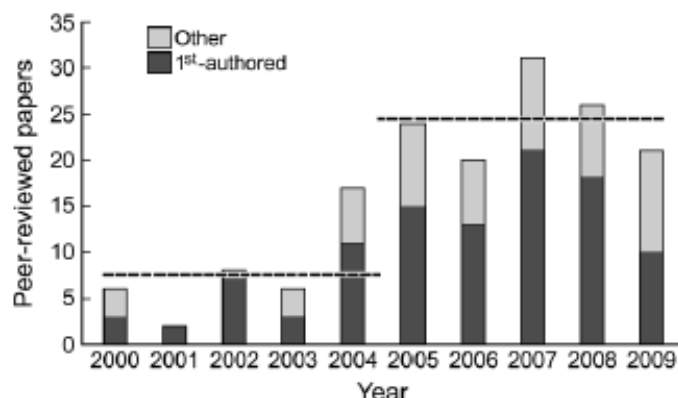
Villy
Christensen
Associate
Professor



Marina
Campbell
Administration

The *Sea Around Us* is a collaboration between the University of British Columbia in Vancouver, Canada, and the Pew Environment Group, Washington, D.C., USA, devoted to assessing the impact of fisheries on the world's marine ecosystems, and proposing policies to mitigate these impacts.

The project started in mid 1999, and thus celebrated its tenth anniversary in July 2009. In early 2005, we issued a five-year retrospective which emphasized the wide scope of our work, and our productivity. We recently issued a similar ten-year retrospective, emphasizing that our scope has become even wider, more focused on fisheries economics and public policy, and that our productivity has increased more than threefold – at least as measured by the number of peer-reviewed contributions authored and co-authored by our members. The reason for this massive increase is obvious: it took us several years to create the complex of global databases (and/or GIS 'layers') that allow inferences on the global ocean. Now that this complex is in place, it has become more straightforward to see global patterns and/or trends that were previously not visible, to assess them, and to develop policies to deal with them.



Number of peer-reviewed articles with *Sea Around Us* members as first (black) or co-authors (grey), 2000-2009. Note the more than threefold increase in the second 5-year period relative to the first.

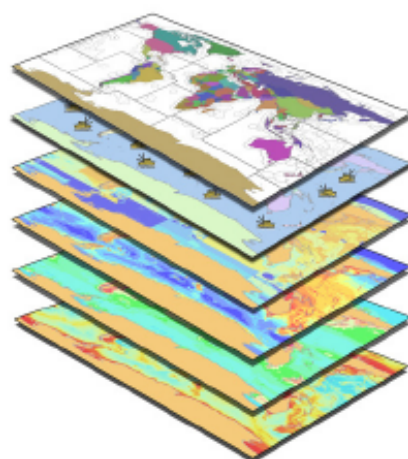
Thus, as a first example, we can now deal with global catches not only in terms of the 'official' global landings assembled and disseminated by the Food and Agriculture Organization of the United Nations, but in terms of their Illegal Unreported and Unregulated (IUU) components, which add to the global catch, and with the fishing effort, the gears and the costs (including subsidies) required to generate that catch, along with its economic value and its disposition through international trade. Also, we can infer long-term trends, because most of our databases start in 1950, and thus span over half a century. Moreover, in some cases where the science allows this, we project these trends into the future.



This applies specially to the studies we performed in 2008-2009 on the potential effects of global warming on biodiversity and fisheries, our second example. The key results we obtained here was that the effects of global warming on marine biodiversity will be major in the Arctic, along the Antarctic Convergence and throughout the intertropical belt, where numerous species will be extirpated in the next half century. For fisheries, we predicted a near constancy of global catches (other things being equal), with increased catches in high northern latitudes, and declining catches in the tropics. However, those results did not yet account for a number of factors, notably reduced oxygen concentrations and acidification, thus providing reasons for more comprehensive analyses in 2010 and beyond.



Sarah Harper
Research
Assistant



- 6) Synthesis, policy and outreach layer
- 5) Fisheries economics layer
- 4) Fisheries catch and fishing effort layer
- 3) Marine biodiversity layer
- 2) Primary production and plankton layer
- 1) Physical/jurisdictional boundaries layer

Illustrating the scope of the *Sea Around Us* through global 'layers', each representing a type of data used and/or contributed to, and which, when jointly analyzed, represent the entire range of ocean issues.



Jennifer Jacquet
Post Doctoral
Fellow



Sherman Lai
Programmer

Overall, the availability of the *Sea Around Us* databases not only allows for more, deeper work by project members, including a host of productive graduate students, but has also generated a flurry of offers of collaboration, resulting in a spectrum ranging from the very fruitful (e.g., with *National Geographic*) to the sensitive, requiring diplomacy ("No, you can't have ALL our data, but we can talk about what you actually need, and which you can use given that you give proper credit"). They establish that the *Sea Around Us* has become an internationally respected player in both the scientific and policy arenas of global fisheries. Not too bad for a ten-year old!



