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Global Fisheries Science Documents Human Impacts on Oceans: The *Sea Around Us* Serves Civil Society in the Twenty-First Century

Dirk Zeller,[1] Maria L.D. Palomares,[2] and Daniel Pauly[2]

[1] *Sea Around Us – Indian Ocean*, School of Biological Sciences, University of Western Australia, Crawley, Western Australia, Australia; email: dirk.zeller@uwa.edu.au

[2] *Sea Around Us*, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, British Columbia, Canada; email: m.palomares@oceans.ubc.ca, d.pauly@oceans.ubc.ca

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Abstract

Fishing provides the world with an important component of its food supply, but it also negatively impacts the biodiversity of marine and freshwater ecosystems, especially when industrial fishing is involved. To mitigate these impacts, civil society needs access to fisheries data (i.e., catches and catch-derived indicators of these impacts). Such data, however, must be more comprehensive than the official fisheries statistics supplied to the Food and Agriculture Organization of the United Nations (FAO) by its member countries, which shape public policy in spite of their deficiencies, notably underestimating small-scale fisheries. This article documents the creation, based on the geographically coarse FAO data, of a database and website (**https://www.seaaroundus.org**) that provides free reconstructed (i.e., corrected) catch data by ecosystem, country, species, gear type, commercial value, etc., to any interested person, along with catch-derived indicators from 1950 to the near present for the entire world.

1. INTRODUCTION

Global fisheries rose to the public consciousness in the 1990s, when the collapse of one of the largest fish stocks in the world—the intensely studied and supposedly well-managed fishery for Atlantic cod (*Gadus morhua*) off Newfoundland and Labrador, Canada (Hutchings & Myers 1994)—became increasingly seen as representative of fisheries as a whole (Grainger & Garcia 1996). Indeed, for a very long time, fisheries stocks (i.e., populations of exploited species of marine life) had been overfished, collapsed, and disappeared from human memory in many places around the world (Jackson et al. 2001), leading to a form of sequential stock depletion that was missed by the public (Roberts 2007). Concurrently, the realization grew that governments' scientific and regulatory agencies were, in many countries, neither able nor even mandated to address these problems. Indeed, they often lacked even the most fundamental data and tools, such as comprehensive catch data time series and stock assessment models, which can be used in countries where fisheries-independent data are not available (i.e., in most of the world).

In large part as a response to these challenges coming to greater prominence during the 1990s, the *Sea Around Us* research initiative (**https://www.seaaroundus.org**) was launched in 1999 at the former Fisheries Centre—now the Institute for the Oceans and Fisheries—at the University of British Columbia in Vancouver, Canada, with strong support from the Pew Charitable Trusts. The first period of *Sea Around Us* research and activities related to the human impact of global fisheries (**Table 1**) was documented by Pauly (2007). The *Sea Around Us* has since created its first international geographic node, the *Sea Around Us – Indian Ocean* at the University of Western Australia (**https://www.seaaroundus-io.org**), in response to the Indian Ocean being underrepresented in many global scientific investigations, particularly in larger-scale and big-picture fisheries science and conservation. One exception may be the high-value Indian Ocean industrial tuna fisheries, which receive considerable attention from many countries as well as regional management through the Indian Ocean Tuna Commission. However, these fisheries embody considerable equity issues, as they are dominated largely by distant-water fleets from Europe and East Asia, with beneficial ownership residing largely outside the Indian Ocean region (Andriamahefazafy & Kull 2019, Campling 2012). More importantly, however, the small-scale coastal fisheries of the countries around the Indian Ocean rim, which are important contributors to food security and local livelihoods for millions of people, are often neglected or underrepresented in the science and policy debates around fisheries and marine resource conservation. The *Sea Around Us – Indian Ocean* is ideally placed to fill some of the data and science gaps for this ocean basin (e.g., Christ et al. 2020; Zeller et al. 2020, 2021).

2. DEVELOPMENTS AND CONTRIBUTIONS FROM THE *SEA AROUND US*

Following on from the earlier paper by Pauly (2007), we present six major developments and contributions of the *Sea Around Us* and *Sea Around Us – Indian Ocean* research initiatives that address the human impact of global fisheries over the last few decades: catch reconstructions, an improved database and open data user interface, fishing effort data, biomass estimates and trends, a return to global coverage of marine protected areas (MPAs), and a move toward also covering freshwater fisheries.

2.1. Catch Reconstructions

If one wants to understand the impact humanity has on marine ecosystems through fishing, then the most important question to ask first is how much humanity actually takes out of the ocean—that is, how much fish and other aquatic life is caught in space and over time. That was also

Table 1 Building blocks and parameters that can help define and guide the development of a globally transformative research initiative such as the *Sea Around Us* initiative on global fisheries (adapted from Meeuwig 2019)

Driver	Comment	Example
Recognize	Civil society is the ultimate stakeholder safeguarding against uncontrolled or excessive ocean exploitation.	The *Sea Around Us* ensures that society is provided with the data and equipped with the knowledge to facilitate a move toward long-term sustainability of fisheries (e.g., Pauly & Zeller 2016a, Pauly et al. 2002).
Reject	One should not automatically accept the status quo of scientific thinking or convention and should reject the common trap of letting "perfect" get in the way of "better" in terms of data and insights.	The *Sea Around Us* demonstrates that one can reconstruct (estimate) unreported and undocumented fish catches even with imperfect or limited information, and accept the potentially higher uncertainty associated with such estimates (e.g., contributions in Pauly & Zeller 2016b).
Share	An open and transparent data- and product-sharing attitude allows knowledge to grow exponentially and new data to be developed.	The *Sea Around Us* has an open data and open documentation policy and freely shares data and data products as well as underlying documentation of data processes. Such open data and documentation policies empower achievements and progress that go beyond what a single team can achieve and empower others to use these data and products (e.g., in Carlson et al. 2021).
Globalize	Too many so-called global analyses are actually case-study based, and they often interpret biased subsets of data as if they were representative of global fisheries patterns or trends.	The *Sea Around Us* approach to global analysis is indeed global—that is, all countries and all fisheries must be considered and included, irrespective of the depth or perceived quality of the available data. The associated data uncertainty is openly estimated and documented. This approach ensures that analyses are considered in a full global context, avoiding the distortions that selective case-study-based analyses can generate (Pauly & Zeller 2017a, Pauly et al. 2018).
Communicate	Science communication goes beyond documenting research in reports and peer-reviewed scientific papers published in specialist journals that are often not accessible to scientists in developing countries or to civil society. These papers do form the scientific foundation upon which communication with civil society is based. However, such communication needs to be amplified across platforms, disciplines, and audiences.	The *Sea Around Us* has a professional outreach officer who actively engages in science-based communication across multiple social media platforms (e.g., Univ. B.C. 2021, **https://www.seaaroundus.org/about**, **https://seaaroundus-io.org/news**). *Sea Around Us* team members regularly communicate with journalists and nonscience media and education outlets (e.g., Meeuwig et al. 2018, Pauly & Zeller 2017b). Important ecological and fisheries concepts have been mainstreamed by translating them into intuitive language such as "shifting baselines" and "fishing down marine food webs." A deliberate effort has also been made to maximize the publication of open access papers to empower scientists in developing countries.
Publish	Publishing (and thus documenting scientific research) is at the core of how science advances.	The *Sea Around Us* not only ensures its work is published in peer-reviewed scientific journals across a wide spectrum of specialization fields, but also tries to maximize publication of open access papers to empower wide distribution and accessibility around the world (e.g., Pauly & Zeller 2016a). Also, the decision to create a now extensive series of high-quality research reports and working papers (e.g., Palomares et al. 2021), all freely available online, makes this work quickly available prior to its publication in the scientific literature.

