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Counting fish: a typology for fisheries catch data

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Good decisions ideally require good data. Here, we present a straightforward typology for the broad classification of fisheries catch data. At each stage in the reporting chain, from fisher to national/international agencies, fisheries catches can be: known and reported; known and underreported; unknown and overreported; or unknown and underreported. Here, we consider largely the data reporting at the national/international level. Unfortunately, experience has shown that scientists and managers often do not know or are unconcerned with which category their data falls within a country's complete data system, or how to deal with this problem, leading to considerable implications for management. Of these four categories, the underreporting of catches seems the likeliest and most common outcome, which inevitably leads to mismanagement and misallocations of fisheries resources. Attempts to improve catch data should be undertaken, particularly via the development of catch baselines through catch reconstructions and adoption of a transparent and comprehensive country-wide expansion approach. Such an approach not only helps address shifting baselines but identifies aspects of data improvement that can be implemented in future data collection. The taxonomy presented here is a conceptual first-order analytical tool to classify data status, and hence influence management decisions.

Keywords: catch data; catch reconstruction; data reporting; fisheries management; uncertainty

Introduction

Some fisheries catch data serve only as eulogies for once thriving enterprises (e.g. the North Atlantic cod fisheries). Conversely, some data-poor fisheries may be well managed (Johannes 1998). The usefulness of catch data can be debated, but the general assumption is that scientific evidence based on data is a prerequisite for policies to protect resources, and to manage the people using them. In his description of sustainable fisheries, Charles (2001) writes, "It is a truism that good decisions require good information." However, are users of these data fully aware of the completeness (or lack thereof) of the data they rely on for management decisions or policy advice?

Global fisheries reports, data and interpretation are part of the mandate of the Food and Agriculture Organization of the United Nations (FAO), whose constitution requires the collection, analysis, interpretation, and dissemination of information related to nutrition, food, and agriculture (Ward 2004). The FAO

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(1997) definition of "Fisheries Management" includes "the integrated process of information gathering". The United Nations Convention on the Law of the Sea (UNCLOS) in 1982 provided an international framework for highly migratory fish stocks and is even more explicit about the data collecting principles countries should follow.

Since 1950, FAO has compiled, from every country, reported fisheries landings and related data broken down into weight by taxa as well as spatially, by 18 large statistical areas.[1] This database, known as FishStat (see http://www.fishstat.org), provides the only global time series for national fisheries landings.

These FAO catch data have served as the primary source for many global and regional studies evaluating and interpreting global fisheries trends (e.g. Garcia and de Leiva Morena 2003), demonstrating "fishing down the marine food web" (Pauly et al. 1998), estimating the fuel usage of the global fishing fleet (Tyedmers et al. 2005), inferring the potential collapse of fisheries worldwide (Worm et al. 2006), or assessing potential management options (Costello et al. 2008). Policy-makers, and organizations that set out to inform them (e.g. the World Resources Institute), often use FAO catch data to determine national earnings from fish exports, production trends, and per capita fish consumption.

FAO catch data are also used in conservation policies. An example is the Marine Trophic Index, partly based on global fisheries data and quantifying changes in marine food webs, which is one of eight measures of biodiversity to be used by countries party to the Convention on Biological Diversity (Pauly and Watson 2005). Significantly, while many national fisheries agencies tasked with assessing and managing national fisheries argue that FAO data for their country are unreliable and/or not fully accurate, they generally overlook the simple fact that these FAO data are in reality their country's data, as reported by their agency and their government. Thus, national fisheries policy and management are essentially based on these data.[2]

At the same time, recent studies have called into question how closely FAO fisheries data correspond to reality (Watson and Pauly 2001; Clarke et al. 2006; Zeller et al. 2007). In general, the deficiencies associated with FAO catch data are the responsibility of FAO's member countries, where science priorities, human and financial resources and the political agenda affect data quality. Also, because FAO requires countries to report fisheries "landings" rather than "catches", many fish that are caught but not landed (e.g. discarded fish) are excluded from the datasets.

