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Abstract

It is well recognized that not all fisheries catches are reported or recorded properly by either government or non-government agencies. In Mexico, barriers to full reporting include an extensive and often not easily accessible coastline, mostly *de facto* open access fisheries, poor administrative practices and generalized corruption throughout the fishing sector. Amid declines in fish stocks and subsequent economic benefits, notably at local scales, a fundamental change in strategy is needed away from expansion of fishing effort and toward ecological and economic sustainability. An important step in this endeavor is to provide a quantitative *pre-mortem* analysis of Mexico's total marine fisheries catches during the last half-century, from 1950-2010. Results suggest that during this time period, total catches were nearly twice as high as the official reports, with an average annual catch of 1.4 million tonnes (t) compared to 765 thousand t in official statistics. In the last year of available data, 2010, official and reconstructed catches were 1.5 million and 2.1 million t, respectively. These results highlight problems with management *status quo* and *ante*, yet this study does not seek to single out a responsible party. Rather, it is a call to the many sectors of society that contribute to a lack of control and that must work together to overcome current conditions in order to increase and sustain the benefits from Mexico's marine fisheries for both current and future generations.

Introduction

The most important lesson learned after a century of modern fishing is that the world's oceans are not inexhaustible, as previously held both in popular and academic circles (e.g., Melville 1851; Huxley 1883). Since this (opportune) realization, the main endeavor of the fisheries science community has been to develop quantitative methods by which fish stocks can be monitored and assessed in order to gauge their status with respect to given management reference points (e.g., Baranov 1918; Ricker 1954; Beverton and Holt 1957; Hilborn and Walters 1992; Froese and Kesner-Reyes 2002). The single most important component of these status indicators is the catch of a given stock, and it thus has received the most attention in terms of data gathering both at the local and global scale, with a global database of catches since 1950 maintained by the FAO (Garibaldi 2012; www.fao.org/fishery). The use of catch as a stand-alone indicator of fishery status has been extensively discussed (e.g., Branch *et al.* 2011; Carruthers *et al.* 2012; Froese *et al.* 2012; Kleisner *et al.* 2012), but it remains the foundation for nearly all other assessment methods, and the only information freely collected by fishing fleets. The current sub-optimal state of most marine fish stocks (FAO 2012) has prompted organizations at the international, regional and national level to confront fisheries issues with management decisions, with the reliability of catch statistics being of particular concern.

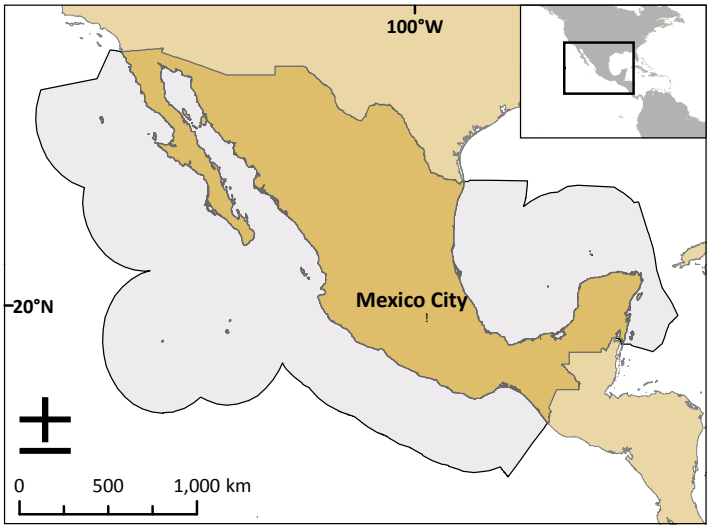

Figure 1. Map of Mexico and its Exclusive Economic Zone

Fisheries in Mexico, reflecting the overarching political system, have historically been characterized by constant shifts in objectives and management schemes (OECD 2006). They have thus evolved from an overlooked sector, to a primary source of food and job creation, to a casualty of neo-liberal reform and now to the object of an apparent tug-of-war between *laissez-faire* management on the one hand and ecological conservation priories on the other (Espinoza-Tenorio *et al.* 2011b). The participation and influence of scientists, academics and conservation organizations in fisheries management has also evolved towards a more holistic understanding of the

social, political and ecological context of Mexican fisheries, with an increase in training in and application of novel quantitative methods to assess national fisheries' status (Hernández and Kempton 2003). Unfortunately, a lack of effective fisheries governance in general, and catch monitoring in particular, has resulted in highly uncertain fishery statistics, which often lack the quality to be informatively used within quantitative assessments that reflect reality.

Illegal, unreported and unregulated (IUU) fishing is a significant issue all over the world, and can seriously misrepresent fish production at any level (Agnew *et al.* 2009; The World Bank 2012). In Mexico, a large fishing sector (300,000 fishers), versatile boats and gear, an extensive coastline, corruption and a limited capacity for monitoring and enforcement, result in significant IUU catch (Rodríguez-Valencia and Cisneros-Mata 2006). Even in the case of legal fishers, official statistics rely on the compulsory but unenforced submission of catch logs by fishers or buyers to the local fisheries office. In both cases, there is no further validation of catch, and catch logs are often filled in on the spot (and often for a fee) by fishery officers based on the fishers' memory of past catch (Espinosa-Romero *et al.* 2012). A survey of Mexican fishery experts including scientists, officials, fishers and others, found that in some fisheries, "irregular" fishing (unreported and illegal) currently represents 40-60% of reported catch (Cisneros-Mata *et al.* 2012). This estimate does not account for discards in shrimp trawls, which historically have had a 1:10 shrimp to bycatch ratio and are widely regarded as the single most important source of unreported bycatch (Vázquez *et al.* 2004).

