

## A RECONSTRUCTION OF COLOMBIA'S MARINE FISHERIES CATCHES<sup>1</sup>

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### ABSTRACT

Colombia has coasts on the Atlantic and Pacific Oceans, but its marine fisheries have been limited by the relatively small size of commercially important stocks. However, fishery resources have traditionally been exploited by coastal communities, and industrial fisheries have grown in recent years with the intensification of tuna fishing in both oceans. The management of Colombia's fisheries has been hampered by frequent administrative changes, which has notably led to the loss of parts of the official landings data. We reconstructed Colombia's fisheries catches in the Atlantic and Pacific Oceans for the period 1950-2005. We used secondary sources of information to estimate missing data, and estimated subsistence fishing and the unreported by-catches of the shrimp and tuna fisheries. Our results suggest that for the period 1950-2004, the marine fisheries catches of Colombian may have been more than 1.8 times higher than the landings reported by FAO on behalf of Colombia (1.4 times higher in the Colombian Pacific; 2.0 times higher in the Atlantic). The implications for management are discussed.

### INTRODUCTION

Colombia has coasts on the Atlantic (Caribbean Sea) and Pacific Oceans (Figure 1), but its fisheries, although diverse, have been limited by the relatively small size of commercially important stocks (Prado and Drew 1999). Nonetheless, fishery resources historically have been an important part of the livelihood of human communities on both coasts (Squires and Riveros 1978, Pérez-Ramírez 1986, Prado and Drew 1999). Fisheries management in Colombia has been impaired by frequent transfers of management responsibilities between government agencies. In past years, the National Institute of Fisheries and Aquaculture (INPA) was responsible for the collection and analysis of fisheries statistics



**Figure 1.** Colombia's EEZ and major ports in Atlantic and Pacific waters.

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and the regulation of fishing activities from 1990 to 2003. With its closure, these responsibilities were assigned to the Colombian Institute of Rural Development (INCODER), a subsidiary agency of the Ministry of Agriculture and Rural Development.

### Industrial fisheries

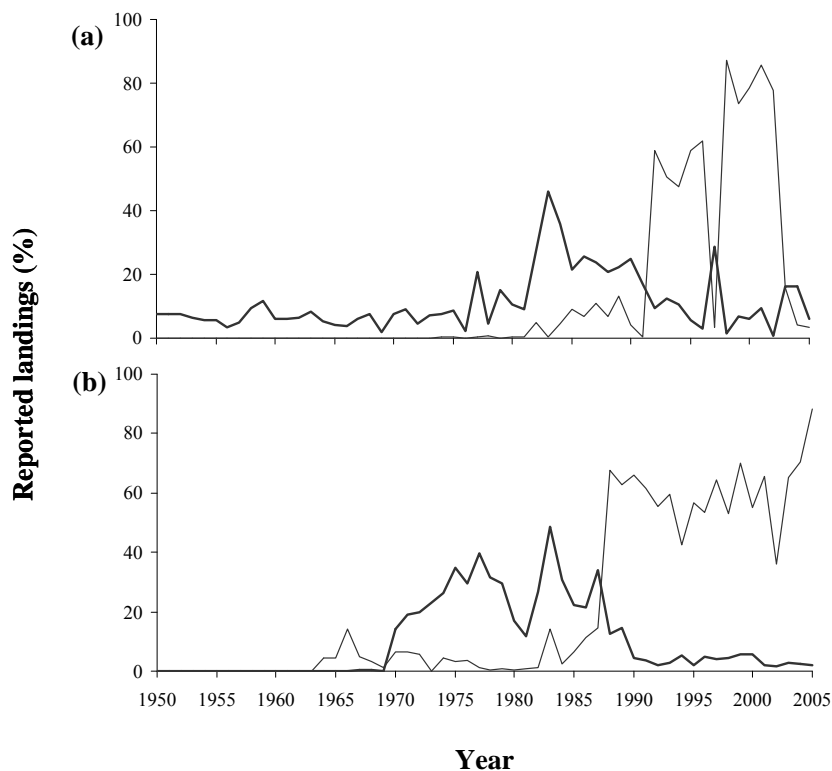
Industrial fishing (defined as boats larger than 15 m) in Colombia began with shallow-water shrimp trawling in the Pacific Ocean (for *Penaeus occidentalis*, *Xiphopenaeus riveti*, and *Trachypenaeus* spp.) in the late 1950s, and in the Caribbean Sea (for *Farfantopenaeus brasiliensis*, *F. notialis*, and *F. schmitti*) in the mid-1960s (Gómez-Canchong *et al.* 2004). Shrimp was the most important contribution of the industrial fishery to total reported landings in both oceans until the mid-1980s, when overfishing began (Mora-Lara 1987, INDERENA 1988, Figure 2). Since then, tuna has been the most important component of industrial landings (Ministerio de Agricultura 1993, Beltrán-Turriago and Villaneda-Jiménez 2000; Figure 2). Tuna fishing takes place in EEZ waters of the Atlantic and Pacific with boats of less than 400 t capacity, and in international waters (for *Thunnus albacares* and *Katsuwonus pelamis*) with larger boats (Beltrán-Turriago and Villaneda-Jiménez 2000).