Here, we present a clear and straight-forward typology for fisheries data with examples in each category. We anticipate this can assist not only to illustrate and raise awareness about some issues of data quality so as to address and overcome them, but also provide a simple, first-order "data-test" all fisheries scientists undertaking assessments and providing policy advice should undertake to clearly comprehend the scale of limitations of their data. Hence, such a "data-test" provides guidance for the level of additional precautionary management actions that need to be considered under the specific data limitations encountered in each case.

A typology of fisheries data

The general classification framework for fisheries data presented here conceptually combines the possibilities of the "knowing" and "reporting" of fisheries catches. We recognize that both "knowledge" and "reporting" of a country's catch can occur in degrees, so it is best to consider each of these fields as a continuum. At the national and international level, we recognize countries can never report *all* of their catch. Given these caveats, fisheries catch data are best considered in four broad categories (Table 1), each of which applies at every link in the supply chain of data collection, from the original fisher to the collection/reporting agencies (e.g. local, national, and international). Here, however, we focus primarily at the country level, with direct implications for international institutions such as FAO.

Catch known and reported

This is the ideal classification toward which national collectors and reporters of fisheries data should strive. In this scenario, reported catch reflects as accurately as possible the actual catch being taken. At the national and international level, we suspect this is an empty data set; each time we investigate at those levels, assumed reporting accuracy evanesces. For example, the USA is often thought to have good catch statistics. However, upon close inspection, the statistics of the National Marine Fisheries Service do not include discarded bycatch (Harrington et al. 2005), recreational fish catches (Coleman et al. 2004), illegal catch (J. Sutinen, personal communication, 2006), nor fish caught within the 3-mile coastal limit of some state waters (e.g. Arctic Alaska; Booth and Zeller 2008), which means that the reported national catches are lower than actual catch. A country that likely comes closest to meeting the criteria for this category is Cuba (Baisre et al. 2003).

Within a country's fisheries system, the best examples of knowing catch and reporting it are fisheries with high levels of observer coverage. The groundfish trawl fishery in British Columbia, Canada, for instance, has had 100% observer coverage since 1996 (Branch et al. 2006). Often, actual catch for such fisheries is reported spatially in great detail at the regional level (i.e. for assessments of specific stocks and management), but not publicly available because the spatial data are deemed commercially sensitive. Often, however, such well-reported sectors form only a small part of a country's total reported data. Hence, the overall problem persists.

Catch known and underreported

This is likely one of the more common categories for fisheries statistics. In this case, actual catch is greater than reported catch. At the level of fishers, the case of underreporting known catches (or not reporting them altogether) can be an intentional form of cheating and often takes place due to illegal activity at the fisher level (including the wasteful practice of "high-grading"). From shrimp and finfish trawl fisheries in the Eritrean EEZ (Tesfamichael and Pitcher 2007) to sturgeon poachers in Oregon (Cohen 1997), underreporting by fishers who know their catch is very common worldwide (Pitcher et al. 2002). Globally, Illegal, Unreported and Unregulated (IUU) catches were estimated as at least 11 million tonnes in 2007 (roughly 15% of total reported catch), valued between US$10 and $23 billion (Agnew et al. 2009).

At the country level data recording, and hence reporting, are stymied by disincentives for fishers to report catch – i.e. the opportunity costs associated with taking time to complete forms, fear of punishment, political support, and material gain (Herrera and Kapur 2007), though this has not always been the case (Rosenberg et al. 2005). Knowing the catch and not reporting it also occurs inadvertently at the

Table 1. Typology of reporting systems for fisheries data.

