

ON THE IMPORTANCE OF FISHERIES CATCHES, WITH A RATIONALE FOR THEIR RECONSTRUCTION¹

Daniel Pauly

Sea Around Us, Fisheries Centre, University of British Columbia, Vancouver, BC, Canada

Fishing must generate a catch, whether it is done by West African artisanal fishers supplying a teeming rural market, by the huge trawler fleets in Alaska that supply international seafood markets, by women gleaning on a reef flat in the Philippines to feed their families, or by an Australian angler bragging about it in a bar. Indeed, a fishery is defined by the amount and kind of fish caught and by their monetary value. This is how we judge a fishery's importance, compared with other fisheries and other sectors of the economy. It seems clear that the health of a fishery should be measured by changes in the magnitude and species composition of catches, along with other information, such as the growth and mortality of the fish that are exploited. Yet a debate has been recently raging about whether to use catch data to infer the status of fisheries, causing great confusion among fisheries scientists and managers. If the muddle continues, it could undermine the credibility of fisheries science.

The key role of catch data is the reason why the Food and Agriculture Organization (FAO) first began compiling fishery statistics soon after the agency was founded in 1945. A part of the United Nations' attempt to "quantify the world" (Ward 2004), these compendia

turned, in 1950, into the much-appreciated *FAO Yearbook of Fisheries Catch and Landings*. The findings are based on annual data submissions by FAO member countries, vetted and harmonized by its staff. In contrast with the many international databases used to track major food crops (e.g., rice, wheat, maize), the *Yearbook* has been, to this day, the only global database of wild-caught fish and other marine species. As such, the *Yearbook* is widely cited as the major source for inferences on the status of fisheries in the world (Garibaldi 2012).

However, in many countries, particularly in the developing world, the government's role in monitoring their fisheries seems to end with the annual ritual of filling in catch report forms and sending them to FAO, as parodied in Marriott (1984). For others, mainly developed countries, collecting catch data from fishing ports and markets is only a start, and the bulk of their fishery-related research is in the form of "stock assessments." This term refers to a series of analytic procedures using a variety of data, often time series of commercial catch (figure 1.1), complemented by information on the age, size, or structure of the fish in that catch, tag and recapture data, stock abundances deduced through mathematical models or by fishery research vessels, and so on. The purpose is to infer the biomass of the populations or stocks that are being exploited and to propose levels of total allowable catch (TAC, or quota).