(*Continued*)

Table 1 (*Continued*)

Driver	Comment	Example
Challenge	A key role for scientists is to challenge perceived scientific and public opinions that are contradicted by evidence. Thus, speaking truth to power via clearly documented evidence is crucial, as is the need to challenge the capture of most fisheries science and government fisheries departments by the fishing industry.	The *Sea Around Us* approach to fisheries science, via globally comprehensive and open data access, highly diverse publications, and dialogue approaches with civil society and other stakeholders in ocean affairs, speaks a quiet truth that underpins its contributions to civil society and reframes society's understanding of the oceans (e.g., Marchand 2021).

one of the first questions the *Sea Around Us* was challenged with in its initial phase: What is the actual catch of the world's maritime fisheries, as opposed to the nominal catch data that the Food and Agriculture Organization of the United Nations (FAO) receives from its member countries and then harmonizes and disseminates (Garibaldi 2012)? Importantly, the data reported by the FAO on behalf of countries are landings, not catches, because they explicitly omit catches that are discarded at sea during fishing operations (Zeller et al. 2018). Also, the data provided to the FAO often include only cursory coverage of small-scale fisheries, frequently leaving out large amounts of artisanal and especially subsistence and recreational catches (Freire et al. 2020, Zeller et al. 2015). This imbalance in coverage is the result of selective national data collection and reporting systems in the various countries (Zeller et al. 2015) and is not only a developing-country problem (e.g., Lescrauwaet et al. 2013). Additionally, the data reported by the FAO do not explicitly attempt to include illegally caught fish, thus masking the issues with illegal, unreported, and unregulated (IUU) fisheries.

After much deliberation on various options for addressing this question, a catch reconstruction methodology was developed that corrected for omissions in catch data. This methodology was first systematically applied to the US flag–associated island territories in the Pacific on the invitation of the US Western Pacific Regional Fishery Management Council (Zeller et al. 2005, 2006, 2007, 2008). The methodological approach of catch reconstruction was detailed by Zeller et al. (2016) and is based on two basic principles (Pauly 1998): (*a*) Fisheries are social activities, and thus it is not possible for fisheries to exist about which there are no data or information, and (*b*) 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 in official data.

Altogether, the *Sea Around Us* has conducted and facilitated more than 200 separate catch reconstruction studies over a span of more than 15 years, covering the 273 exclusive economic zones (EEZs) of all maritime countries or their overseas territories for the years 1950–2010. The reconstructions are corrected as soon as feedback of any shortcoming is received, and they are updated regularly. These contributions—of which well over 160 are now documented in the peer-reviewed literature (**https://www.seaaroundus.org/articles**)—involved approximately 400 coauthors, of which approximately 100 were team members of the *Sea Around Us* and 300 were external colleagues from countries on all continents. In addition to the country/EEZ-specific reconstructions, a separate data harmonization was undertaken of the global fisheries for tuna and other large pelagic fisheries under the mandate of the five tuna regional fisheries management