The industrial shrimp trawlers have remained virtually unchanged since they began operating in Colombia (Zúñiga-Clavijo *et al.* 2004, Rueda *et al.* 2004). Most trawlers have a capacity of 20-40 t (Barreto-Reyes *et al.* 2001). They are fuel-inefficient, and, as their gear is unselective, a large proportion of the by-catch is discarded, or is retained and marketed without being reported to the fisheries authorities (Duarte *et al.* 2006). Shrimp trawlers in the Caribbean are based in Barranquilla, Cartagena, and Santa Marta (Figure 1), but they fish along the entire coast (Giudicelli 1979). In the Pacific Ocean, there are shrimp trawlers in Buenaventura and Tumaco (Barreto 1986, Rueda *et al.* 2004, Figure 1). The Buenaventura trawlers operate along the entire Pacific coast, while the trawlers based in Tumaco operate only in the local waters (Barreto 1986, Mora-Lara 1986).

In the Pacific, Colombia also has an industrial fishery for anchoveta (*Cetengraulis mysticetus*) and thread herring (*Opisthonema* spp.), which are used in fish-meal and fish-oil production (Beltrán-Turriago and Villaneda-Jiménez 2000). There are small industrial fisheries for spiny lobster (*Panulirus argus*) and queen conch (*Strombus gigas*) off the San Andrés Archipelago in the Caribbean (Figure 1). Also, there is industrial fishing for fish of high value (e.g., snappers, groupers, sharks) in the Caribbean and Pacific Ocean. Most of the products of the industrial fisheries are exported (Beltrán-Turriago and Villaneda-Jiménez 2000).

### Small-scale fisheries

Small-scale fisheries (nets cast from the shore and boats less than 15 m) target coastal resources in both oceans and supply a large part of the marine fish landed in Colombia (Magnusson *et al.* 1983, Mora-Lara 1987, Pereria-Velásquez 1993). There are approximately 14,000 small-scale fishers in the Caribbean, and approximately 15,000 in the Pacific coast (Beltrán-Turriago and Villaneda-Jiménez 2000). The most



**Figure 2.** Percent contribution of shrimp (dark line) and tuna (light line) to total reported landings in Colombia's (a) Atlantic and (b) Pacific Oceans for 1950-2005. In years for which official data were not available, FAO landings statistics were used (see text for details).

common fishing gears used by small-scale fisheries are cast nets, gill nets, surrounding nets, traps, and long lines (Beltrán-Turriago 2001). Surrounding nets are widely used by small-scale fishers to capture shrimp, and their mesh size is frequently below the legal limit (Friedemann and Arocha 1984, Mora-Lara 1986, 1987, Beltrán-Turriago 2001). These nets capture large numbers of immature shrimp and fish (Mora-Lara 1987). In 1986 (the last year for which data were available), 36% of the reported catch of *Penaeus occidentalis* landed in the port of Buenaventura was captured by the small-scale fishery using surrounding nets (Mora-Lara 1987). In the Tumaco area, shrimp fishing is done with artisanal trawl nets that are operated from motorized canoes. The small mesh size of these nets (1.0-2.5 cm) and their deployment in mangrove areas results in the incidental catch of large numbers of juvenile fish (Friedemann and Arocha 1984). Although small-scale fisheries supply the majority of the seafood that is consumed in Colombia, part of their product is purchased by the industrial sector and exported (Beltrán-Turriago, 2001).

**Table 1.** Number of taxa (common names) included in the marine landings statistics currently available from the Colombian fisheries management agency (INCODER).

Categories	1975-1990		1991-2005	
	Atlantic	Pacific	Atlantic	Pacific
Fishes	29	29	135	173
Crustaceans	4	4	13	21
Mollusks	4	4	1	10

estimate unreported catches, consisting of discarded and unreported by-catches of the shrimp industry, fish caught and consumed by fishers and their families (subsistence), and fish caught incidentally during tuna fishing. Finally, we compare the reconstructed total catch time series to the landings statistics reported by FAO (FAO Fishstat).