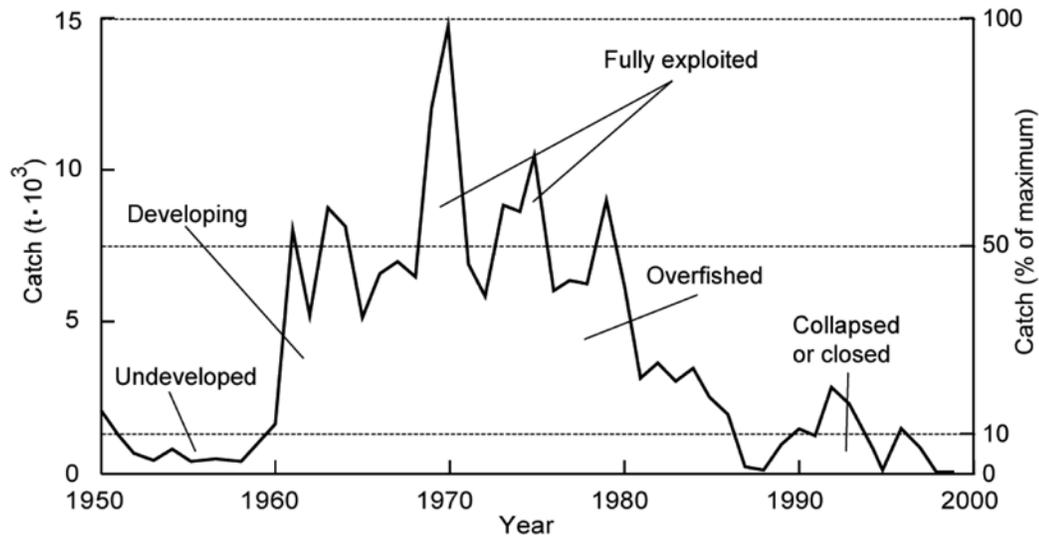


Figure 1.1. A typical catch time series, as can be used in conjunction with the method of Martell and Froese (2013) to perform a basic assessment of the fishery that generated that catch. The scale to the right defines the categories (“undeveloped,” “developing,” “fully exploited,” etc.) used to describe the status of the underlying fisheries.

However, traditional stock assessments are extremely expensive, ranging from roughly US\$50,000 per stock (assuming 6 months for experts to analyze existing data) to millions of dollars when fisheries-independent data are required (Pauly 2013). Along with a worldwide scarcity of expertise, this is why 20% at most of the more than 200 current maritime countries and associated island territories perform regular stock assessments. Moreover, these assessments deal only with the most abundant or most valuable species exploited. For some countries or territories, this may be one species, a dozen, or about two hundred, as in the United States. In all cases, this is only a small fraction of the number of species that are exploited, if only as unintended bycatch, which is often discarded.

Therefore, FAO always encouraged the development of methods that would allow scientists to infer the state of fisheries without stock assessments, or with limited ones (see Gulland 1969, 1971, 1983). This practice was driven by FAO’s mission to inform policy makers about the state of fisheries in all countries of the world, including those without access to stock assessment expertise and the costly research vessels needed to collect fisheries-independent data.

To this end, FAO developed what are now called stock-status plots (SSPs; figure 1.2), which showed the status of the various fish stocks over time (Grainger and Garcia 1996). The status of each fishery was inferred from the shape of its catch time series. Essentially, increasing or stable catches meant fisheries were okay, and declining catches meant fisheries were in trouble. These SSPs or equivalent graphs were interpreted vertically, by comparing the percentage of stocks in a given state (e.g., “developing,” “developed,” “fully exploited,” “overfished”) in different years. The information was reported in press releases and in issues of the *State of the World Fisheries and Aquaculture* (SOFIA), a biannual narrative interpretation of the FAO fishery statistics. In successive SOFIAs (including the last available; see figure 13 in FAO 2014, p. 37), FAO notes that these percentages tend to get worse but does not analyze the SSPs further. However, much of what people throughout the world think they know about global fisheries originates from SSPs and similar approaches.

SSPs were also adopted and modified by researchers outside FAO, first by Rainer Froese of the GEOMAR Institute in Kiel, Germany (Froese and Kesner-Reyes 2002) and later by the group of which I am principal investigator, the *Sea Around Us*, whose work is featured in this