Catch is …	Reported vs. actual catch	Characteristics	Indicators	Examples	Sources
Known and reported	Reported = actual (perfect accuracy)	Strong fisheries management structures; adequate resources for monitoring; often developed world	Observer coverage common; high resolution to species level in dataset	Alaska salmon, Canadian West-coast groundfish and sablefish fisheries	Branch et al. (2006)
Known and underreported	Reported < actual (intentional underreporting)	Fisheries often operating illegally – quota busting, defying EEZ boundaries or laws; Sectors perceived to be of minor influence and/or without management or reporting mandates	Export data exceed catch data for certain taxa	discards, shark finning, high grading, renaming and mislabeling, recreational fisheries	Coleman et al. (2004), Jacquet and Zeller (2007b), Jacquet et al. (2008)
Unknown and overreported	Reported > actual (intentional overreporting)	Centralized government with a policy of economic growth; Lacking independent statistical reporting agencies	Increase in fisheries catches suspiciously consistent; Biological models do not support reported amount of fisheries resources being captured	China	Watson and Pauly (2001)
Unknown and underreported	Reported < actual (unintentional underreporting)	Poor resources for data collection (e.g. developing countries); Sectors not mandated for reporting (e.g. developed world)	Only export commodities (e.g. shrimp, tuna) are reported; Per capita fish estimates based on reported data are much lower than those collected from independent sources or reported in other countries regionally	Small-scale, subsistence, recreational fisheries	Jacquet and Zeller (2007a), Zeller et al. (2008), Wielgus et al. (2009)

country level. The island of Zanzibar, Tanzania, for instance, reports its fisheries catch through a fisheries institution independent from the mainland Tanzanian fisheries institution. The catch is known, but Zanzibar's catch is not incorporated into the official Tanzania statistics and hence is not reported to FAO on behalf of Tanzania. This oversight is significant, as Zanzibar fishers account for one-quarter of the country's catch (Jacquet and Zeller 2007b). Thus, reliance on the officially reported data for major policy decisions, such as access agreements and quotas for EU fleets to Tanzanian waters, may be substantially misleading. The consequence of present-day underreporting catches is to subvert stock assessments, management and policy, contributing to overoptimistic catch quotas, and undermine the sustainability of fisheries. Yet, despite knowledge and estimates of such underreporting being available to many countries, most continue to ignore these data in their reporting efforts (see e.g. Zeller et al. 2010).

The non-reporting of discards is particularly problematic. Fundamentally, most countries ignore discards entirely in their reporting activities. This seems mainly driven by the historic perspective on "landings" rather than "catches", based on a narrowly defined market economics focus. At a time when the world is focusing on ecosystem-based management (Pikitch et al. 2004), such a narrow perspective, and the associated disregarding of discarded catches, is no longer viable or acceptable. For many fisheries, good estimates of discards are available and need to be expanded gear-wide and country-wide, such as the study that estimated that nearly one-quarter of all fish caught by US fisheries are discarded (Harrington et al. 2005). In other cases, it is necessary to rely on expert knowledge to complement literature for estimates of discards. This was the case for total catch estimation in Mozambique, which had to rely on grey literature and personal communication for an estimate of shrimp fisheries discards, which accounted for nearly two times the landed amount of targeted shrimp (Jacquet and Zeller 2007a).

Misreporting, when fishers know what they catch but report it as some other species, is also common (Jacquet and Pauly 2008). When English fishers exceed their cod quota, they simply mislabel their cod as "ling" (Clover 2006). Around 40% of randomly tested shark fillets labeled as "lemon sharks" in New Zealand were discovered to be hammerhead and bronze whaler sharks, which are illegal to target (Smith and Benson 2001).

Catch unknown and overreported

In this peculiar case, reported catch exceeds actual catch. This type of intentional misreporting usually stems from a strong centralized government with a state directive for a planned growth in fisheries. Watson and Pauly (2001) described an instance of this statistical malpractice when their predictive fisheries models could not explain reported catch trends for China. China's high reported catches (and the regular, annual increases in reported catches) were in accordance with the central government's fisheries growth policies but not with what their large Exclusive Economic Zone was capable of biologically producing. Hence, China overreported fisheries catches each year since the mid-1980s. Given the substantial contribution China's catches made to total global catches, the required correction changed the global trend of fisheries catches dramatically (Watson and Pauly 2001). As a consequence, FAO now presents global fisheries with China separate from the rest of the world.