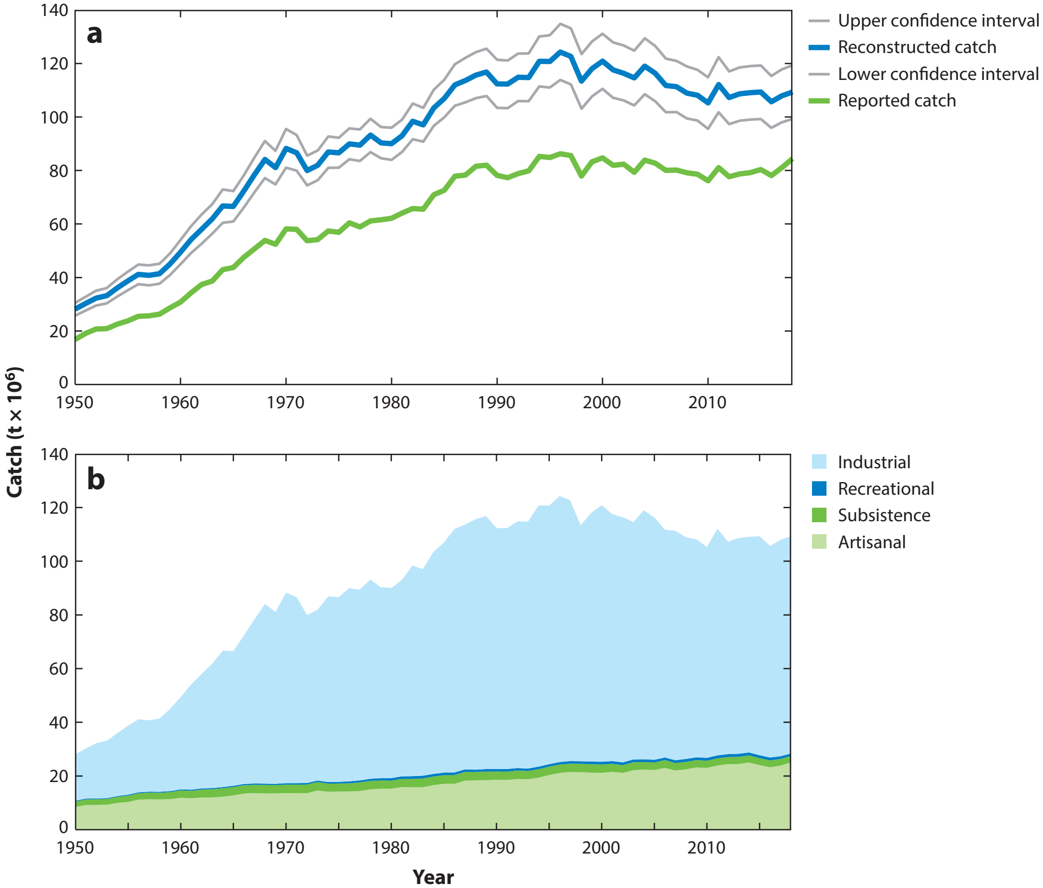

Figure 1

Global marine fisheries catches for 1950–2018. (*a*) Catches reported by the FAO based on submissions from its member countries without confidence intervals and catches based on the sum of the catch reconstructions performed or inspired by the *Sea Around Us*. The confidence intervals for the reconstructed time series were estimated by combining for each year, using the Monte Carlo method, the uncertainty associated with each sector in each national reconstruction into an overall 95% confidence interval (Pauly & Zeller 2017a). (*b*) Reconstructed total catches for all countries in the world by large-scale (industrial) and small-scale (artisanal, subsistence, and recreational) sectors. All data exclude plants, corals, sponges, reptiles, and marine mammals. Abbreviation: FAO, Food and Agriculture Organization of the United Nations. Figure updated with permission from data published by Derrick et al. (2020a,b) (CC BY-NC-ND 4.0) and Pauly & Zeller (2016a, 2017a) (CC BY 4.0 and CC BY-NC-ND 4.0, respectively).

organizations, which manage fishing in both high-seas waters and countries' EEZs (Coulter et al. 2020, Le Manach et al. 2016). These reconstructed catch data, which essentially complement official data as reported by the FAO on behalf of countries with best estimates of unreported catches, form the basis for the improved catch data freely available through the *Sea Around Us* web portal (**https://www.seaaroundus.org**). These data also provided the foundation for an article whose title summarized the main findings of this >15-year activity: "Catch Reconstructions Reveal that Global Marine Fisheries Catches Are Higher than Reported and Declining" (Pauly & Zeller 2016a) (**Figure 1*a***). This study also clearly demonstrated that industrial (also called large-scale) fisheries dominate global marine catch levels and trends (**Figure 1*b***). In the same year, a >500-page multiauthored work titled *Global Atlas of Marine Fisheries* was also published, which presented the methods and major results of the *Sea Around Us* research activities and the reconstruction project and included 273 one-page summaries of the fisheries of the maritime countries of the world and their overseas territories (Pauly & Zeller 2016b).

These reconstructed catch data are regularly revised and updated, most recently with an update to the data year 2018 (Derrick et al. 2020a,b). Such updates are carried out either via dedicated country revisions (e.g., Christ et al. 2020, Khalfallah et al. 2017, Ulman et al. 2020, Vianna et al. 2020a) or by applying a short-term forward carry of the previously reconstructed data trends (Noël 2020). Such forward-carry approaches are also routinely used by the FAO for the reported nominal landings data in cases of missing annual reports or inadequate reporting to the FAO by countries, which has been documented to occasionally occur for approximately 50% of all countries (Garibaldi 2012).

One important insight derived from the large number of individual reconstructions is that many of the national data collection and reporting systems inadvertently contain an inherent time series bias that contributes directly to shifted baselines (Pauly 1995). This was first identified for Tanzania and Mozambique (Jacquet & Zeller 2007a,b; Jacquet et al. 2010), and this issue is now known as the presentist bias (Pauly & Zeller 2019, Zeller & Pauly 2018). More recently, additional cases of the presentist bias have been identified, for example, in the national catch data for Greece (Tsikliras et al. 2020). This time series bias occurs when improvements in official catch data reporting systems (e.g., inclusion of a previously unmonitored fishery) lead to an increase in current catches without the corresponding past catches being corrected retroactively (Zeller & Pauly 2018). In other words, the presentist bias can cause time series of catch trends to look artificially better (i.e., more positive) than they actually are, thus obscuring cases where real catch has leveled off or is declining. The presentist bias is likely to occur in many if not all official long-term time series data from countries, even if it may be subtle or deeply buried. The main point to understand about the presentist bias, however, is that it is an unintentional downside of something that is actually beneficial—namely, the continuous improvement efforts in data collection systems over time. Nevertheless, the presentist bias needs to be adjusted for over the entire time period of reported data—back to 1950, in the case of global catch statistics.

Also, by assessing the quality and coherence of the data that are used for the reconstruction, the author(s) of each country and/or territory catch reconstruction could quantify the degree of confidence associated with given periods and fishing sectors covered by the reconstructed catch estimates, using the criteria in **Table 2**. This approach and the criteria were adapted from a procedure used by the IPCC (see Zeller & Pauly 2016). As these measures of confidence—or uncertainty, as they can also be interpreted—are carried over into half-degree latitude–longitude cell catch data, they can be reexpressed as measures of data confidence or data uncertainty at the

Table 2 Scores for evaluating the quality of time series of reconstructed catches, along with their approximate confidence intervals

Score	± (%)	Corresponding IPCC criteria[a]
4: very high	10	High agreement and robust evidence
3: high	20	High agreement and medium evidence *or* medium agreement and robust evidence
2: low	30	High agreement and limited evidence *or* medium agreement and medium evidence *or* low agreement and robust evidence
1: very low	50	Low agreement and limited evidence

[a]IPCC criteria are from Mastrandrea et al. (2010, figure 1), who note that the level of confidence increases (and hence confidence intervals are reduced) "when there are multiple, consistent independent lines of high-quality evidence" (p. 3).

EEZ level or for other geographies and for various taxa or stocks. Note that the *Sea Around Us* is the only entity in the world providing fisheries catch data that are associated with estimates of their uncertainty.

Maintaining and updating these catch data reconstructions on a global scale is a time- and resource-consuming effort, and hopefully, an increasing number of countries will see the benefits and advantages of adopting reconstruction approaches and methods for their own data collection and estimation systems. Such national adoptions could rapidly lead to more complete and comprehensive data reporting at both the national and international levels. Such actions can close the gaps between official reported data and total reconstructed catch data, which would be a great contribution to global transparency and accountability. Until country authorities decide to take such steps, hopefully with the assistance of the FAO, a close collaboration of in-country experts with the *Sea Around Us* would ensure that the best and most reliable data revisions and updates for their respective countries can be undertaken.