In light of the apparent disconnect between the recognized importance of catch statistics for management and the state of data monitoring in Mexico, alternative methods must be used in order to provide better estimates. Catch reconstructions have been employed extensively to address this issue (e.g., Zeller *et al.* 2007; Zeller *et al.* 2011), under the fundamental thesis that 'unknown catch' does not equal 'zero catch' (Pauly 1998). Although this is a simple and logical observation, attaching numbers to qualitative knowledge is powerful in conveying the seriousness of the issue and the need for action; this is indeed the main objective of the present study. Following this principle, we provide the first comprehensive estimate of unreported fisheries catches in Mexico, from 1950 to 2010.

Methods

The reconstruction of Mexico's marine fisheries catch was undertaken within a structured database as explained below. Information was gleaned from a variety of sources, including peer-reviewed and grey literature, and expert knowledge, with every attempt made to employ it in a conservative manner (Zeller and Pauly 2007). The main difference between the methods used for this reconstruction with respect to those used in the past is that the focus is on reconstructing catch series by particular species, rather than by a fishery sector.

The FAO fisheries database for Mexico was used as a baseline for subsequent estimations, and consisted of 192 individual catch series of varying taxonomical precision, reported by year from 1950-2010. A series of descriptive categories were assigned to each catch series, and to every reconstructed series, and included:

a. Taxon: scientific name for the group, as precise as possible;

b. Group: elasmobranchs (e.g., sharks, rays), large pelagic fish (e.g., tunas, jacks), small pelagic fish (e.g., anchovies, sardines), benthopelagic fish (e.g., snappers, triggerfish), benthic fish (e.g., flounders), cephalopods (e.g., octopus, squids), gastropods (e.g., abalone, snails), bivalves (e.g., clams, mussels), echinoderm (e.g., sea cucumbers, sea urchins), other (e.g., seaweeds);

c. Target: main target of fishery (e.g., the "tuna" or "shrimp" fisheries use specific gears but catch many species other than shrimps and tunas, both targeted and as bycatch);

d. Sector: artisanal (open deck, outboard or no engine), industrial (covered deck, inboard engine), recreational (food or sale are *not* the main motive for fishing), subsistence (catch kept for consumption in the household);

e. Type: reported (FAO statistics), unreported legal (non-quantified catch by fishers operating legally), unreported illegal (non-quantified catch by domestic fishers operating illegally in any way), unreported discard (non-quantified discarded catch);

f. Input: FAO, reconstructed;

g. Area: Pacific, Atlantic;

h. FAO name: the name for the species or species group as it appears in the FAO data;

i. Individual reference: a binary variable denoting whether specific information related to unreported catch was found for a given fishery;

j. Interpolated: a binary variable denoting whether a time series of catch was interpolated to fill data gaps.

Two initial sources were invaluable for the initial search for information on each catch series. The Mexican National Fisheries Chart (DOF 2004-2012) is an official document that lists all species recognized as fished, and includes a brief summary on every major commercial fishery by area; the assessment and management "Red Book" (INAPESCA

2006) contains reports on all currently assessed species. If no information was found to justify clear gaps in a catch series, these were linearly interpolated. When data was missing at the start of a series, for example, if the first four years of a catch series were missing and the fifth was 500 tonnes, the first year was assigned half the value of the fifth (thus assuming the fishery had not grown from zero catch in 1950) and the other years linearly interpolated. Or, if catch records were missing from, say, 1960-1965, these were linearly interpolated from reported catch in 1959 and 1966. Interpolated catch was designated as unreported and used as the new baseline for subsequent estimations of unreported catch.

Whatever specific information was found for a given catch series was used to estimate the magnitude of unreported catch in (metric) tonnes (t) per year, entered as new catch series in the database (including the appropriate descriptors). According to an extensive survey of fishery experts in Mexico, on average (over several fisheries) unreported ("irregular") fishing contributes a further 45% of catch (90% of which is illegal) relative to reported landings (Cisneros-Mata *et al.* 2012). Around half of illegal catch is subsequently bought by processors and reported with legal catches (first author's pers. obs.), so these would appear in FAO statistics. A conservative ratio (relative to reported catch) of 15% for unreported legal catch and 22% for unreported illegal catch were added to current reported catches when no other information was available for a specific fishery, or in the case of the broadly defined finfish (*escama*) fishery. According to fishers and buyers, legal unreported catches have decreased during the last decades due to improvements in monitoring, while unreported illegal catch has increased due to a growing number of fishers and the addition of fishery regulations. Therefore, the ratio of unreported legal and illegal catch from 1950-2010 were assumed to vary linearly, from 40-15% and from 10-22%, respectively. Due to a general lack of data, we were not able to apply sensitivity analyses directly, but a confidence interval of +/- 15% was applied to resulting aggregate catch estimates (based on variance of expert opinions reported in Cisneros-Mata 2012).

A major component of unreported catches in Mexico is the shrimp trawl fishery, where most bycatch is usually discarded. Catches were first separated into artisanal and industrial sectors based on the historical number of vessels by sector (1970-2007, CONAPESCA 2001-2007; other years linearly extrapolated) and current catch ratio (DOF 2010). Shrimp catches were split into species based on available catch ratios (DOF 2004, 2010) and the average ratio when data were unavailable. Shrimp to bycatch ratios for industrial fisheries were 1:10 and 1:3 for the Pacific and Atlantic Ocean, respectively (Bojórquez 1999) and, for artisanal fisheries, 1:3 for legal gears and 1:10.5 for illegal gear in both oceans (Amezcua *et al.* 2006). Bycatch composition and discard rates were variable, with the discard rate reported as being higher in the Pacific and in the industrial fishery (Rosales 1976; Paul and Hendrickx 1980; Bojórquez 1999; Vázquez *et al.* 2004). For specific estimation procedures for each fishery, see Appendix I in Cisneros-Montemayor *et al.* (2013).