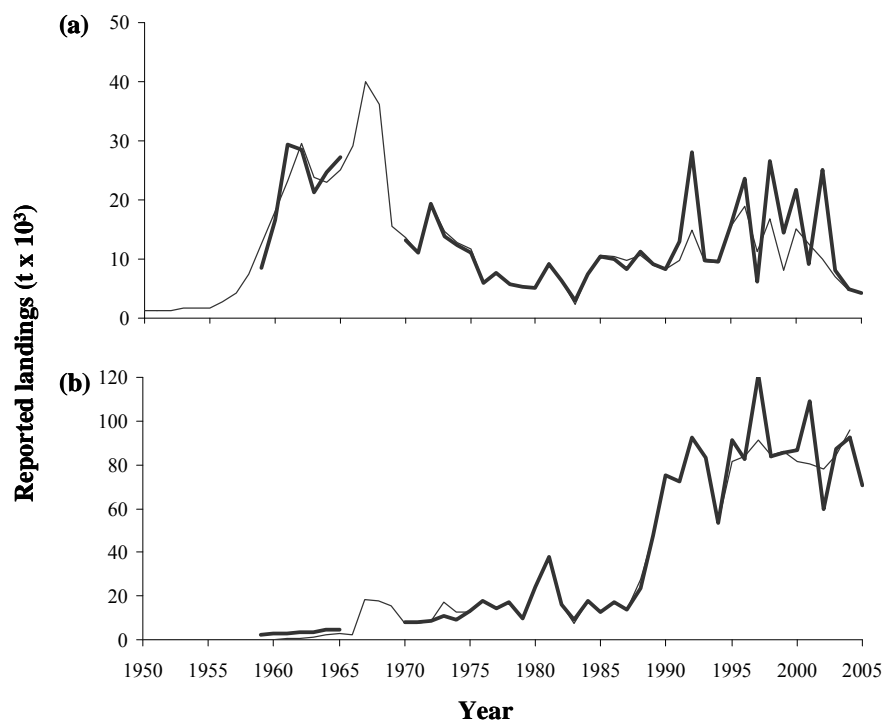
## MATERIALS AND METHODS

### *Officially-reported landings*

Parts of Colombia's official landings data have been lost during the multiple changes in the fisheries management system; INCODER currently holds official landings data only for the years 1975-2005. This information consists of landings data for different number of taxa (by common names of species) for different years, as summarized in Table 1.

Official data for the years 1959-1965 and 1970-1974 were obtained from secondary sources (Ciardelli-Fadul 1968 and Mora-Lara 1986, respectively). These statistics consist of total landings for the Atlantic and Pacific Oceans, and are not disaggregated by taxa. For completing the reported landings time series, we assumed that the country's officially-reported landings

Here we present a reconstruction of the Colombian Atlantic and Pacific fisheries catches for the years 1950-2005, which was conducted using the methodology in Zeller *et al.* (2006, 2007). First, we reconstruct the officially-reported landings and estimate the percent contribution of small-scale fisheries. We then



**Figure 3.** Reported landings statistics for Colombia in the (a) Atlantic and (b) Pacific Oceans for 1950-2005. Note differences in scale. Data obtained from the fisheries management agency (INCODER) or secondary sources are indicated by the dark line, and landings data from FAO are represented by the light line.

for missing years (1950-1958 and 1966-1969) could be represented by the data reported for those years by FAO on behalf of Colombia. This assumption was made because the officially-reported landings for the intervening years are similar to those reported by FAO (Figure 3).

### *Contribution of the small-scale sector*

INCODER provided us with estimates of the percent contribution of the small-scale fisheries to total reported landings for 1999-2005. One additional estimate was found for each ocean in the literature (Table 2).

The percent contribution of small-scale fisheries for all other years was estimated using the following procedure. Tunas, clupeids, spiny lobster, and queen conch are fisheries that are targeted mainly by industrial fleets. We regressed the (arc-sine transformed) percent contribution of the small-scale sector for the known years (Table 2) against the catch of these fisheries, and obtained a significant inverse relationship (Atlantic:  $r^2=0.79$ ,  $F=22.86$ ,  $P<0.01$ ; Pacific:  $r^2=0.78$ ,  $F=20.77$ ,  $P<0.01$ ). The regression equations were used to estimate the percent contribution of the small-scale sector for the missing years in each ocean.