Catch unknown and underreported

Similar to the case of knowing the catch, but not reporting it, this scenario also results in actual catches being larger than those reported. Often, not reporting is not intentional but instead an oversight due to lack of resources, cultural biases, or perceived management and hence reporting mandate. However, the fact that catches are underreported is known. This scenario is the one most commonly applicable to the small-scale sector, including artisanal and subsistence fishing (Cheunpagdee et al. 2006; Pauly 2006; Wielgus et al. 2009) and recreational fishing (Zeller et al. 2008).

Chuenpagdee

In general, data collection for the subsistence or small-scale fishing sector seems to suffer the ''streetlight parable'': the search for lost keys focuses under the streetlight where one can see best but not necessarily where the keys can be found. Although collecting data from industrial fisheries and a few small-scale ports or markets may be easier, it may be unrepresentative of total catches. Such ''streetlight'' sampling of catches is often all that a country can afford in terms of resources, and these efforts should be applauded, encouraged and fostered. However, this logic regularly breaks down once these sampled data are not expanded into country-wide estimates for reporting. This situation is sadly most common. In Ecuador, for example, national fisheries data are only gathered from eight small-scale fishing ports, representing only 38% of the nation's fishers (Jacquet et al. 2008). Similarly, in Mozambique, only 115 of the 658 small-scale ports are monitored and reported. Thus, reported catches for the Mozambican small-scale sector reflect the landings of only 62% of canoe fishers (Jacquet and Zeller 2007a). In both cases, fisheries catches are not extrapolated to the country as a whole and we suspect this oversight occurs in many countries around the world.

Discussion

The typology of fisheries catch data presented here can be used when considering issues of data quality and possible gaps in information. By categorizing and simplifying what is often considered a complex data problem, we can ensure scientists and managers dealing with or relying on reported data can evaluate their country's fisheries typology. Simply undertaking such a straight-forward first-order conceptual analytical evaluation should clarify problems, as well as suggest solutions. There are several indicators that suggest to which category data belong (Table 1). For instance, if a dataset describes a fishery with high levels of observer coverage or high resolution to the species level, it is likely the data reflect a fishery where the catch is known and reported. On the other hand, if only export commodities (e.g. shrimp, tuna) are reported in a national dataset, or per capita fish estimates based on reported data are much lower than those collected from independent sources (e.g. household surveys), there is probably a good portion of a country's catch that is unknown and underreported.

Several options exist for improving the problem of reporting and understanding fisheries catches. All scientists, managers and policy advisors should endeavor to assess and understand these options. First, scientists and fisheries managers must accept that an estimation of actual catch (even a crude one) is preferable to the alternative (and less true) option of reporting zero fish caught in cases where hard time-series data do not exist (e.g. discards or subsistence catches). Essentially, a careful country-wide non-zero estimate, although not necessarily with high statistical precision, has clearly a higher statistical accuracy than a precise, but inaccurate reported catch of zero in catch statistics (i.e. no data being interpreted as zero catch). The need for improvement in this realm is particularly evident in the non-industrial, non-commercial fishing sector, where increased efforts should be made to establish comprehensive, even if non-annual sampling, estimation and expansion schemes (Zeller et al. 2007). At the national level, frame surveys, which count the number of fishers and per fisher catch rates, and are designed to complement port sampling, should be used to obtain countrywide estimates of fisheries catches. International and regional organizations (e.g. FAO, SPC) should facilitate, train, and coordinate efforts to re-estimate total catch using sampling, expansion, and interpolation methods. Overall, the onus is on countries, as well as international agencies (such as FAO) to change the data mandate from "landings" to "catches". While landings had (and still have) an important role to play in economic analyses, the increasing focus on ecosystem-based management (Pikitch et al. 2004) make the focus on landings subservient to total catches. Hence, it is clear that fisheries statistics need to change their focus and content.