2.2. Revamped Technology: Improved Database and Open Data User Interface

To support and empower the evaluation and assessment of humanity's impact on global oceans via fishing, any data, analysis, and research output must be freely and widely available. Thus, data transparency and free and open availability of research and data are crucial. The original *Sea Around Us* databases, spatial allocation routines, and website, as designed and created at the start of the *Sea Around Us* in the early 2000s (Watson et al. 2005), increasingly suffered from restrictive functionality, limited processing speed, and an absence of open data access for external users. Furthermore, the original database structure, processing, and web routines were not readily adaptable to a new catch reconstruction data system. Thus, between 2014 and 2016, with support and technical expertise from the Paul G. Allen Family Foundation and Vulcan Inc., the *Sea Around Us* engaged in a redesign, redevelopment, and rebuild of its database infrastructure and capacity, programming and allocation algorithms, and web-portal user interfaces (**Figure 2**). Some of the primary objectives were system standardization, increased and streamlined data processing speed and capacity, and public access and open data use. While this work is not a specific scientific achievement in itself, it has made data processing much faster and more efficient, permitting revised and updated data to be more easily processed and integrated into the web portal (Zeller et al. 2016).

For the first time, these revamped databases and data portal permitted direct and independent access to *Sea Around Us* data by end users via a web-based direct data download function. The revised data portal provides access to and visualization of data for several spatial and fisheries-relevant entities (**Figure 3**), such as EEZs, large marine ecosystems (Pauly et al. 2008, Sherman & Hempel 2008), marine ecoregions (Spalding et al. 2007), and regional fisheries management organizations' mandated management areas (Cullis-Suzuki & Pauly 2010, 2016), combined with associated open data download options. The portal also provides a global interactive mapping tool that allows users to view spatially dedicated data as time series maps (**Figure 4**). This tool is a crucial step forward in open access data in fisheries science, and within a short period has contributed to the increasing use of reconstructed data by scientists and other users around the world, including more than 300 papers published by non–*Sea Around Us* scientists.

To improve on customizable open data access, the *Sea Around Us* partnered with the University of British Columbia's Cloud Innovation Centre (**https://cic.ubc.ca**) to develop an Open Data service through Amazon Web Services (**https://aws.amazon.com/opendata**). This service provides a serverless architecture using Jupyter Notebooks (**https://jupyter.org**) that will enable technically knowledgeable users to extract customized data sets from the *Sea Around Us* databases. Note

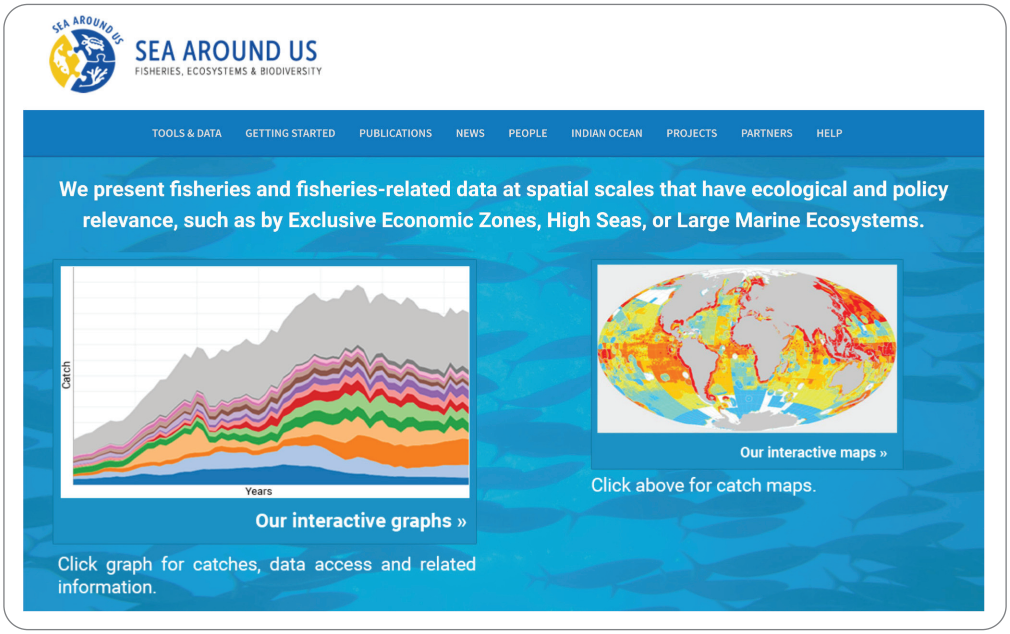

Figure 2

The revamped and improved tools and data portal at **https://www.seaaroundus.org**, which enables direct and open access to the data for every maritime country in the world.

that users with free Open Data accounts will be able to gain access to this new service, which includes a step-by-step instruction guide. This service will launch in 2022.

So far, the responses from multiple users on the *Sea Around Us* data and technology revamp have been positive, and comments are welcome (see **https://www.seaaroundus.org/feedback**). The *Sea Around Us* data and tools will be improved regularly, especially if critical feedback is accompanied by documented evidence that helps resolve problems and/or by offers of collaboration from country or topic experts.

2.3. Fishing Effort

The impact of fishing on ecosystems and hence the success or failure of fisheries management and conservation endeavors have often been examined largely through catch data trends and patterns, especially in countries with fewer resources. However, overfishing and the collapse of fish stocks is usually the result of excessive fishing effort (i.e., too many boats, too much fishing time and power, or both) (Davidson et al. 2014). Therefore, data that complement catch data, such as comprehensive and standardized fishing effort data, can provide insights into the status of fisheries and their underlying fish stocks and thus support a better understanding of the human fisheries impact on marine ecosystems.