Subsistence and recreational fisheries have significant catches, yet are relatively small compared with the commercial sector. Recreational catch by species for the billfish fishery were used as reported in Cisneros-Montemayor *et al.* (2012); it is important to highlight that this does not include other recreational catch, which is often limited at local scales but may prove more significant in the aggregate (first author's pers. obs.). Subsistence catch in Mexico is present in the form of fisher's take-home catch for their household consumption. Total subsistence catch was calculated based on the number of artisanal and smaller industrial vessel (shrimp and finfish) fishers (by ocean) and the assumption that each fisher keeps 100 kg·year^{-1} (270 g/day) for home consumption. This assumes that fishers on other industrial vessels (e.g., tuna or sardine) do not keep fish for home consumption, which may be an underestimation but is supported by the fact that these fishers act more as simple crew and have less power over day-to-day catch.

Published references regarding unreported catch in Mexican fisheries are scarce, so assumptions on their magnitude were necessary in several cases and are acknowledged as such. This study is intended to be the first iteration in an ongoing effort to improve Mexican fisheries catch statistics, and the resulting catch database is freely available from the first author upon request. Proposed revisions to one or several catch series by other researchers can then be discussed and the database (and documentation) updated.

Results

From 1950-2010, total unreported catch was estimated at over 44 million t, equal to 94% of official landings as reported to the FAO (46.6 million t). Even with our conservative estimation methods and allowing for potential error in the ratios applied, total reconstructed catch was and remains almost two times higher than official catch as reported to the FAO (Figure 2a). On average during the past 61 years, total reconstructed catch (reported and unreported was over 1.5 million t·year^{-1}, compared to 796,000 t·year^{-1} in the official statistics (Table 1).

Estimated catch by type during the study period are presented in Figure 2a. Catch of Pacific sardine (*Sardinops sagax*) is excluded from this figure, as the high and currently increasing catch of this small pelagic fish can mask overall catch trends.

A total of 192 entries, 96 per ocean, are reported in FAO catch statistics, corresponding to 148 taxa, though 5 corresponded to marine mammals and reptiles, not considered in this study. The resulting database of reconstructed catch includes 246 taxa and a total of 758 entries including catch type and sector. Specific information regarding unreported

Table 1. Summary of catch statistics by type in Mexico, 1950-2010.

	Catch by period (t x 10^3)			
Type	**1950**	**2010**	**Total (1950-2010)**	**Average/Year (1950-2010)**
Reported	89	1,407	46,600	764
Unreported	399	436	19,758	323
Discards	17	258	24,648	404
Subsistence	4	32	808	13
Recreational	9	4	59	1
Total	518	2,137	91,873	1,505

catch was available for almost 40% of resulting time series, and 73 time series were interpolated to estimate obvious gaps in the time series, most in early years (see Appendix I in Cisneros-Montemayor *et al.* 2013).

In the aggregate, bottom trawls targeting shrimp have historically accounted for the highest total estimated catch (reported, unreported, illegal and discarded), with over 37 million t (54% of which was discarded) from 1950-2010, followed by finfish gillnets (*escama*; 24 million t), small pelagic seiners (19 million t) and large pelagic seiners and longlines (3.7 million t). Over the same time period, all other fisheries caught almost 11 million t (Figure 3).

In terms of catch by species group, the highest total catch over the study period corresponded to benthopelagic fish (42.3 million; all catches in tonnes), followed by small pelagic fish (19.6 million), crustaceans (including crabs, lobsters and shrimps; 12.6 million), large pelagic fish (6.4 million), bivalves (3.1 million), cephalopods (1.9 million), elasmobranchs (1.8 million), benthic fish (1.8 million), gastropods (1 million), echinoderms and other invertebrates (200 thousand).

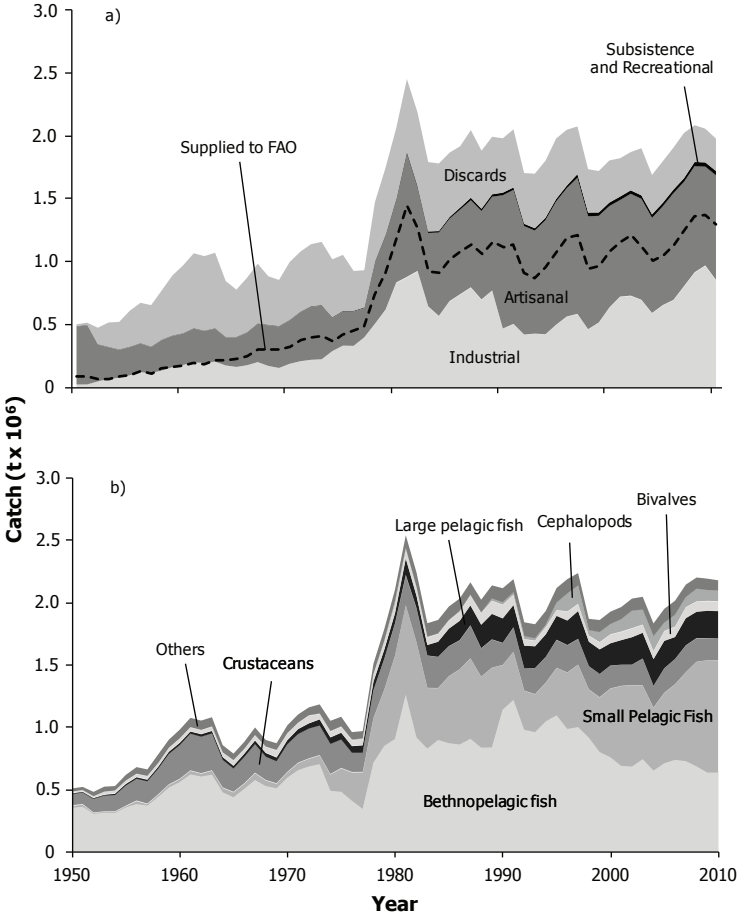

Figure 2. Total reconstructed catches of Mexico, 1950-2010, by a) fisheries sector; and b) major taxonomic groups. 'Other' represents 5 additional taxonomic categories.