Ashley
McCrea-Strub
Post Doctoral
Fellow

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Senior
Research
Fellow



Reg Watson
Senior
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Arash
Tavakolie
Senior .NET
Developer



Maria Lourdes
Palomares
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Grace Ong
Administration





2010-2011

Sea Around Us Project



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The Sea Around Us project is devoted to studying and documenting the impact of fisheries on marine ecosystems throughout the world's oceans. With the maturing of the approaches and methods the project has developed since its start, in mid-1999, the project is now able to sustain a high rate of scientific productivity. Thus, the number of publications project members have authored or co-authored in the period covered here is in excess of 65 peer-reviewed journal articles (see list of publications on p. 30) and a very large number of related book chapters and other publications.

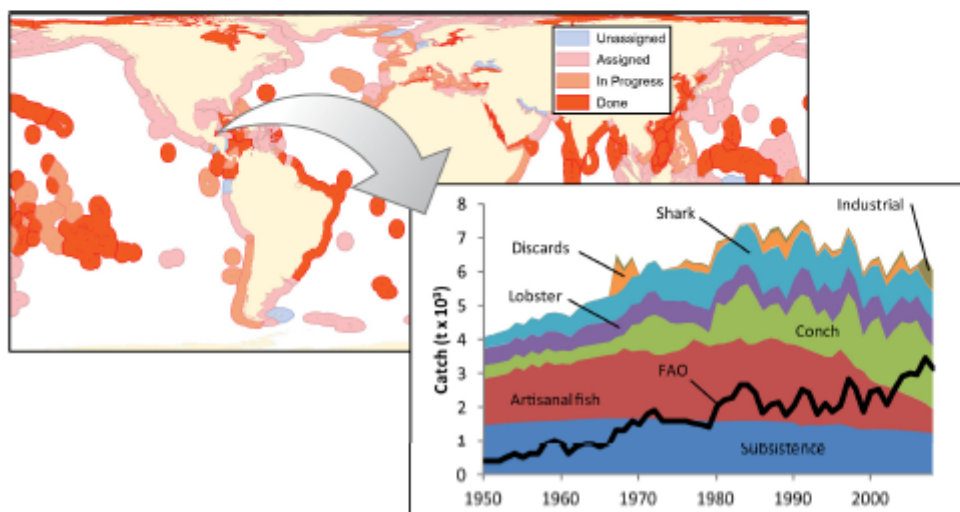
Particularly notable among our journal articles were the contributions by Tremblay-Boyer et al. (2011), which used EcoTroph, a model newly developed by our French colleague Didier Gascuel to infer changes in the biomass of high-level predators in the world ocean since 1950, and the review by Sumaila et al. (2011) of the potential economic effects of global warming on fisheries, which build on earlier work by William Cheung, who has now returned to the Fisheries Centre. A good example of our non-peer reviewed publications is the report entitled "Too Precious to Drill", edited by Deng Palomares and Daniel Pauly (2011), on the marine biodiversity of Belize, which also documents our close linkages with, and commitment to, developing countries. However, the major emphasis of the Sea Around Us project in the 2010-2011 period was undoubtedly the catch reconstruction work that we do, which has brought us, as of December 2011 within striking distance of our goal of reconstructing the catch of all maritime countries and territories of the world in 2012.

Our reconstructions all start in 1950, to provide a strong contrast to the present, and include catches by all fisheries sectors. Thus, besides the traditional focus on commercial fisheries, reconstructions also account for subsistence and recreational fisheries, and discards by industrial trawl fisheries, to cite some examples of catches that are frequently omitted from the statistics that countries submit to the Food and Agriculture Organization of the UN (FAO).

The Sea Around Us has previously shown that much of the data presented by FAO on behalf of its member countries are problematic. Therefore, the project has developed and applied a methodology for 'reconstructing' real catches from coastal countries based on detailed analysis of the peer-reviewed and grey literature and the use of assumption-based interpolations (Zeller et al., 2007). This provides a more comprehensive portrayal of historical fisheries catch data for all sectors than what is otherwise available. Such reconstructions have shown, for example, that Tanzania's official reported fisheries data prior to the year 2000 excluded all catches for Zanzibar, despite this island group having a dedicated fisheries agency collecting data. Due to such underreporting, actual



total catches taken by Tanzanian fishers are around 70% higher than official statistics lead one to believe (Jacquet et al., 2010). However, missing catch data are not only an issue for developing countries. The fisheries of the nine highly developed coastal countries surrounding the Baltic Sea in north-eastern Europe appear to catch over 30% more than is reported by the countries' official statistics (Zeller et al., 2011a), while certain ecosystems, such as the High Arctic, are even more neglected in countries' official records, as illustrated by the near total absence of arctic fisheries catches in the official data provided by the USA, Canada and Russia (Zeller et al., 2011b). Our approach to deriving total catch time series estimates shows that the incorporation of historical 'anecdotes' (i.e., isolated observations) and local studies in catch reconstructions can provide crucial baselines.