Researchers must also recognize the need to synthesize historical documents and incorporate anecdotes and case studies into their work. Many existing documents tend to reiterate the commonly held assumption, based on biased databases, that many small-scale fisheries catches are small. Studies affirm that the incorporation of historical anecdotes and reconstruction of catches can provide better baselines and compelling results, both ecological (e.g. Jackson et al. 2001; Zeller et al. 2007) and economical (Zeller et al. 2006; Jacquet et al. 2008; Wielgus et al. 2009).

For fisheries in developed countries, comprehensive onboard monitoring systems (e.g. Zeller et al. 2010) need to be implemented. However, care has to be taken that all catches (including non-target and discarded catches) are recorded and reported. Historically, many observer programs fall short on this requirement. Similarly, the international community should initiate efforts (via FAO) to get countries to collect and report more holistically on fisheries discards. Again, country-wide expansions based on subsets of sampled data should be used in cases of resource limitations. To further improve accounting, the international community must establish a better system of monitoring on the high seas (Agnew et al. 2009). The global network of Regional Fisheries Management Organizations, while so far largely ineffective at management (Cullis-Suzuki and Pauly Forthcoming), is theoretically perfectly suited to monitor high seas catches.

The issue of fisheries data reporting is not trivial and the concern is not only for the resource. The chronic underreporting of the small-scale fishing sector leads to inequitable policy decisions that favor industrial fisheries (that often compete for the same resources), underestimate the economic contribution of small-scale fishing (Zeller et al. 2006; Wielgus et al. 2009), and jeopardize food security (Jacquet and Zeller 2007a). Furthermore, the corrections to inflated Chinese catch data suggested that world fish catches are not increasing but, in fact, declining (Watson and Pauly 2001).

Similarly, improvements in data collection and/or reporting over recent decades may distort historic data trends, especially if retroactive data corrections are not implemented. The FAO catch data are not static and can change each year as FAO tries to improve reporting, or receives modified member country data. But one must be careful at how to interpret improvements. In Mozambique, new systems of reporting implemented in 2003 indicated catches in the small-scale fishing sector were more than double those previously reported (Jacquet and Zeller 2007a). However, this does not mean that fishers are twice as well off or that there was an increase in small-scale effort. Rather, it simply showed a change in data collection methods. Significantly, and unfortunately, the knowledge and understanding gained from the improved data collection was not retroactively applied to historic data to illustrate the previously hidden total catches (Jacquet and Zeller 2007a).

Overall, the most important change that needs to be implemented in light of the move towards ecosystem-based management (Pikitch et al. 2004) is the realization that national and international statistics can no longer only reflect market economics (i.e. landings used by markets), but need to reflect actual extractions from the marine ecosystems. This requires a fundamental shift in focus of data collection and reporting from market-oriented landings to ecosystem-focused total catches. Using the typology proposed here as a conceptual analytical framework will assists responsible institutions in fulfilling their ecosystem-based mandate with respect to data reporting.

Conclusion

Astronomers use high-powered telescopes to peer across the universe at light that has traveled through space for billions of years. Such "superb seeing" enables astronomers to look directly at the past. Fisheries scientists and managers do not have this astronomical good fortune. Instead, fisheries scientists perceive the past through their own personal experience, the anecdotes of others (written or oral), or, most often, through quantitative national or international catch data sets. Unfortunately, as we have illustrated, these historic data sets have various problems of incompleteness.

The typology presented here can serve as a conceptual analytical framework to encourage and assist institutions and individuals with data collection and reporting responsibilities. This framework allows identifying, assessing and evaluating the procedures for improving historic and future data reporting in line with the needs of ecosystem-based management.

Although it is theoretically possible to get people to reveal their private information (Myerson 1979), perfect information (i.e. certainty) is frequently missing from statistics, including fisheries data sets. But we should not allow uncertainty to cloud good decision-making, and fisheries managers must focus on the trends of the data rather than focusing on the unknown (Rosenberg 2007). When it comes to managing fish, as well as compiling fisheries catch data, it is better to be vaguely right than precisely wrong.