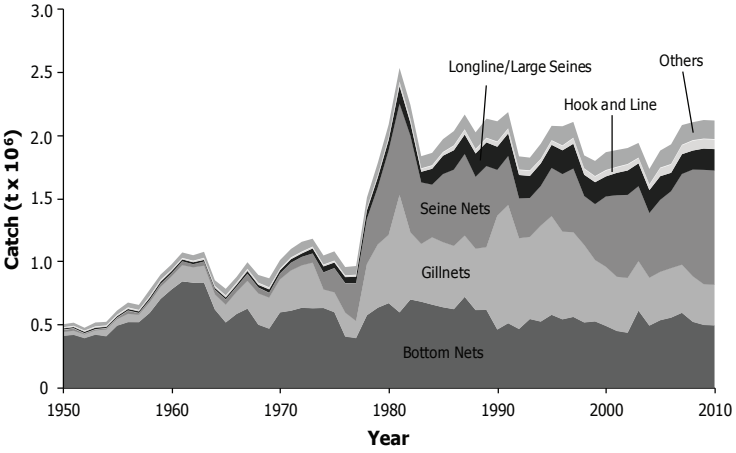

Figure 3. Total reconstructed catches of Mexico, 1950-2010, by gear type

Discussion

Results show that from 1950-2010, total fisheries catch was almost twice as high as the official statistics as reported to the FAO (Table 1). As expected from qualitative observation, unreported catch compared to reported catch was higher at the beginning of the study period (4.6:1 from 1950-1960). During this time, fishing cooperatives were granted exclusive fishing access, but there was little government interest or oversight of the sector until the creation of the National Fisheries Institute in 1962 (OECD 2006). Lack of regulation combined with the introduction of nylon netting and bottom trawl gear since the 1950s led to high unrecorded catch and discards (Figures 2, 3), particularly in the Gulf of California shrimp and totoaba fisheries (Bahre *et al.* 2000). Management was strengthened by the onset of fisheries promotion programs in the 1970s, which succeeded in increasing fish catches, but did so largely through extensive government subsidies to the fisheries sector, mainly for technology, infrastructure and fuel (Espinoza-Tenorio *et al.* 2011b). Total catch has remained relatively stable for the last three decades, though catches have diversified over time, with 40% of taxa present in catches in 1950 compared to 2010. The addition of these new fisheries (notably for jellyfish, squid and swimming crabs), along with recent increases in the abundance of small pelagic fish, have masked declines in catch of benthopelagic fishes and other groups for the last two decades (Figure 2b).

Four decades after the push for industrialized fisheries in Mexico, two main issues have arisen. First, as national fishing fleets are now large and relatively well-equipped, further subsidies only serve to finance overfishing, undermining the resource base and jeopardizing future ecological function and economic benefits (e.g., Munro and Sumaila

2002). Second, as with any other economic incentive scheme, the fishing industry's attitude and strategy following government support without accountability, has resulted in limited private innovation and investment in efficiency, not to mention a lack of effective management control (OECD 2006; Espinoza-Tenorio *et al.* 2011a). Thus, the addition of potentially helpful policies intended to limit catch instead results in more unreported catch (Figure 2a). Nevertheless, the overall ratio of unreported to reported catch has decreased over time, from over 4:1 in 1950 to 0.45:1 in 2010 (Table 1). This partly follows from declines in overall catches, lower discarding ratios as more species are retained and landed, and the explosive growth of fisheries for small pelagics (Figure 2b).

However, this also reflects improvements in monitoring capacity and disposition on the part of government agencies, and the work of research centers and non-government agencies within fishing communities to encourage documentation of landings and other pertinent information (Hernández and Kempton 2003; Sáenz-Arroyo *et al.* 2005). The decision to use FAO data as a baseline for estimations followed from a thorough analysis of national data freely accessible from CONAPESCA (the national governing body for fisheries and aquaculture) in its statistical yearbooks. Though discrepancies were found in this data and the reporting process from dockside to FAO is unclear, the fact that statistics are collected at a national level, compiled in a comprehensive manner (errors notwithstanding), and furthermore made freely available over the internet, is an important development in the management of national fisheries and allowed for a study of this scope to take place at all. In many cases, this included the ability to allocate catches by taxa of varying precision, which is invaluable for the application of informative stock assessments.

Quantitative fisheries analysis in Mexico has made significant advances over the last decades; indeed, all but two of the 17 fisheries in the official assessment and management reference book (INAPESCA 2006) incorporate stock assessment methods including age-structured surplus-production models, virtual population analyses, and bioeconomic models. Together with a wider inclusion of stakeholders into the management process (Hernández and Kempton 2003), moving towards a quantitative understanding of the dynamics of fish stocks certainly aids monitoring of stocks and ecosystem status. However, the current deficiencies in recorded catch statistics as highlighted in this study raise questions about the results of confronting structured statistical models with highly uncertain data (Walters and Ludwig 1981; Hilborn and Walters 1992). Most of the species that are currently assessed do have relatively better catch monitoring in place, but an investment in recording full and accurate catch statistics (not to mention an updated estimate of nominal artisanal effort, reported as static for the last 15 years) is *sine qua non* for the future expansion of stock assessment efforts. In the meantime, it would be highly advisable for any quantitative assessment to consider and present results for a wide range of potential parameter assumptions (Schnute and Hilborn 1993), even those as basic as the actual catch taken by a fishery.