A large range of different and nonstandardized measures of fishing effort are used around the world, which makes global comparisons difficult. To deal with this, a globally standardized fishing effort measure was developed, namely the power input in fisheries (i.e., kWday) (Anticamara et al. 2011, Belhabib et al. 2018, Watson et al. 2013, Zeller et al. 2021). This measure was also used to estimate CO_2 emissions by global fisheries in the context of climate change (Greer et al. 2019a). Similar research efforts were undertaken independently but in parallel (Parker et al. 2018),

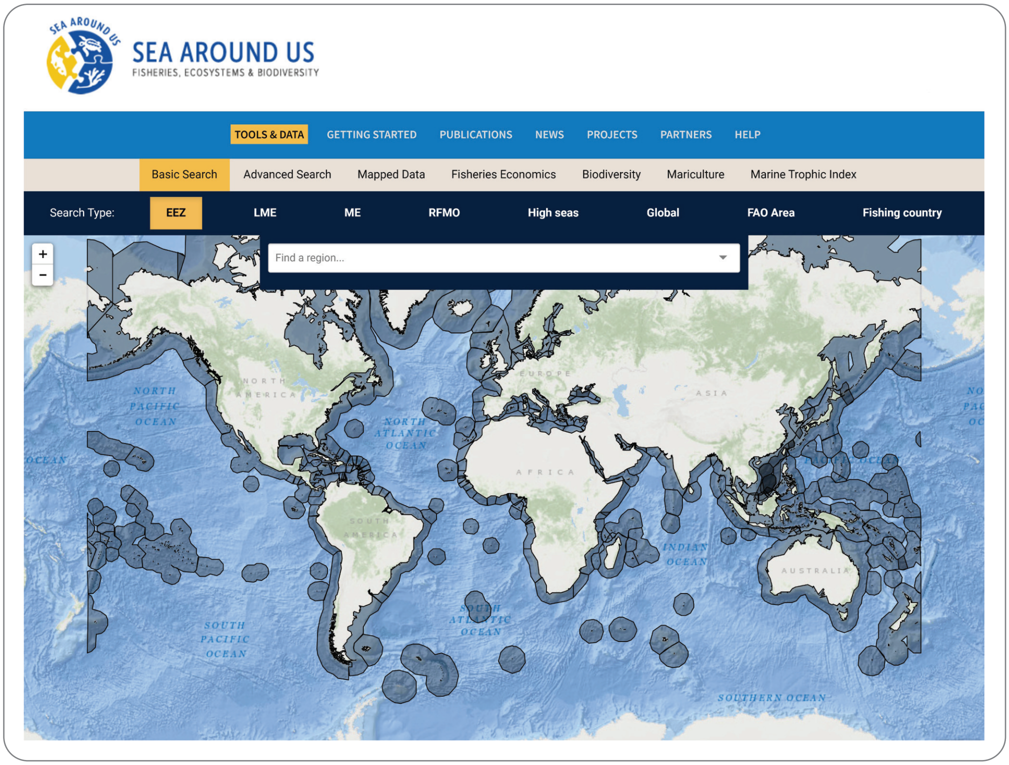

Figure 3

The revised and improved *Sea Around Us* data portal (**https://www.seaaroundus.org/data/#/eez**), enabling direct access to and downloading of reconstructed catch data for several spatial and fisheries-relevant entities, including exclusive economic zones, large marine ecosystems, marine ecoregions, and regional fisheries management organizations' mandated management areas.

enabling international comparisons (Greer et al. 2019b, Ziegler et al. 2019). At the time of writing, these global fishing effort data remain preliminary but are being improved upon (e.g., Christ et al. 2020, Vianna et al. 2020a). The existence of global fishing effort data with a standardized measurement unit (kWday) allows fishing effort to be combined with reconstructed catch data to derive catch-per-unit-effort (CPUE) time series. Such CPUE data provide broad indicators of the general status and trend of the fish resources underlying fisheries in an area (e.g., Belhabib et al. 2018, Zeller et al. 2021), particularly when they are corrected for the creeping increase in catchability due to improved technology, such as echo sounders, GPS, and other technologies (Palomares & Pauly 2019). The consistent and often strongly declining CPUE trends over extended time periods noted in such studies to date provide a first-order insight into a generally declining resource base, even in the absence of formal stock assessments (**Figure 5**)—for example, for the Mozambique Channel region in East Africa (Zeller et al. 2021) or fisheries in West Africa (Belhabib et al. 2018).

2.4. Biomass Estimates and Trends

Modern fisheries tend to overfish the resources upon which they depend, unless they are restrained by well-enforced management actions. Therefore, it is necessary to impose restrictions on fisheries, such as limits on how much they are allowed to catch in a given year, generally called the total allowable catch, which is often subdivided into quotas. However, to set such total