**Table 2.** Estimates of the percent contribution of the small-scale sector to total reported landings in Colombia.

Source	Area	Year	Contribution (%)
Duarte & García (2002)	Atlantic	1995	29.2
INCODER	Atlantic	1999	13.6
INCODER	Atlantic	2000	12.4
INCODER	Atlantic	2001	31.3
INCODER	Atlantic	2002	18.8
INCODER	Atlantic	2003	59.4
INCODER	Atlantic	2004	52.0
INCODER	Atlantic	2005	72.3
Mora-Lara (1986)	Pacific	1986	67.5
INCODER	Pacific	1999	6.5
INCODER	Pacific	2000	11.1
INCODER	Pacific	2001	5.3
INCODER	Pacific	2002	12.8
INCODER	Pacific	2003	4.8
INCODER	Pacific	2004	5.0
INCODER	Pacific	2005	2.4

### *Unreported by-catch and discards of the shrimp fisheries*

Two studies in the Atlantic Ocean and two in the Pacific Ocean investigated the by-catch of the industrial shrimp fishery. In the Atlantic, INDERENA (1983) reported a mean retained by-catch/shrimp ratio of 2.59 for 3 trawlers during a typical 21-day fishing trip in the southern Caribbean, while the mean discards/shrimp ratio was 11.46. In a study of the shrimp-trawling fleet operating during 3 months in the central and northern Caribbean, Duarte *et al.* (2006) found a mean retained by-catch/shrimp ratio of 2.54 and a mean discards/shrimp ratio of 7.70. Because the Atlantic fleet fishes along the entire Caribbean coast, we averaged these estimates and obtained a mean retained by-catch/shrimp ratio of 2.57 and a mean discards/shrimp ratio of 9.58.

In the Pacific, Trujillo (1983) reported on the catches of shrimp trawlers in Tumaco over a 10-month period. He estimated a retained by-catch/shrimp ratio of 3.9 and a discards/shrimp ratio of 1.32. For a 21-day fishing trip of a boat based in Buenaventura, Barreto-Reyes *et al.* (2001) documented a retained by-catch/shrimp ratio of 2.13 and a discards/shrimp ratio of 0.80. The fishing fleet in Buenaventura is approximately 5 times larger than the Tumaco fleet (Mora-Lara 1986), and we used this weight to estimate mean rates of 2.43 for retained by-catch/shrimp and 0.89 for discards/shrimp.

In a study of the shrimp by-catches that were reported to the fishing authorities in Cartagena between 1974 and 1983, García (1985) found a by-catch/shrimp ratio of 0.15. This value was subtracted from the mean retained by-catch/shrimp ratios above, and the resulting rates and the mean discard/shrimp ratios were applied to shrimp landings to estimate the unreported retained by-catch and discards for each area. We are not aware of studies that have measured the by-catch of small-scale shrimp fisheries in Colombia. Because of the lack of selectivity of the fishing methods employed by these fisheries, we assumed that their by-catch rates (discards and unreported retained by-catch) were the same as those of the industrial shrimp fisheries.

### *Subsistence fishing*

Rodas-López *et al.* (1994) found that small-scale fisheries in the Cartagena region sold only 59.5% of their catch. The remaining 40.5% was of low economic value and was retained for consumption by the fishers and their families (i.e., subsistence). During an exploratory study of fishery resources throughout the Colombian Caribbean, Manjarrés-Martínez *et al.* (2005a, b, c) reported that the percent contribution of commercially important fish to the total catch was 51.1%, 54.2%, and 65.5% in April, July, and October/November, respectively. The estimates of subsistence catch in Rodas-López *et al.* (1994) were based on data for November, so we used the ratio of the mean percent contribution of the catch of low commercial value (43.1%) to the percent contribution in October/November (34.5%) to estimate that the

annual percentage of the total catch that is not sold by small-scale fishers is 50.6% ( $1.25 \times 0.405$ ). In 1986, 98% of the fish landed in the Caribbean, excluding tunas, was caught by the small-scale sector. This suggested that 49.6% of total catches (excluding tunas) was not reported in the Caribbean area. Thus, we adjusted the reported fish landings in the Caribbean (excluding tunas) by a factor of 1.98 ( $1/0.504$ ) to account for subsistence fishing.