Though discrepancies in catch statistics have many implications for fisheries management, it is perhaps most troubling that in a country where 20 million people are undernourished (95% children; Olaiz-Fernández *et al.* 2006), over 25% of fisheries catch over the last 60 years (currently 400,000 t/year) has been subsequently thrown overboard (Table 1). There is a pressing need for economic incentives that re-align these fishing strategies; subsidies could indeed play a role here through development of novel processing methods (Allsopp 1980), or perhaps helping enforce retention of bycatch, while boosting prices for "trash" fish that can then sold at a discount in key regions of the country. Exclusion devices on trawl gear, which had the highest catch of any gear type (37 million t; Figure 3), can significantly reduce catch of large fish and turtles (Aguilar-Ramirez and Rodríguez-Valencia 2010), but bycatch ratios have nonetheless remained high (Bojórquez 1999; Vázquez *et al.* 2004; Meltzer *et al.* 2012; Fig 3) and devices are often de-activated at sea by fishing crews (Cox *et al.* 2007). Many other fisheries discard catch (e.g., Amezcua *et al.* 2006; Rodríguez-Valencia and Cisneros-Mata 2006; Ramírez-López 2009; Santana-Hernández *et al.* 2009; Shester and Micheli 2011), but trawl gear is where efforts to combat this wasteful practice, both through avoidance and retention of bycatch, would be most fruitful (FAO 1982). Bycatch limits must be set for all fisheries in Mexico, yet thus far this has only been applied to billfish in commercial shark longliners (DOF 2007; Cisneros-Montemayor *et al.* 2011). As more fish stocks become fully or over-exploited, Mexico's fisheries will develop more efficient technology and enforcement to eliminate and/or efficiently use bycatch and discards. Our results provide a first estimate of the magnitude of these currently wasted resources.

Clearly, many assumptions are required for this type of study (Pauly 1998), though every attempt was made to provide estimates that were both substantiated by available information and erred on the conservative side. The main foreseeable obstacle was a shortage of first-hand information about particular species or fisheries, but in the end, 40% out of a total of 243 taxa were supported by specific information, and sources for aggregate groups (e.g., finfish) most likely adequately represent many others (DOF 2004, 2010). The uncertainty associated with estimations given limited information requires that methods be clearly stated and every assumption made clear, hence the inclusion of methods and sources for each fishery (see Appendix I in Cisneros-Montemayor *et al.* 2013). Others are encouraged to question the methods used for a given fishery, analyze the raw results, and propose revisions to estimations if better information is available.

From 1950-2010, total fisheries catch in Mexico, including both unreported legal and illegal catch and discarded bycatch, was almost twice as high as official statistics. This reflects a lack of clear policy to discourage such ill practices, a well as deficiencies in the reporting, monitoring and recording process which cannot be attributed to a single responsible party. Nevertheless, the fact that such a study was possible owes to advances in participation and interest in the sustainable use of the marine ecosystem, which we hope will continue and strengthen in the future, helping attain potential societal benefits. For this to become a reality, a change in culture must ensue including fishers, fishing leaders, field and administrative officials, technicians, researchers and all those involved in generating, collecting, processing, storing and publishing data and information.

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References

Agnew DJ, Pearce J, Pramod G, Peatman T, Watson R, Beddington JR and Pitcher TJ (2009) Estimating the worldwide extent of illegal fishing. PLoS ONE 4(2): 1-8.

Aguilar-Ramirez D and Rodríguez-Valencia JA (2010) Tecnologías para reducir la captura incidental en las pesquerías de camarón del Golfo de California. Instituto Nacional de Pesca (INAPESCA), World Wildlife Fund (WWF). 50 p. Available at: http://www.wwf.org.mx/wwfmex/descargas/rep-tec-RS-INP-INAPESCA-WWF-1030.pdf [Accessed: March 05, 2012].

Allsopp WHL (1980) Fish by-catch from shrimp trawling. The main protein resource for Caribbean Atlantic countries: Reality and potential. Round table on non-traditional fishery products for mass human consumption, Inter-American Development Bank, Washington, DC. 33 p.

Amezcua F, Madrid-Vera J and Aguirre-Villaseñor H (2006) Efecto de la pesca artesanal de camarón sobre la ictiofauna en el sistema lagunar de Santa María La Reforma, suroeste del Golfo de California. Ciencias Marinas 32(1B): 97-109.

Bahre CJ, Bourillón L and Torre J (2000) The Seri and commercial totoaba fishing (1930-1965). Journal of the Southwest 42(3): 559-575.

Baranov FI (1918) On the question of the biological basis of fisheries. Nauchnyi issledovatelskii ikhtiologicheskii Institut Isvestia 1: 81-128.

Beverton RJH and Holt SJ (1957) On the dynamics of exploited fish populations. Fish and Fisheries Series 11. Chapman & Hall, London. 533 p.

Bojórquez LF (1999) Shrimp bycatch utilization in Mexico. *In* Clucas I and Teutscher F (eds.), Report and proceedings of FAO/DFID expert consultation on bycatch utilization in tropical fisheries. National Resources Institute, Chatham, U.K.

Branch TA, Jensen OP, Ricard D, Yimin Y and Hilborn R (2011) Contrasting global trends in marine fishery status obtained from catches and from stock assessments. Conservation Biology 25(4): 777-786.

Carruthers TR, Walters CJ and McAllister MK (2012) Evaluating methods that classify fisheries stock status using only fisheries catch data. Fisheries Research 119-120: 66-79.

Cisneros-Mata MA, Espinosa MJ and Torre J (2012) Magnitud e impacto de la pesca irregular en México contribución a un análisis sistémico. Instituto Mexicano para la Competitividad AC, Guaymas, Mexico.