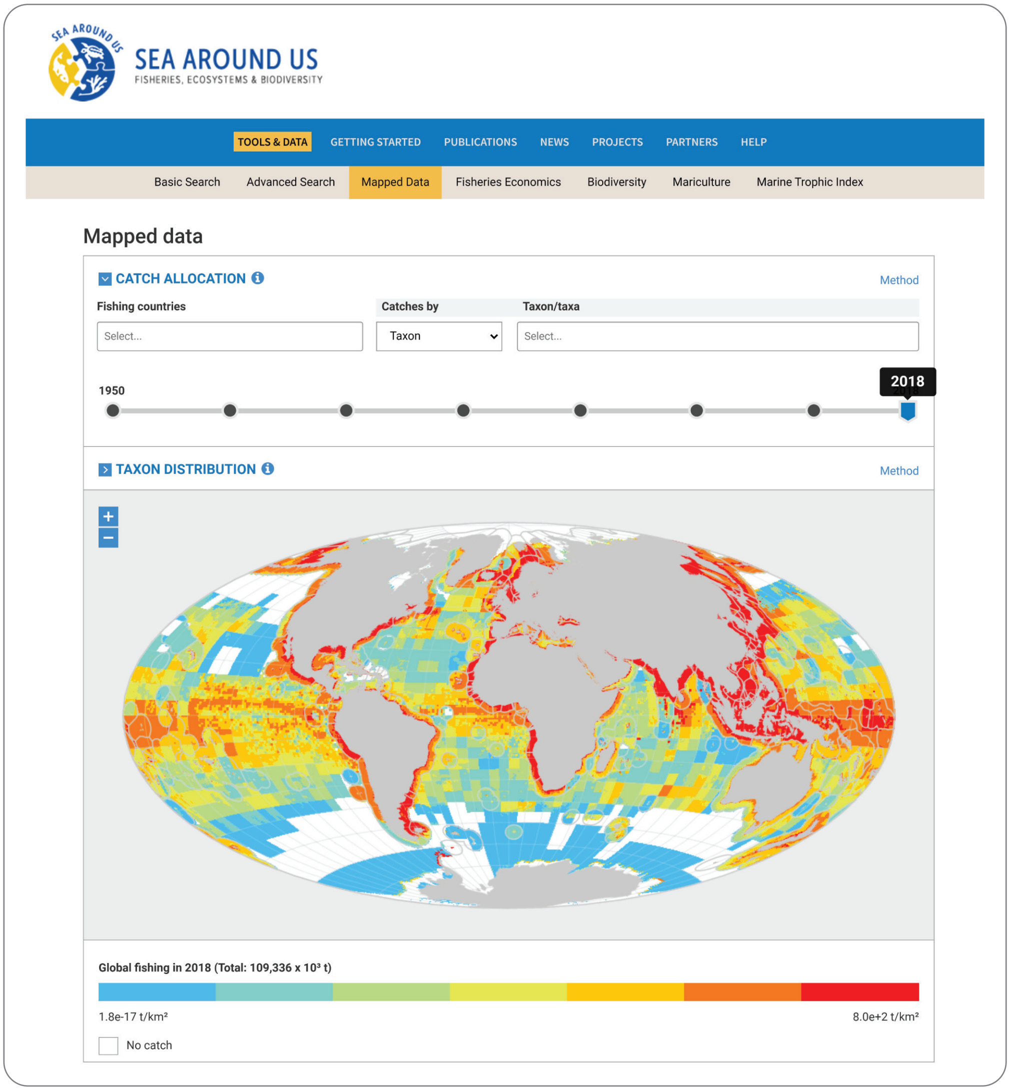

Figure 4

The interactive mapping tool of the *Sea Around Us* web portal (**https://www.seaaroundus.org/data/#/spatial-catch**), which allows users to view spatially dedicated data as time series maps.

allowable catches and quotas, the amount of fish left in the water (i.e., a stock's biomass) must be known. Such information is ideally obtained through stock assessments—the analytical process of estimating trends in the biomass of a self-sustaining population of fish and deriving likely sustainable levels of exploitation (i.e., fishing effort) and catch for the upcoming year.

In recent years, traditional stock assessments and their methodologies have become enormously complicated and data hungry, which is why traditional stock assessments are undertaken for only a minority of the tens of thousands of fish and invertebrate populations that are exploited throughout the world. However, a long-term research partner of the *Sea Around Us*, Dr. Rainer Froese, and his colleagues have developed a suite of stock assessment approaches for use in

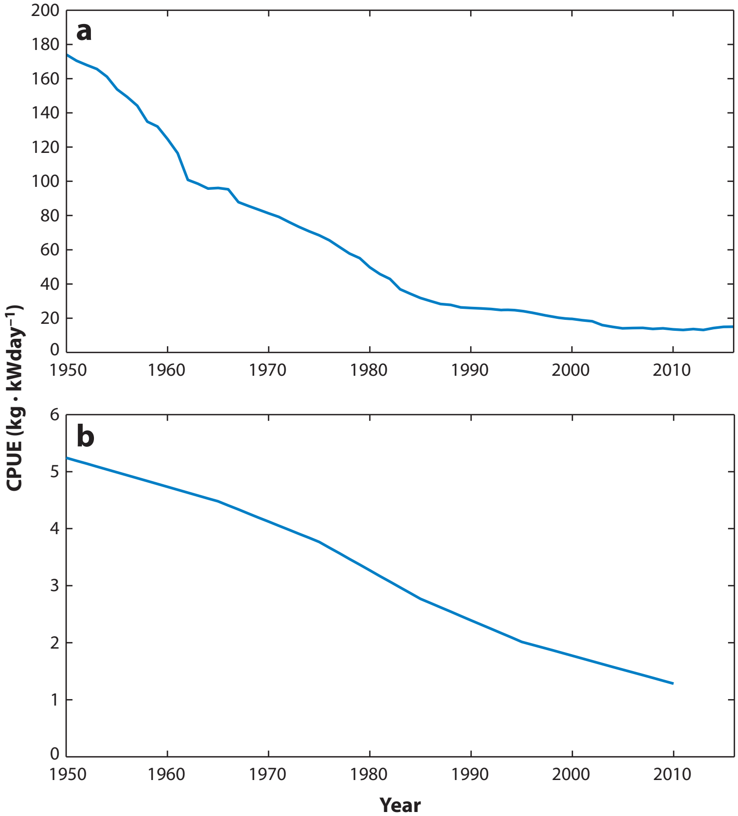

Figure 5

Derived CPUE time series for (*a*) small-scale artisanal and subsistence fisheries in the Mozambique Channel region in East Africa and (*b*) artisanal fisheries in West Africa, as derived from the combination of the independently reconstructed catch and fishing effort data from the *Sea Around Us*. Abbreviation: CPUE, catch per unit effort. Panel *a* adapted from Zeller et al. (2021) (CC BY 4.0); panel *b* adapted from Belhabib et al. (2018) (CC BY 4.0).

data-limited situations, such as those prevailing for many stocks in most of the world's fishing areas and countries. These methods include the now well-tested and established CMSY (catch maximum sustainable yield) approach, which requires only catch time series as input along with easy-to-obtain ancillary quantitative information on the taxon being assessed (Froese et al. 2017), and the AMSY (abundance maximum sustainable yield) approach, which relies on relative abundance data, such as CPUE time series (Froese et al. 2019).

The year 2020 saw the publication of estimated long-term biomass trends for more than 1,300 fish and invertebrate populations of more than 480 species exploited by fisheries in the 232 coastal marine ecoregions (Spalding et al. 2007) around the world (Palomares et al. 2020). These assessments were derived using the CMSY stock assessment method as applied to the reconstructed global fisheries catch data for 1950–2014. Overall, the results suggest a consistent decline in the fisheries biomass of exploited populations, in virtually all climatic zones and ocean basins in the world (**Figure 6**).