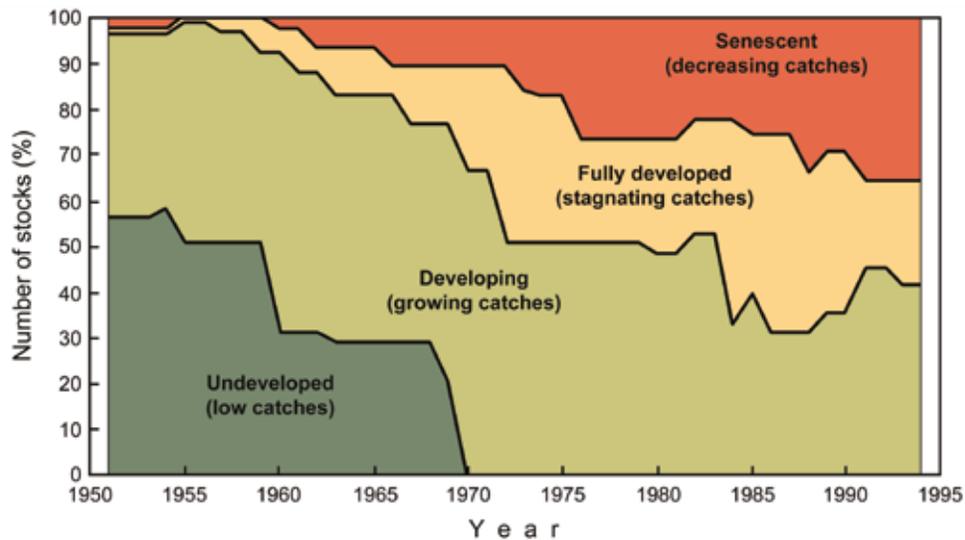


Figure 1.2. Interpretation of multiple catch time series (as in figure 1.1), pioneered by Grainger and Garcia (1996) and based on about 400 important stocks monitored by FAO. Such graphs, now called stock-status plots, are conventionally interpreted vertically, that is, by reading, for a given year, the percentage of stocks in the different categories. This is where the annually changing percentage of “overfished” or “collapsed” stocks that are communicated to the public originate. Note that these percentages are very sensitive to the details of definitions used for the different status categories. (Modified from Grainger and Garcia 1996.)

volume. Jointly, we demonstrated that an increased number of the stocks had “collapsed,” meaning that catches were less than 10% of their historic maximum. Moreover, the transition from one state (e.g., “fully exploited”) to another (e.g., “overexploited”) was occurring at a faster rate than previously thought. These were dramatic findings, yet they generated little press and even less action.

The world finally started paying attention to the SSP findings in 2006, when Boris Worm and his colleagues published “Impacts of Biodiversity Loss on Ocean Ecosystem Services” in *Science* magazine (Worm et al. 2006). For the first time, the authors used these trends to project a date by which all stocks would “collapse”: 2048.² The expert press release that accompanied the article (see Baron 2010) focused on this newsy aspect of what was a broad study, triggering an enormous amount of press coverage on all continents. The headlines were uniformly alarmist: “Fisheries collapse by 2048” (*The Economist*), “Seafood may be gone by 2048” (*National Geographic*), and “The end of fish, in one chart” (*The Washington Post*), among many more.

A strong pushback emerged, including wide and understandable criticism of the

precise date, 2048, which mingled Mayan (2012) and Orwellian (1984) undertones. Stock assessment experts mocked the *projection*, which was mistaken for a *prediction*, with many arguing that scientists shouldn’t extrapolate beyond the data. Yet good science always implies some inference beyond one’s data; otherwise, it would consist only of *descriptions*. Moreover, most critiques overlooked the fact that “collapsed” stocks can continue to be fished. Indeed, this is what already occurs in vast areas of the ocean. Two notorious examples are the Swedish west coast, where a long-collapsed Atlantic cod stock continues to be exploited (Sterner and Svedäng 2005), and the Gulf of Thailand, where the demersal fish biomass was reduced in the 1990s to less than 10% of its value in the early 1960s, when trawling began, yet also continues to be exploited (Pauly and Chuenpagdee 2003). This is 2048—now.

Still, the criticism was so strong that several co-authors of the study opted not to defend it publicly. Consequently, fisheries scientists such as me, who are concerned with the state of global fisheries, had to either duck or defend the spirit of the 2048 projection, even if we did not agree with all its particularities.