Cisneros-Montemayor AM, Christensen V, Arreguín-Sanchez F and Sumaila UR (2012) Ecosystem models for management advice: An analysis of recreational and commercial fisheries policies in Baja California Sur, Mexico. Ecological Modelling 228: 8-16.

Cisneros-Montemayor AM, Cisneros-Mata MA, Harper S and Pauly D (2013) Extent and implications of IUU catch in Mexico's marine fisheries. Marine Policy 39: 283-288.

Cox TM, Lewinson RL, Zydelis R, Crowder LB, Safina C and Read AJ (2007) Comparing effectiveness of experimental and implemented bycatch reduction measures: the ideal and the real. Conservation Biology 21(5): 1155-1164.

DOF (2004) Acuerdo por el que se aprueba la actualización de la Carta Nacional Pesquera y su anexo. Poder Ejecutivo—Secretaría de Medio Ambiente, Recursos Naturales y Pesca, Diario Oficial de la Federación (DOF), México.

DOF (2007) Norma Oficial Mexicana NOM-029-PESC-2006, Pesca responsable de tiburones y rayas. Especificaciones para su aprovechamiento. Poder Ejecutivo–Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, Diario Oficial de la Federación (DOF), México. 44 p.

DOF (2010) Acuerdo mediante el cual se da a conocer la actualización de la Carta Nacional Pesquera. Poder Ejecutivo-Secretaría de Medio Ambiente, Recursos Naturales y Pesca, Diario Oficial de la Federación (DOF), México.

Espinosa-Romero MJ, López-Manriquez M and Torre-Cosío J (2012) Programa de talleres sobre marco regulatorio para el manejo sustentable de pesquerías ribereñas en el Noroeste y Sureste de México. Informe Final a la Dirección General de Ordenamiento Pesquero y Acuícola. CONAPESCA.

Espinoza-Tenorio A, Espejel I and Wolff M (2011a) Capacity building to achieve sustainable fisheries management in Mexico. Ocean and Coastal Management 54: 731-741.

Espinoza-Tenorio A, Espejel I, Wolff M and Zepeda-Domínguez JA (2011b) Contextual factors influencing sustainable fisheries in Mexico. Marine Policy 35: 343-350.

FAO (1982) Fish by-catch – bonus from the sea: report of a technical consultation on shrimp by-catch utilization in Georgetown, Guyana, 27-30 October 1981. Food and Agriculture Organization of the United Nations (FAO). 163 p.

FAO (2012) The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nations (FAO), Food and Aquaculture Department, Rome. xvi+209 p.

Froese R and Kesner-Reyes K (2002) Impact of fishing on the abundance of marine species. ICES Document CM 2002/L:12, International Council for the Exploration of the Sea (ICES). 15 p.

Froese R, Zeller D, Kleisner K and Pauly D (2012) What catch data can tell us about the status of global fisheries. Marine Biology 159(6): 1283-1292.

Garibaldi L (2012) The FAO global capture production database: A six-decade effort to catch the trend. Marine Policy 36: 760-768.

Hernández A and Kempton W (2003) Changes in fisheries management in Mexico: Effects of increasing scientific input and public participation. Ocean and Coastal Management 46: 507-526.

Hilborn R and Walters CJ (1992) Quantitative fisheries stock assessment. Choice, dynamics and uncertainty. Chapman and Hall, New York. 570 p.

Huxley TH (1883) Inaugural meeting of the fishery congress. Address delivered June 18 1883. William Clowes and Sons, Limited, London. 22 p.

INAPESCA (2006) Sustentabilidad y pesca responsable en México. Evaluación y manejo, INAPESCA (Instituto Nacional de Pesca), México. xvi+544 p.

Kleisner K, Froese R, Zeller D and Pauly D (2012) Using global catch data for inferences on the world's marine fisheries. Fish and Fisheries [doi: 10.1111/j.1467-2979.2012.00469.x].

Meltzer L, Blinick NS and Fleishman AB (2012) Management implications of the biodiversity and socio-economic impacts of shrimp trawler by-catch in Bahía de Kino, Sonora, México. PLoS ONE 7(6): e35609.

Melville H (1851) Moby Dick: Or, the whale. Penguin Books, London. 592 p.

Munro G and Sumaila UR (2002) The impact of subsidies upon fisheries management and sustainability: the case of the North Atlantic. Fish and Fisheries 3(4): 233-250.

OECD (2006) Agricultural and fisheries policies in Mexico: Recent achievements, continuing the reform agenda. OECD Publishing. 338 p.

Olaiz-Fernández G, Rivera-Dommarco J, Shamah-Levy T, Rojas R, Villalpando-Hernández S, Hernández-Avila M and Sepúlveda-Amor J (2006) Encuesta Nacional de Salud y Nutrición. Instituto Nacional de Salud Pública, Cuernavaca, Mexico. 131 p.

Paul RKG and Hendrickx ME (1980) Crustaceans in the shrimp by-catch from off the coasts of Sinaloa and Nayarit, México. Bulletin of the Southern California Academy of Sciences 79(3): 109-111.

Pauly D (1998) Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin 11(2): 4-7.

Ramírez-López K (2009) Datos estadísticos de la flota palangrera Mexicana dedicada a la pesca del atún aleta amarilla en el Golfo de México durante el período 1994 a 2007. Collect. Vol. Sci. Pap. ICCAT 64(4): 1159-1170.

Ricker WE (1954) Stock and recruitment. Journal of the Fisheries Research Board of Canada 11(5): 559-623.

Rodríguez-Valencia JA and Cisneros-Mata MA (2006) Captura incidental de las flotas pesqueras ribereñas del Pacífico Mexicano. World Wide Fund for Nature (WWF). 127 p.