Notes

1. For some of the 18 statistical areas and time periods, data are also available by smaller sub-areas.
2. We recognize that some taxonomic and spatial resolution is lost in transfer from national use to international reporting. We further acknowledge that national management decisions are also informed by other data and information besides reported catch data.

References

Agnew DJ, Pearce J, Pramod G, Peatman T, Watson R, Beddington J, Pitcher T. 2009. Estimating the Worldwide Extent of Illegal Fishing. PLoS ONE 4(2): e4570. doi:10.1371/journal.pone.0004570.

Baisre JA, Booth S, Zeller D. 2003. Cuban fisheries catches within FAO area 31 (Western Central Atlantic): 1950–1999. In: Zeller D, Booth S, Mohammed E, Pauly D, editors. From Mexico to Brazil: Central Atlantic fisheries catch trends and ecosystem models. Fisheries Centre Research Report, Vancouver, BC. 11(6), 133–139.
Booth S, Zeller D. 2008. Marine fisheries catches in arctic Alaska. Fisheries Centre Research Reports 16(9). Vancouver, Canada: Fisheries Centre, University of British Columbia. p. 59.
Branch T, Rutherford K, Hilborn R. 2006. Replacing trip limits with individual transferable quotas: implications for discarding. Mar Pol. 30:281–292.
Charles AT. 2001. Sustainable fishery systems. Oxford: Blackwell Sciences Ltd.
Chuenpagdee → Cheunpagdee R, Liguori L, Palomares M, Pauly D. 2006. Bottom-up, global estimates of small-scale fisheries catches. Fish Centre Res Rep. 14(8):100.
Clarke SC, McAllister MK, Milner-Gulland EJ, Kirkwood GP, Michielsens C, Agnew D, Pikitch EK, Nakano H, Shivji MS. 2006. Global estimates of shark catches using trade records from commercial markets. Ecol Lett. 9:1115–1126.
Clover C. 2006. The end of the line. New York: The New Press.
Cohen A. 1997. Sturgeon poaching and black market caviar: a case study. Env Bio Fish. 48:423–426.
Coleman FC, Figueira WF, Uleland JS, Crowder LB. 2004. The impact of United States recreational fisheries on marine fish populations. Science. 305:1958–1960.
Costello C, Gaines SP, Lynham J. 2008. Can catch shares prevent fisheries collapse? Science. 321:1678–1681.
Cullis-Suzuki S, Pauly D. Forthcoming. Failing the high seas: a global evaluation of regional fisheries management organizations. Mar Pol.
FAO. 1997. Fisheries management. Vol. 4. FAO technical guidelines for responsible fisheries. Rome: FAO.
Garcia SM, de Leiva Moreno I. 2003. Global overview of marine fisheries. In: Sinclair M, Valdimarsson G, editors. Responsible fisheries in the marine ecosystem. Rome: Food and Agriculture Organization of the United Nations and CABI publishing. p. 1–24.
Harrington J, Myers RA, Rosenberg A. 2005. Wasted fishery resources: discarded by-catch in the USA. Fish Fisheries. 6:35–361.
Herrera YM, Kapur D. 2007. Improving data quality: actors, incentives, and capabilities. Pol Anal. 15:365–386.
Jackson J, Kirby M, Berger W, Bjorndal K, Botsford L, Bourque B, Bradbury R, Cooke R, Erlandson J, Estes J, et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science. 293:629–638.
Jacquet J, Alava JJ, Ganapathiraju P, Henderson S, Zeller D. 2008. In hot soup: sharks captured in Ecuador's waters. Environ Sci. 5(4):269–283.
Jacquet J, Pauly D. 2008. Trade secrets: renaming and mislabeling of seafood. Mar Pol. 32:309–318.
Jacquet J, Zeller D. 2007a. National conflict and fisheries: reconstructing marine fisheries catches for Mozambique. In: Zeller D, Pauly D, editors. Reconstruction of marine fisheries catches by countries and regions (1950–2005). Fisheries Centre Research Reports 15(2). Fisheries Centre, University of British Columbia, p. 35–47.
Jacquet J, Zeller D. 2007b. Putting the "United" in the United Republic of Tanzania: reconstruction marine fisheries catches for Tanzania. In: Zeller D, Pauly D, editors. Reconstruction of marine fisheries catches by countries and regions (1950–2005). Fisheries Centre Research Reports 15(2). Fisheries Centre, University of British Columbia, p. 49–60.
Johannes RE. 1998. The case for data-less marine resource management: examples from tropical nearshore finfisheries. Trends Ecol Evol. 13:243–246.
Myerson R. 1979. Incentive compatibility and the bargaining problem. Econometrica. 47:61–73.
Pauly D. 2006. Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. Maritime Stud. 4:7–22.
Pauly D, Christiensen V, Dalsgaard J, Froese R, Torres F. 1998. Fishing down the marine food web. Science. 279:860–863.
Pauly D, Watson R. 2005. Background and interpretation of the "Marine Trophic Index" as a measure of biodiversity. Phil Trans Royal Soc:. Biol Sci. 360:415–423.