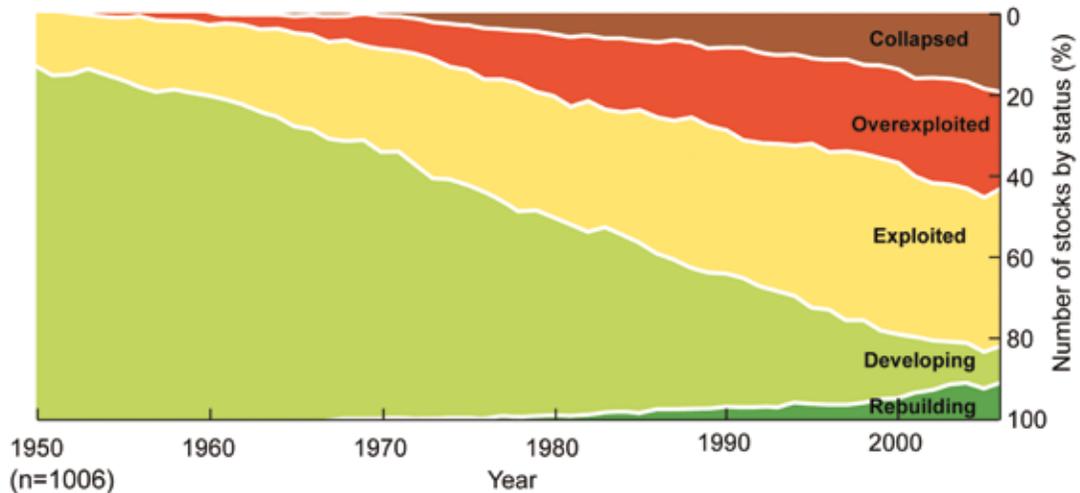


Figure 1.3. Stock-status plots (SSPs) based on more than 1,000 stocks worldwide, whose “developing” category combines the “undeveloped” and “developing” categories of figure 1.2 and which include a new category (“rebuilding”), which will hopefully increase with time (Kleisner et al. 2013). The 2048 projection mentioned in the text was derived by reading an SSP semihorizontally, that is, by extrapolation forward (and downward) from the line separating “overexploited” from “collapsed” stocks. Note the similarity of the trends suggested by this and figure 1.2, whose “senescent” or equivalent categories (“overexploited” and “collapsed”) are clearly increasing. (Modified from Kleisner et al. 2013.)

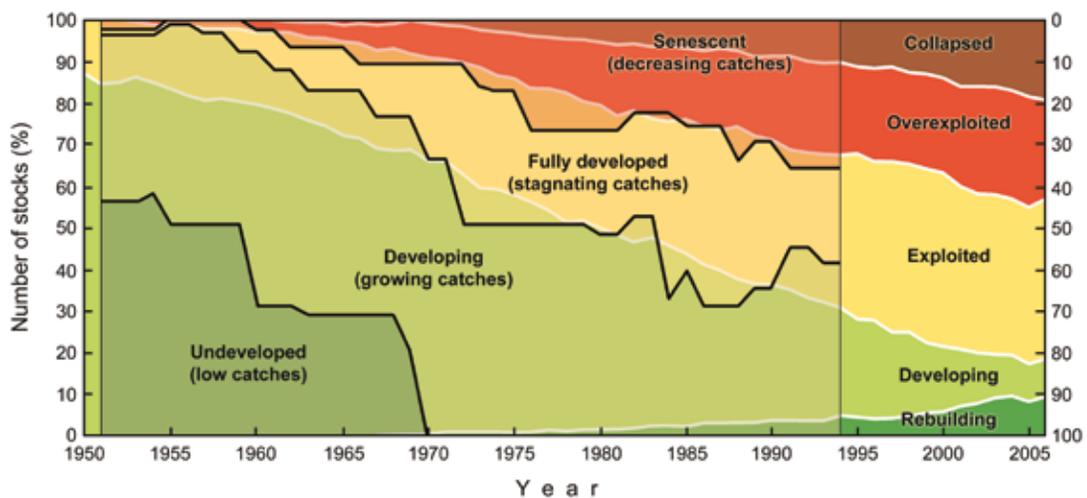


Figure 1.4. Superposing figures 1.2 and 1.3 shows that the trends suggested by these graphs are very robust, that is, they are not very sensitive to the details of the definitions of the categories (e.g., using 10% of the maximum historic catch for defining “collapsed” stocks). Also note that if Grainger and Garcia (1996) had used their graph (figure 1.2) for a 10-year prediction, it would be confirmed by this superposition. (Modified from Kleisner et al. 2013.)