Rosales FJ (1976) Contribución al conocimiento de la fauna de acompañamiento del camarón en alta mar, frente a la costa de Sinaloa, México. pp. 25-80 *In* Reunión sobre los recursos de pesca costera de México, Veracruz. INAPESCA.

Sáenz-Arroyo A, Roberts CM, Torre J, Cariño-Olvera M and Enríquez-Andrade RR (2005) Rapidly shifting baselines among fishers of the Gulf of California. Proceedings of the Royal Society of Biological Sciences 272: 1957-1962.

Santana-Hernández H, Valdez-Flores JJ and Gómez-Humarán IM (2009) Distribución espacial y temporal de las especies que conforman la captura objetivo e incidental, obtenida por los barcos palangreros de altura en el Pacífico Mexicano: 1983-2002. Ciencia Pesquera 17(2): 87-96.

Schnute JT and Hilborn R (1993) Analysis of contradictory data sources in fish stock assessment. Canadian Journal of Fisheries and Aquatic Science 50: 1916-1923.

Shester GG and Micheli F (2011) Conservation challenges for small-scale fisheries: Bycatch and habitat impacts of traps and gillnets. Biological Conservation 144: 1673-1681.

The World Bank (2012) Hidden harvest. The global contribution of capture fisheries. Report No. 66469-GLB; 2012. The World Bank, Washington, D.C. 69 p.

Vázquez SH, Martínez JL and Martínez MN (2004) Shrimp trawling fisheries in the Gulf of California: is the by-catch: Shrimp match relationship a good indicator in the changes and impact in the ecosystem? *In* Presentation Delivered at the Fourth World Fisheries Congress, May 2-6, 2004, Vancouver.

Walters CJ and Ludwig D (1981) Effects of measurement errors on the assessment of stock- recruitment relationships. Canadian Journal of Fisheries and Aquatic Science 38: 704-710.

Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: The last 50 years. Fisheries Bulletin 150: 266-277.

Zeller D and Pauly D (2007) Reconstruction of marine fisheries catches for key countries and regions (1950-2005). Fisheries Centre Research Reports 15 (2), University of British Columbia, Vancouver. 163 p.

Zeller D, Rossing P, Harper S, Persson L, Booth S and Pauly D (2011) The Baltic Sea: estimates of total fisheries removals 1950-2007. Fisheries Research 108: 356-363.

Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately for Mexico, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Recreational
1950	89,300	416,000	33,800	468,000	3,760	9
1951	90,000	428,000	34,200	480,000	3,790	10
1952	63,100	415,000	173,800	300,000	3,820	11
1953	72,300	447,000	254,800	261,000	3,840	12
1954	87,701	437,000	285,500	235,000	3,870	13
1955	101,802	513,000	374,500	236,000	3,900	14
1956	129,701	548,000	430,800	243,000	3,930	15
1957	112,501	546,000	433,100	222,000	3,960	17
1958	153,602	625,000	514,700	260,000	3,990	19
1959	168,301	731,000	626,100	269,000	4,020	20
1960	176,701	802,000	702,300	272,000	4,050	22
1961	201,600	873,000	774,400	296,000	4,080	27
1962	192,101	860,000	768,600	280,000	4,110	37
1963	216,302	863,000	784,500	291,000	4,140	38
1964	218,305	636,000	601,400	249,000	4,160	47
1965	232,006	554,000	517,300	265,000	4,200	44
1966	251,806	629,000	582,300	294,000	4,240	63
1967	308,006	689,000	643,600	349,000	4,270	61
1968	309,206	587,000	517,800	374,000	4,310	55
1969	309,008	560,000	484,500	380,000	4,340	52
1970	337,092	676,000	610,500	398,000	4,380	59
1971	384,905	713,000	640,000	453,000	4,530	119
1972	412,905	745,000	664,000	488,000	4,910	177
1973	424,487	756,000	676,700	498,000	5,410	90
1974	380,492	665,000	745,600	294,000	6,210	110
1975	438,564	642,000	770,800	303,000	6,500	168
1976	470,977	487,000	639,300	312,000	6,810	136
1977	508,536	457,000	698,000	260,000	7,280	161
1978	764,368	747,000	934,800	569,000	7,730	168
1979	936,141	853,000	1,092,600	688,000	8,160	173
1980	1,204,318	905,000	1,336,600	763,000	9,610	330
1981	1,517,098	1,030,000	1,366,100	1,168,000	10,910	1,861
1982	1,298,568	946,000	1,460,100	771,000	11,600	1,655
1983	957,808	880,000	1,150,200	674,000	12,170	1,301
1984	979,917	884,000	1,083,400	767,000	12,690	575
1985	1,113,930	858,000	1,201,600	757,000	13,540	504
1986	1,189,986	846,000	1,247,000	772,000	15,110	2,361
1987	1,246,075	921,000	1,357,800	788,000	17,040	4,082
1988	1,194,700	832,000	1,208,700	799,000	17,930	1,352
1989	1,297,550	845,000	1,277,600	845,000	18,950	1,264
1990	1,236,857	883,000	859,700	1,239,000	19,160	2,222
1991	1,255,443	937,000	921,400	1,251,000	19,200	846
1992	1,043,108	802,000	819,800	1,005,000	18,930	921
1993	986,696	842,000	859,700	949,000	18,960	962
1994	1,072,794	864,000	858,100	1,059,000	19,140	775
1995	1,194,012	926,000	964,600	1,135,000	19,260	981
1996	1,321,646	871,000	1,012,200	1,159,000	19,780	1,296
1997	1,362,923	877,000	994,900	1,216,000	26,920	2,281
1998	1,069,093	802,000	820,400	1,021,000	26,920	3,337
1999	1,103,341	759,000	887,800	946,000	26,920	1,246
2000	1,203,294	727,000	1,000,600	901,000	27,160	1,556
2001	1,298,605	669,000	1,084,800	854,000	27,180	1,429
2002	1,364,759	671,000	1,109,300	898,000	27,180	1,568
2003	1,255,356	795,000	1,141,900	880,000	27,180	1,619
2004	1,144,702	691,000	975,800	831,000	27,190	1,787
2005	1,202,538	750,000	1,061,600	862,000	27,120	2,350
2006	1,240,136	778,000	1,060,900	927,000	27,090	2,524
2007	1,355,943	792,000	1,211,700	906,000	27,070	3,338
2008	1,472,419	733,000	1,254,800	917,000	30,690	3,448
2009	1,499,383	697,000	1,310,300	851,000	31,390	3,420
2010	1,407,482	694,000	1,169,000	897,000	32,090	3,800