Pikitch EK, Santora C, Babcock EA, Bakun A, Bonfil R, Conover DO, Dayton P, Doukakis P, Fluharty DL, Heneman B, et al. 2004. Ecosystem-based fishery management. Science. 305:346–347.
Pitcher TJ, Watson R, Forrest R, Valtysson H, Guénette S. 2002. Estimating illegal and unreported catches from marine ecosystems: a basis for change. Fish Fisheries. 3:317–339.
Rosenberg A. 2007. Fishing for certainty. Nature. 449:989.
Rosenberg A, Bolster WJ, Alexander KE, Leavenworth WB, Cooper AB, McKenzie MG. 2005. The history of ocean resources: modeling cod biomass using historical records. Front Ecol Environ. 3:84–90.
Smith PJ, Benson PG. 2001. Biochemical identification of shark fins and fillets from the coastal fisheries in New Zealand. Fish Bull. 99:351–355.
Tesfamichael D, Pitcher T. 2007. Estimating the unreported catch of the Eritrean Red Sea. Afr J Mar Sci. 29:55–63.
Tyedmers P, Watson R, Pauly D. 2005. Fueling global fishing fleets. Ambio. 34:635–638.
Ward M. 2004. Quantifying the world. Bloomington: Indiana University Press.
Watson R, Pauly D. 2001. Systematic distortions in world fisheries catch trends. Nature. 424:534–536.
Wielgus J, Zeller D, Caicedo-Herrera D, Sumaila UR. 2009. Estimation of fisheries removals and primary economic impact of the small-scale and industrial marine fisheries in Colombia. Mar Pol.
Worm B, Barbier EB, Beaumont N, Duffy N. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science. 314:787–790.
Zeller D, Bale S, Booth S, Rossing P, Harper S, Pauly D. 2010. Fisheries catches from the Baltic Sea large marine ecosystem: 1950–2007. In: Rossing P, Booth S, Zeller D, editors. Total marine fisheries extractions by country in the Baltic Sea: 1950-present. Fisheries Centre Research Report 18(1), Vancouver, p. 5–35.
Zeller D, Booth S, Davis G, Pauly D. 2007. Re-estimation of small-scale fisheries catches for U.S. flag island areas in the Western Pacific: the last 50 years. Fish Bull. 105:266–277.
Zeller D, Booth S, Pauly D. 2006. Fisheries contributions to GDP: underestimating small-scale fisheries in the Pacific. Mar Resource Econ. 21:355–374.
Zeller D, Darcy M, Booth S, Lowe MK, Martell SJ. 2008. What about recreational fisheries catch? Potential impact on stock assessment for Hawaii's bottomfish fisheries. Fish Res. 91:88–89.