To its credit, the projection was based on catch time series from virtually the entire world. The overwhelming majority showed that peak catches occurred several decades ago, with current catches increasingly derived from “overexploited” and “collapsed” stocks (figures 1.2 and 1.3). Although there is no way to *predict* where anything will be in 2048 or even 10 years from now, it would certainly be better if we could reverse current trends. So far we have not done so, even

though some stocks are rebuilding (figures 1.3 and 1.4).

Before this defense could be mounted, the detractors began focusing on another criticism of the 2048 projection, claiming that catch data do not contain any information about stock status. In interviews, keynote lectures, and other outlets, they argued that full-fledged stock assessments are essential to understanding fisheries; without them, we are essentially left in the dark.

This is a case of allowing the perfect to become the enemy of the good. Even without perfect data, we can infer when fisheries are in serious trouble and make efforts to conserve them. After all, maintaining catches is the *raison d'être* of fisheries science. One can and should infer, at least tentatively, the status of fisheries from the catch data—if this is all we have (see figure 1.1; Froese et al. 2012, 2013; Kleisner et al. 2013). It is a mistake to assume that we must remain in Muggle-like ignorance unless we have access to the magic of stock assessments.

Accepting this doctrine would put us at the mercy of stock assessment models that can be fatally flawed. For example, the models used to study the Canadian northern cod fishery in the 1990s (Walters and Maguire 1996) were considered the best in the world. In fact, experts thought the models were so good that it was not necessary to consider the catch data from the coastal trap fisheries, which could not, like the trawlers, follow the cod to where they retreated as their numbers declined. Thus, the stock assessment experts were as surprised as the general public when the fishery had to be closed. The trawlers had decimated the stock under their noses, which they could have seen if they had analyzed the coastal trap data. Note that it is not even faulty stock assessments that are at issue here; it is the notion that one type of approach is so good that it makes all other approaches superfluous.

More importantly, this doctrine would discourage efforts to improve the quality of fisheries statistics worldwide, which is bemoaned by FAO in successive issues of SOFIA. It would also thwart attempts to manage, to the extent possible, the fisheries of developing countries. If leading fisheries scientists claim that catch data are useless, why would resource-starved governments invest in reforming and improving their statistical systems?

This flawed thinking would affect not only developing countries but also the community of stock assessment experts themselves. Without the collection of catch data, experts could end up either with beautiful stock assessment

models applied to lousy data, as in the northern cod example above, or needing more of the costly fishery-independent data that can be used to correct for misreported commercial catch data (Beare et al. 2005).

We gain nothing from the notion that only a select group has the key to understanding fisheries, especially if that key cannot open any doors outside a small number of developed countries. Such claims undermine the credibility of the many fisheries scientists throughout the world who attempt to extract actionable insights from sparse data and to advise their governments on how to manage their fisheries even if they cannot afford formal stock assessments.

Fortunately, there is a solution: We all agree that many stocks need to be rebuilt and that doing so would lead to sustainable increases of catches and economic benefits (Sumaila et al. 2012). In fact, the more depleted the stocks currently are, the more is to be gained by rebuilding them.

Moreover, our systematic reevaluation of the FAO statistics suggests that developed countries tend to underreport their catches by about 30%–50% (Zeller et al. 2011), and many developing countries underreport by 100%–500% (Cisneros-Montemayor et al. 2013; Pauly and Zeller 2014; Zeller et al. 2007, 2015). (One notable exception is China, which overreports its catches because officials are rewarded for high yields.) This new perspective suggests that fisheries play a far more important role in the rural economy of developing countries than previously assumed and that rebuilding depleted fish populations on a grand scale would have greater benefits than so far imagined (other implications are presented in chapter 14).

Consequently, more attention should be given to the reliable collection of catch data throughout the world. In particular, we need to devise cost-effective systems to acquire accurate fisheries catch data, along with ancillary data on fishing effort, and its economic equivalent, catch value and fishing cost.

These ideas have been apparent to me since my first field experience in Ghana in

1971 and in Indonesia in 1974 and 1976. They were reinforced in 1979 when J. A. Gulland, a world-renowned scientist and senior staff member at FAO, commented that fisheries experts should emphasize three things: “the catch, the catch and the catch.” Yet often catch data seem to be entirely missing from certain areas of countries or territories, particularly for informal, small-scale fisheries. In such cases, catch statistics can be reconstructed from other data.