These assessments are incorporated into the *Sea Around Us* website as interactive graphs of biomass, catch, and exploitation rate (**Figure 7**) with reference to the maximum sustainable yield

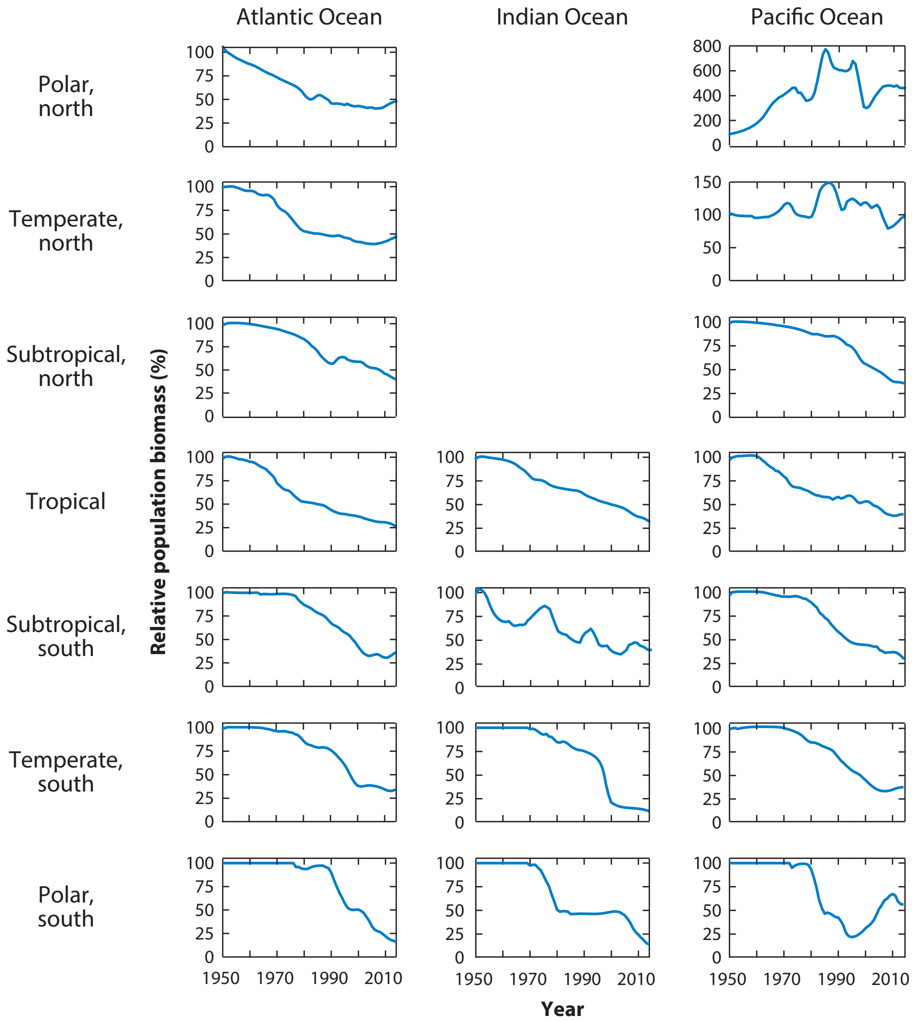

Figure 6

Relative changes over time in the population biomass of analyzed populations in the marine ecoregions of the world (Spalding et al. 2007), expressed as a percentage of the average biomass at the start of the time series (1950–1954), grouped by climatic zone and ocean basin. Note that the Indian Ocean is limited to the north by the Asian continent and thus does not have any northern subtropical, temperate, or polar zones. Figure adapted from Palomares et al. (2020) (CC BY 4.0).

(Pauly & Froese 2020, Schaefer 1954). The assessments and the data supporting and enabling them can be downloaded and examined, and assessments can be rerun by the user using various assumptions, or priors. These assessments have recently been updated and expanded in line with updates of the reconstructed catch data (Derrick et al. 2020a,b) and improved upon with new updates of the underlying data-limited assessment method, which allowed the assessment of more than 2,500 stocks of finfish and invertebrates (Palomares et al. 2021; see also **https://www.seaaroundus.org**). These assessments will serve as the basis for various publications. Such biomass assessment activities will help shape the future of the *Sea Around Us*, as there is considerable interest from other groups in global estimates of changes of biomass in the sea that are not biased by overemphasis on

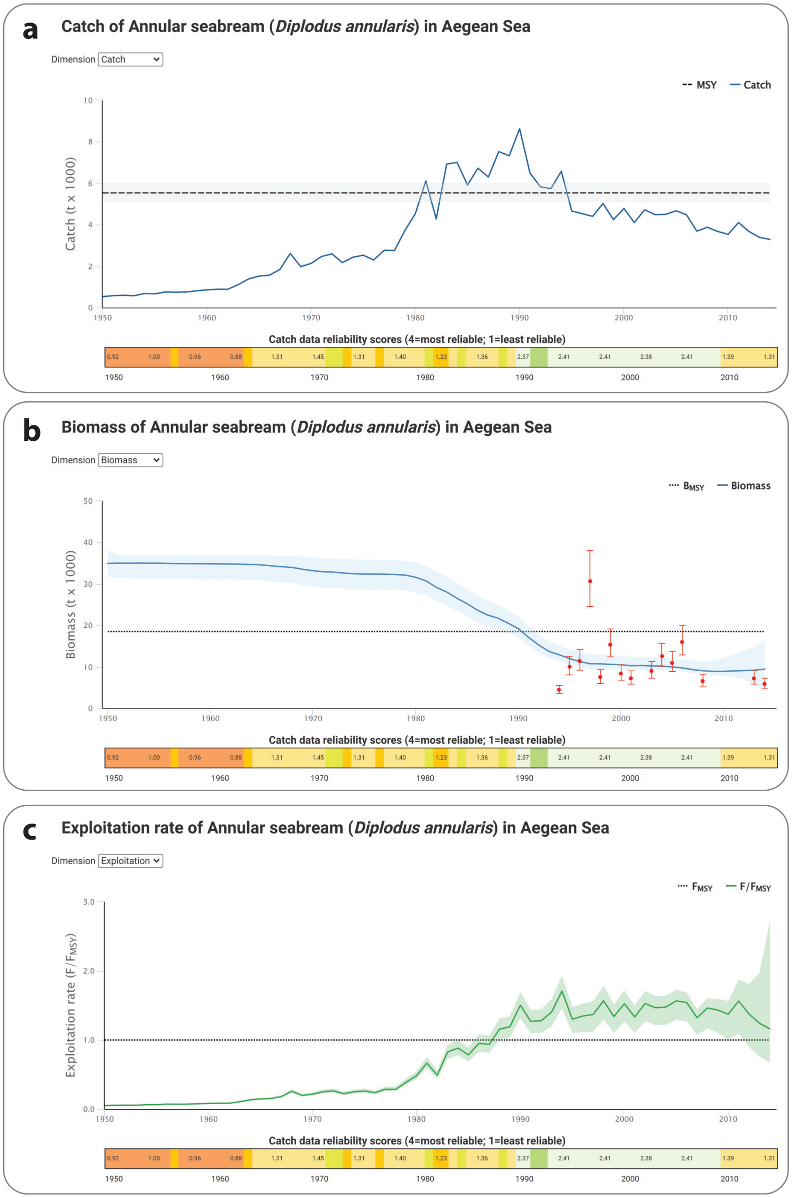

Figure 7

Representative example of the results of the stock assessment conducted using the CMSY++ data-limited assessment method for annular seabream (*Diplodus annularis*) in the Aegean Sea marine ecoregion, presenting time series of (*a*) catch, with MSY level indicated; (*b*) biomass, with B_{MSY} indicated; and (*c*) exploitation rate (F/F_{MSY}), as presented at **https://www.seaaroundus.org/data/#/msy/105601752**. Analyses are based on data from Palomares et al. (2021). B_{MSY} represents the biomass that enables a fish stock to deliver the maximum sustainable yield; F is the fishing mortality rate, that is, the catch relative to the size of the stock (the proportion of fish caught and removed by fishing); and F_{MSY} is the maximum rate of fishing mortality F resulting in a population size of B_{MSY}. Abbreviations: CMSY, catch maximum sustainable yield; MSY, maximum sustainable yield.