Appendix Table A2. Reconstructed total catch (in tonnes) by major group for Mexico, 1950-2010. 'Others' contain 5 additional taxonomic categories.

Year	Benthopelagic fish	Small pelagic fish	Crustaceans	Large pelagic fish	Bivalves	Cephalopods	Others
1950	359,000	15,000	96,100	3,850	6,500	-	24,600
1951	368,000	15,000	98,100	4,090	6,950	-	25,800
1952	312,000	5,000	114,500	4,330	7,390	-	35,100
1953	319,000	5,000	133,000	4,570	17,830	-	40,100
1954	319,000	6,500	137,000	9,300	17,370	1	35,800
1955	362,000	7,700	167,700	11,350	19,310	1	46,200
1956	389,000	22,400	180,500	11,140	20,420	149	53,400
1957	377,000	9,700	184,400	11,900	22,620	148	52,800
1958	446,000	15,360	210,700	13,990	22,600	648	69,900
1959	522,000	20,020	248,700	16,530	26,470	348	65,000
1960	565,000	21,270	273,700	17,250	30,220	548	70,500
1961	627,000	27,930	297,600	16,570	30,220	648	75,000
1962	610,000	22,190	296,200	19,200	29,230	649	75,300
1963	625,000	30,440	299,000	19,370	30,940	848	74,300
1964	483,000	33,600	226,300	20,760	31,340	302	58,700
1965	444,000	38,210	192,200	20,520	38,130	911	52,700
1966	511,000	38,820	216,300	24,440	31,990	1,467	56,700
1967	582,000	53,930	233,000	28,200	37,020	1,857	61,400
1968	533,000	43,710	191,400	28,700	43,640	2,047	53,100
1969	516,000	35,000	181,500	28,600	52,600	2,421	54,100
1970	601,000	41,400	225,800	31,590	49,200	1,756	63,800
1971	661,000	55,600	232,700	39,190	44,500	2,746	66,300
1972	690,000	60,680	242,100	40,730	57,780	3,921	63,500
1973	709,000	68,100	239,900	48,760	41,720	2,011	73,800
1974	495,000	129,520	245,700	51,030	43,200	3,560	82,400
1975	488,000	185,900	231,900	53,440	43,120	4,088	77,200
1976	416,000	225,850	158,300	52,460	42,650	5,660	59,000
1977	350,000	292,400	157,400	57,800	43,510	7,088	59,200
1978	721,000	354,220	225,000	68,500	55,980	4,481	82,600
1979	855,000	447,980	247,500	73,580	61,260	11,881	92,400
1980	912,000	665,330	258,200	81,710	71,980	27,660	93,300
1981	1,263,000	719,120	238,800	134,130	71,030	18,044	102,600
1982	922,000	761,430	270,800	100,000	67,010	7,304	115,900
1983	834,000	484,450	259,100	84,490	59,790	8,951	106,900
1984	903,000	414,500	249,200	121,430	60,530	6,707	108,800
1985	877,000	535,230	240,000	140,730	63,540	7,695	108,100
1986	867,000	600,690	232,000	155,990	71,130	10,961	98,900
1987	912,000	644,070	262,000	161,360	79,070	9,491	99,100
1988	841,000	566,790	227,500	188,910	91,380	10,314	101,000
1989	843,000	637,340	225,400	205,520	102,940	22,881	105,300
1990	1,146,000	356,350	175,900	197,370	107,360	23,868	113,000
1991	1,224,000	384,360	194,400	179,440	80,810	24,753	105,100
1992	984,000	312,040	177,300	182,810	50,120	27,363	111,400
1993	965,000	302,260	209,100	174,540	43,440	21,625	112,900
1994	1,052,000	308,700	205,400	181,330	57,100	20,310	112,400
1995	1,100,000	378,740	223,900	192,570	44,160	63,907	117,500
1996	991,000	451,200	218,600	197,810	70,210	149,253	115,300
1997	1,006,000	499,440	204,700	224,330	55,400	152,256	99,700
1998	921,000	385,220	185,700	196,460	46,960	46,903	90,800
1999	806,000	437,260	186,400	197,050	55,210	84,516	97,000
2000	764,000	549,610	183,900	178,070	70,100	85,578	99,700
2001	695,000	639,380	169,100	197,320	66,080	103,002	97,900
2002	690,000	651,940	162,200	220,210	70,320	144,522	96,900
2003	749,000	588,770	215,500	206,730	63,660	124,242	103,000
2004	657,000	502,190	175,600	213,530	62,010	121,923	103,300
2005	716,000	562,870	196,500	219,590	76,870	70,280	111,500
2006	744,000	603,440	201,900	176,860	81,440	98,522	112,900
2007	733,000	710,460	214,500	218,840	86,250	84,686	100,700
2008	691,000	837,230	188,000	212,030	81,490	106,257	90,100
2009	641,000	898,830	175,000	221,940	77,150	91,257	91,400
2010	642,000	899,060	171,600	221,850	77,080	91,252	81,000