The text below, slightly modified from an article I wrote in 1998, provides the rationale for such reconstructions.³ It was inspired by discussions that took place at a conference held by the FishBase Project⁴ in Trinidad in May and June 1998.

THE CATCH IN USING CATCH STATISTICS

It is widely recognized that catch statistics are crucial to fisheries management. However, the catch statistics routinely collected and published in most countries are deficient in numerous ways. This is particularly true of the national data summary sent annually by the statistical offices of various Caribbean and Pacific countries to the FAO for inclusion in their global statistics database (see Marriott 1984).

A common response to this situation has been to set up intensive but short-term projects devoted to improving national data reporting systems. Their key products are detailed statistics covering the (few) years of the project. However, without statistics from previous periods, these data are hard to interpret. This is a major drawback, because it is the changes in a dataset that demonstrate important trends.

Therefore, reconstructing past catches and catch compositions is a fundamental task for fisheries scientists and officers. In fact, it is necessary to fully interpret the data collected from current projects. For example, suppose that the fisheries department of Country A establishes, after a large and costly sampling project, that its reef fishery generated catches of 5 and 4 t/km²/year for the years 1995 and 1996, respectively. The question now is, are these catch

figures low values relative to the potential of the resource, thus allowing an intensification of the fishery, or high unsustainable values, indicative of an excessive level of effort?

Clearly, one approach would be to compare these figures with those of adjacent Countries B and C. However, these countries may lack precise statistics or have fisheries that use different gears. Furthermore, Country A’s minister in charge of fisheries may be hesitant to accept conclusions based on comparative studies and may require local evidence before making important decisions affecting her country’s fisheries. One approach to deal with this very legitimate requirement is to reconstruct and analyze time series, covering the years preceding the recent period for which detailed data are available and going as far back in time as possible (e.g., to the year 1950, when the aforementioned annual FAO statistics begin). Such data make it possible to quickly evaluate the status of fisheries and their supporting resources and to evaluate whether further increases in effort will be counterproductive (box 1.1).

BASIC METHODOLOGY FOR CATCH AND EFFORT RECONSTRUCTION

The key part of the methodology proposed here is psychological: One must overcome the notion that “no information is available,” which is the wrong default setting when dealing with an industry such as fisheries. Rather, one must realize that fisheries are social activities, bound to throw large shadows onto the societies in which they are conducted. Therefore, records usually exist that document some aspects of these fisheries. All that is needed is to find them and to judiciously interpret the data they contain. Important sources for such undertaking are

- 1 Old files of the Department of Fisheries
- 2 Peer-reviewed journal articles
- 3 Theses and scientific and travel reports, accessible in departmental or local libraries or branches of the University of the West Indies or the University of the South Pacific, or through regional databases

BOX 1.1. QUICK INTERPRETATION OF CATCH AND EFFORT DATA

Daniel Pauly, *Sea Around Us*, University of British Columbia, Vancouver, Canada

There is a huge literature dealing with the fitting of surplus production models to time series of catch and effort data. Strangely enough, one rarely finds quick assessments based on the key properties of these models. A simple method for such assessments is presented here.

Two key predictions of the parabolic Schaefer model (Schaefer 1957; Ricker 1975) are that catch/effort (U) declines linearly with effort (f) and that a stock is biologically overfished if U , in the fishery exploiting that stock, has dropped to less than 50% of its level at the onset of the fishery.

Thus, with two estimates of U , a higher one pertaining to an early state of the fishery (U_{then}) and a lower one pertaining to a later state or to the present state (U_{now}), and the corresponding levels of effort (f_{then} and f_{now}), one can assess the present status of a fishery by first calculating

$$b = (U_{\text{then}} - U_{\text{now}})/(f_{\text{now}} - f_{\text{then}}), \text{ and } a = U_{\text{then}} + (bf_{\text{then}}).$$

Then, using a and b , one can calculate Maximum Sustainable Yield (MSY) and its associated level of effort (f_{MSY}) from $f_{\text{MSY}} = a/(2b)$, and $\text{MSY} = (af_{\text{MSY}}) - (bf_{\text{MSY}} \cdot f_{\text{MSY}})$.