developed-country fisheries and are not impacted by either the presentist bias in underlying catch data (Zeller & Pauly 2018) or the problematic use of truncated time series in stock assessments (Schijns & Pauly 2022).

2.5. Reconnecting with Marine Protected Areas

The first phase of the *Sea Around Us* in the early 2000s saw the creation of the first global database of MPAs, MPA Global (Boonzaier & Pauly 2016, Wood et al. 2008). This database was based on the separation of marine from terrestrial protected areas in the World Database on Protected Areas (UNEP-WCMC 2022) and complemented that database with new marine entries. However, MPA Global was abandoned when the Marine Conservation Institute (**https://marine-conservation.org**) created the more complete Marine Protection Atlas (**https://mpatlas.org**). Then, for a while, the *Sea Around Us* work on MPAs concentrated on specific MPAs and declared or planned marine reserves (Palomares et al. 2012, Relano et al. 2021, Ruiz-Leotaud & Pauly 2018).

Eventually, however, the *Sea Around Us* returned to global coverage of MPAs, marine reserves, and other areas protective of marine biodiversity, in two steps. The first was the inclusion in the volumes presenting the catch reconstruction update to 2018 for each maritime country and territory of the world (Derrick et al. 2020a,b) of a section featuring the treaties and conventions on the protection of (marine) biodiversity of which they are members, and quoting literature sources on the effectiveness of their MPAs and other protected areas. The second was the creation of a new MPA page on the *Sea Around Us* website that presents the information from the first step, with deep links to entries in the Marine Protection Atlas and to FishBase (**http://www.fishbase.org**) and/or SeaLifeBase (**http://www.sealifebase.org**), so that life-history information can be readily acquired about the protected species of fish and/or animals other than fish that are explicitly mentioned. This new page thus provides a bridge between the detailed fisheries data available on the *Sea Around Us* website and the multitude of MPAs included in the Marine Protection Atlas, which should allow better assessments of what is actually protected.

2.6. Getting Fresh

The original core mission of the *Sea Around Us* was to focus on the marine environment (Pauly 2007). However, fisheries also occur in freshwater systems such as lakes and rivers, and while the marine environment dominates global fisheries catches (FAO 2020), freshwater, or inland, fisheries cannot be ignored. Therefore, the *Sea Around Us* has begun to investigate the data situation for freshwater fisheries as a complement to its global marine fisheries activities.

A key difference between marine and freshwater fisheries is that virtually all freshwater fisheries are small-scale in nature—that is, they are dominated by artisanal, subsistence, and recreational activities, with little or no industrial fishing. By contrast, marine fisheries catches are dominated by industrial fisheries (**Figure 1*b***), even though the small-scale marine sectors contribute substantially and directly to local food and livelihood security (Teh & Pauly 2018, Zeller et al. 2015).

Initial work on freshwater fisheries by the *Sea Around Us – Indian Ocean* includes the successful application of the core catch reconstruction approach (Zeller et al. 2016) to the freshwater fisheries of Kenya (Schubert 2020). This research highlighted that Kenya's freshwater catches are underreported by at least 30% (Schubert et al. 2022), which parallels the global marine catch underreporting for the most recent years (Pauly & Zeller 2016a). However, Schubert et al. (2022) pointed out that that the overall underreporting rate for freshwater fisheries globally is likely much higher, given that Kenya is considered to be one of the countries in Africa with the best freshwater fisheries data on the continent, based on an FAO audit of African freshwater fisheries (Welcomme & Lymer 2012). An evaluation of the officially reported catch data for freshwater fisheries as presented by the FAO suggested that reported inland fisheries catches greatly increased on a global scale for developing countries, while plateauing for moderately developed countries and declining for well-developed countries (Sorensen & Palomares 2021). Thus, socioeconomic factors influence how well and what countries report.

Further research should address the substantial data challenges surrounding freshwater fisheries. This is of particular importance given that these fisheries play a key food and nutritional security role for millions of people in developing countries (Bennett et al. 2021, Vianna et al. 2020b).

3. 2023 AND BEYOND: THE FUTURE OF THE *SEA AROUND US*

The research and data products generated over the last >20 years through the *Sea Around Us* often have been groundbreaking and positively disruptive in the field of fisheries science, driven largely by the unique viewpoint taken throughout: that fisheries are globally interconnected biological and socioeconomic systems, with sustainability deeply rooted in and requiring structurally healthy and productive ocean ecosystems in time and space. This viewpoint is reflected in globally unique, ecologically and politically spatialized data sets that not only span nearly 70 years for every country in the world but also account comprehensively for unreported and discarded catches as well as fishing sectors. Furthermore, the deep links to fully integrated economic parameters such as ex-vessel prices (Sumaila et al. 2007, Swartz et al. 2013, Tai et al. 2017) and fisheries subsidies (Sumaila et al. 2013, 2016, 2019, 2021), as well as comprehensive biodiversity, ecosystem, and governance information sources, make for a truly unique global data and information system around fisheries. And all of it is freely available via the data portal at **https://www.seaaroundus.org**, as an expression of an open data policy.

Thus, the *Sea Around Us* initiative, now well established, will continue to exploit its global niche (i.e., concentrating on global fisheries issues) and add further worldwide data sets to its website. It is hoped that this resource, driven by research staff at the University of British Columbia and the University of Western Australia and supported by the database and technical staff at Quantitative Aquatics in the Philippines, will serve the global community, environmental and conservation nongovernmental organizations, and governmental/intergovernmental organizations and agencies as a reliable and well-documented data and information source for years to come.

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Errata

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