Illustrating the Exclusive Economic Zones of the different maritime countries and their overseas territories, covering 40% of the ocean, and 90% of the marine catch. The different colors refer to the status of historic catch reconstructions, of which an example for Belize is provided here (Zeller et al., 2011c; see p. 39).

With the 2012 completion of our coverage of all maritime countries and territories, we will be finally able to promptly quantify the actual contribution of fisheries to food security of the world, examine region-specific trajectories of fisheries catches (likely to strongly differ from those derived from the FAO database), and jointly with our new global database on fishing capacity help settle issues of the impact of fisheries on stocks.

www.seaaroundus.org



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Sea Around Us

2012-2013

The *Sea Around Us* is devoted to studying, documenting and communicating the impact of fisheries on global oceans. One major way to quantify this impact is through the catches that fisheries extract from ecosystems, and indicators based on these catches. However, there are many uncertainties associated with the marine fisheries catches of most countries, and thus, almost a decade ago, the *Sea Around Us* launched an activity designed to overcome this problem, which we call 'catch reconstruction'. The *Sea Around Us* was consumed by this activity during 2012 and 2013, and we thought we would be able to complete catch reconstructions covering the years 1950 to 2010 for all maritime countries of the world by the end of 2013.

We underestimated the work required for true global coverage: there were just too many countries, island territories and ecosystems to cover for our planned 'Atlas of Fisheries Impacts on the World's Marine Ecosystems' to go to press in 2013. However, it should go to press in 2014.

Still, major advances were made. For example, Fisheries Centre Research Reports were published with reconstructions for countries in the Red Sea (Tsefamichael and Pauly 2012), West Africa (Belhabib et al. 2012, 2013), the Persian Gulf (Al-Abdulrazzak and Pauly 2013), and various islands (Harper et al. 2012); together with publications for numerous countries and or groups of countries (see e.g., Abudaya et al. 2013; Ainley and Pauly 2013; Edelist et al. 2013; Pauly et al. 2013; Ulman et al. 2013).



In July 2013, Deng Palomares and Daniel Pauly spent a week teaching an updated version of the ELEFAN software at the University Cheikh Anta Diop in Dakar, Senegal. (Photo: Najih Lazar)



A fishing boat at Taganga, a village in Colombia. (Photo: Robin Ramdeen)

Moreover, some of these country reconstructions - notably that of Senegal (Belhabib et al. 2013) - had spectacular results, i.e., providing an estimation of the loss of revenue inflicted on Senegal by illegal fishing, which motivated Senegal's Minister of Fisheries to arrest a vessel fishing illegally in its waters. Other West African countries endorsed our reconstructions and particularly the estimation of foreign catches in their waters, a promising development that we will follow up on beyond 2013.



Other activities of the Sea Around Us included (1) involvement with the Pew Charitable Trusts' Global Ocean Legacy Project, for which we reviewed the fisheries and biodiversity of sites which could be turned into large marine reserves, e.g., the Exclusive Economic Zone of New Zealand's Kermadec Islands (Palomares et al. 2012); (2) the completion of a major comparative review of country's fisheries rehabilitation potential for the Bloomberg Foundation (Kleisner et al. 2012), (3) Oceana (Pauly et al. 2012), and (3) the Rockefeller Foundation (Kleisner et al. 2013).

Active involvement in the FishBase Consortium, via the activities of the FishBase Liaison and SeaLifeBase Coordinator (Dr. ML "Deng" Palomares), assures the smooth flow of Sea Around Us data needs (e.g., taxonomic integrity, biogeography, ecological and biological data) from FishBase and SeaLifeBase for analyses, e.g., on the impact of climate change on marine ecosystems and fisheries (see Cheung et al. 2012). The *Sea Around Us* also hosts the www.fishbase.ca and www.sealifebase.ca mirror sites since 2012.

The *Sea Around Us* participated in over 20 international conferences, symposia, meetings and similar events in 2012 and 2013. Some highlights include the 2012 AAAS Annual Meeting in Vancouver, the Economist World Oceans summit in Singapore, the 12th International Coral Reef Symposium in Australia, the European Convention of Environmental Laureates, the Expert Roundtable on Fisheries and the Right to Food in Nairobi, the Monaco Blue Initiative in South Korea, and the Aspen Environment Forum, Canada. Furthermore, over 20 keynotes and lectures were given by senior *Sea Around Us* staff, including to policy makers (e.g., Lima, Peru), to FAO staff (Rome, Italy), to a multinational audience of maritime security officials (Victoria, Canada), and to senior West African policy makers in Dakar, Senegal.

Overall, the applied and strategic work of the *Sea Around Us* during 2012-2013 has led to 30 peer reviewed articles in which a team member was first author, and 23 additional publications in which at least one team member was a co-author.



PhD student Dyhia Belhabib and Sea Around Us Principal Investigator Daniel Pauly at the regional Marine and Coastal Forum held in Dakar, Senegal in November 2013.

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