In the Philippines, in about 1900, in the absence of industrial gear, 119,000 fishers reportedly caught 500,000 t/year (Anonymous 1905, p. 564), or 4.2 t per fisher per year. In 1977, 501,000 small-scale fishers reportedly caught 713,000 t (Smith et al. 1980), or 1.42 t per fisher per year. Inserted in the above equation, these numbers lead to $b = 0.0000073$, $a = 5.069$, $\text{MSY} = 880,000$ t/year and $f_{\text{MSY}} = 347,000$ fishers.

The theory and applications of surplus production models have often been the subject of fierce debates, notably on how sustainable MSY really is. However, it is generally agreed that a reduction by 50% or more of initial catch/effort indicates overfishing in just about any stock, at least in economic terms. Therefore, the quick diagnostics suggested above should always be useful as a first approach.

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- 4 Records from harbormasters and other maritime authorities with information on numbers of fishing craft (small boats by type, large boats by length class or engine power)
- 5 Records from the cooperative or private sectors (e.g., companies exporting fisheries products, processing plants, importers of fishing gear)
- 6 Old aerial photos from geographic or other surveys (to estimate numbers of boats on beaches and along piers)
- 7 Interviews with old fishers

ESTIMATING CATCHES

Analysis of the scattered data obtained from these sources should be based on the simple notion that catch in weight (Y) is the product of catch/effort (U , also known as CPUE) times effort (f), or

$$Y = Uf. \quad (1.1)$$

This implies that one should obtain from sources 1–7 estimates of the effort (how many fishers, boats, or trips) of each gear type and multiply it by the mean catch/effort of that gear type (e.g., mean annual catch per fisher

or mean catch per trip). Because the catch/effort of small boats and of individual fishers will differ substantially from that of the larger boats, it is best to estimate annual catches by sector, gear, or boat type, with the total catch estimates then obtained by summing over all gear or boat types.

Moreover, because CPUE usually varies with season, estimation of Y should preferably be done on a monthly basis, by applying equation 1.1 separately for every month, then adding the monthly catch values to obtain an annual sum. Alternatively, a seasonally averaged CPUE can be used. This should be repeated for every component of the fishery, such as the small-scale and industrial components.

Once all quantitative information has been extracted from the available records, linear interpolations can be used to fill in the years for which estimates are missing. For example, if one has estimated 1,000 t as annual reef catch for 1950 and 4,000 t for 1980, then it is legitimate to assume that the catches were about 2,000 t in 1960 and 3,000 t in 1970. This may appear too daring. However, the alternative to this is to leave blanks (so-called no data entries), which later will invariably be interpreted as catches of *zero*, which is a far worse estimate than interpolated values.

ESTIMATING CATCH COMPOSITION

Once catch time series have been established for distinct fisheries (e.g., near shore or reef, shelf, oceanic), the job is to split these catches into distinct species or species groups. Unfortunately, comprehensive information on catch composition is usually lacking. Therefore, the job of splitting the catches must be based on fragmentary information, such as the observed catch composition of a few, hopefully representative, fishing units. Still, combining all available anecdotal information on the catch composition of a fishery (i.e., observed composition of scattered samples) should create reasonable estimates of mean composition. Thus, a report stating that “the catches consisted of groupers, snappers, grunts, and other fish” can be turned into 25%

groupers, 25% snappers, 25% grunts, and 25% other fish as a reasonable first approximation.

A number of such approximations of catch composition can then be averaged into a representative set of percentages, which can be applied to the catches of the relevant period. These percentage catch compositions can be interpolated in time, for example, as 1950–1954 with a composition of 40% groupers, 20% snappers, 10% grunts, and 30% other fish, and 10%, 10%, 20%, and 60%, respectively, for these same groups in 1960–1964. In this case, the values for the intermediate period (1955–1959) can be interpolated as 25% groupers, 15% snappers, 15% grunts, and 45% other fish.

CONCLUSIONS

Estimating catches from the catch/effort of selected gear and fishing effort is a standard method of fisheries management. Reconstruction of historic catches and catch compositions series may require interpolations and other bold assumptions, justified by the unacceptability of the alternative (i.e., accepting catches to be recorded as zero or otherwise known to be incompatible with empirical data and historic records).

There is obviously more to reconstructing catch time series than outlined here, and some of the available methods are rather sophisticated (see Zeller et al. 2015). The major impediment to applying this technique is that colleagues initially do not trust themselves to reconstruct unseen quantities such as historic catches or believe that they can judge the likely level of catches in the absence of “properly” collected data. Yet it is only by making bold assumptions that we can obtain the historic catches needed for comparisons with recent catch estimates and thus infer major trends in fisheries (see also box 1.1).

One example may be given here. The FAO catch statistics for Trinidad and Tobago for the years 1950–1959 start at 1,000 t (1950–1952), then gradually increase to 2,000 t in 1959. Of this, 500–800 t was contributed by “Osteichthyes,” 300–500 t by “*Scomberomorus maculatus*” (now known as *S. brasiliensis*), 100–200 t by “*Penaeus*

spp.,” and 0–100 t by “Perciformes” (presumably reef fishes). On the other hand, the same statistics report, for 1950–1959, catches of zero for fish that are targeted by fishers in Trinidad and Tobago, such as *Caranx* spp., “Clupeoids,” *Thunnus alalunga*, *T. albacares*, and *Katsuwonus pelamis*.

Despite their obvious deficiencies, these and similar data from other Caribbean countries are commonly used to illustrate fisheries trends from the region. Fortunately, it is very easy to improve on this method. Thus, Kenny (1955) estimated, based on detailed surveys at the major market (Port of Spain) and a few reasonable assumptions, that the total catch from the island of Trinidad was on the order of 13 million pounds (2,680 t) in 1954 and 1955, about two times the FAO estimate at this time for both Trinidad and Tobago. Moreover, King-Webster and Rajkumar (1958) provide details of the small-scale fisheries existing on Tobago, from which fishing effort and a substantial catch can be estimated, notably of “carite” (*Scomberomerus regalis*). Furthermore, both of these sources include detailed catch compositions as well, indicating that several of the categories with entries of zero in the FAO statistics (e.g., the clupeoids) generated substantial catches in the 1950s. Other early

sources exist that can be used to corroborate this point. Similar datasets exist in other Caribbean countries.

The text of Pauly (1998) ended here, and this introductory chapter will also, because the 273 one-page accounts for countries or territories presented in the second part of this atlas summarize the analyses I had hoped would be done in the Caribbean and elsewhere. Additionally, chapter 14 presents a first summary of our reconstruction work and its consequences for fisheries research and management.

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NOTES

1. Cite as Pauly, D. 2015. On the importance of fisheries catches, with a rationale for their reconstruction. Pp. 1–11 in D. Pauly and D. Zeller (eds.), *Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts*. Island Press, Washington, DC.
2. This analysis, by Large Marine Ecosystem (LME) using FAO catch data spatialized by the *Sea Around Us*, was performed by Dr. Reg Watson, then a member of the *Sea Around Us*, who thus became a co-author of Worm et al. (2006).
3. The word *reconstruction* is here taken over from historic linguistics (a field that I have an amateur's interest in), wherein extinct languages (Proto-Austronesian, Proto-Bantu, or Proto-Indo-European) are "reconstructed" from words in the daughter languages and rules about phonetic shifts (see Fox 1995; Watkins 2000). One is never sure about the final product but can still offer it to one's colleagues for further scrutiny. It is the same for reconstructed catches.
4. See Palomares et al. (2015).