Tobón-López *et al.* (in press) studied the catch composition of small-scale fisheries in the central Pacific for an entire year. They found that 20 fish families contributed to 64% of the catch. From these 20 families, we added the contribution to total catch of the families that were classified by Tobón-López *et al.* (in press) as having low commercial but high subsistence value (Haemulidae and Sciaenidae), and those families containing species whose catch was not reported in the official statistics (Ophichthidae, Muraenidae, Labridae, Tetraodontidae, Synodontidae, Cirrhitidae, Scaridae, and Balistidae). We used FishBase (Froese and Pauly 2007) to identify the family of fish species that were reported by their (Spanish-language) common names. The contribution of the 10 families above to total catch was 29.1%. In 1989, 76.2% of the fish landed in the Pacific, excluding tunas and clupeids, was caught by the small-scale sector (Pereira-Velásquez 1993). This suggested that 22.2% of total catches (excluding tuna and clupeids) was not reported in the Pacific area. Thus, we adjusted the reported fish landings in the Pacific (excluding tuna and clupeids) by a factor of 1.29 ( $1/0.778$ ) to account for subsistence fishing. We consider that this estimate may be conservative because Tobón *et al.* (in press) reported on only 20 fish families (the other families were grouped in a single category), and it is likely that other families include species that are not marketed, but are important for subsistence.

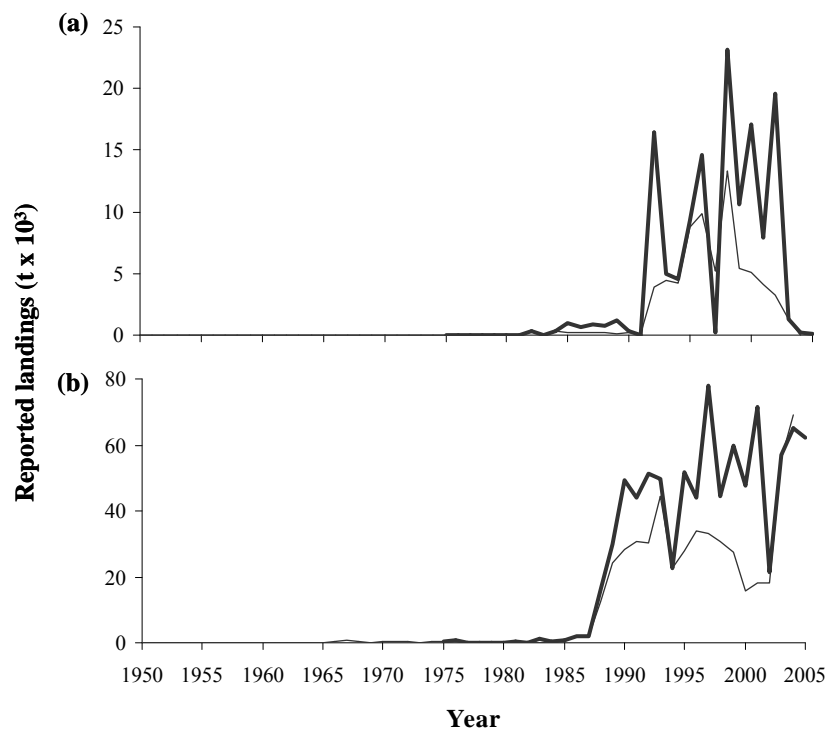
### Discards from tuna fishing

During 4 trips aboard tuna fishing vessels with capacity <400 t in the Colombian Pacific, Lara (2004) reported that the discard/tuna ratio was 0.027 for casts directly on tuna schools and 0.056 for casts on floating objects. The mortality rate for the discarded fish was higher than 99%. Casts on tuna schools caught 1.59 as much tuna per hour as casts on floating objects, so we applied the weighted mean of discards/tuna (0.045) to tuna landings to estimate annual discards. We didn't find studies reporting discard rates for any region in the Caribbean, but the mean discard rate for tuna, bonito, and swordfish fisheries are 2.1 higher in the Atlantic than in the East-Central Pacific (Kelleher 2005), so we applied a discards/tuna ratio of 0.095 to the tuna landings in the Colombian Caribbean.

### RESULTS

Differences in landings between the officially-reported data and those reported by FAO on behalf of the Colombian government have become more pronounced since the intensification of industrial tuna fishing (Figures 3 and 4).

In the Caribbean, differences in reported tuna landings between national sources and FAO statistics accounted for approximately 61% of the variation in the differences in total landings for 1991-2004 ( $r^2=0.608$ ,  $F=18.62$ ,  $P<0.01$ ). In the Pacific Ocean, differences in reported tuna landings accounted for



**Figure 4.** Officially-reported tuna landings (1950-2005, dark line) and tuna landings reported by FAO (1950-2004, light line) for the Colombian (a) Atlantic and (b) Pacific Oceans. Note differences in scale.

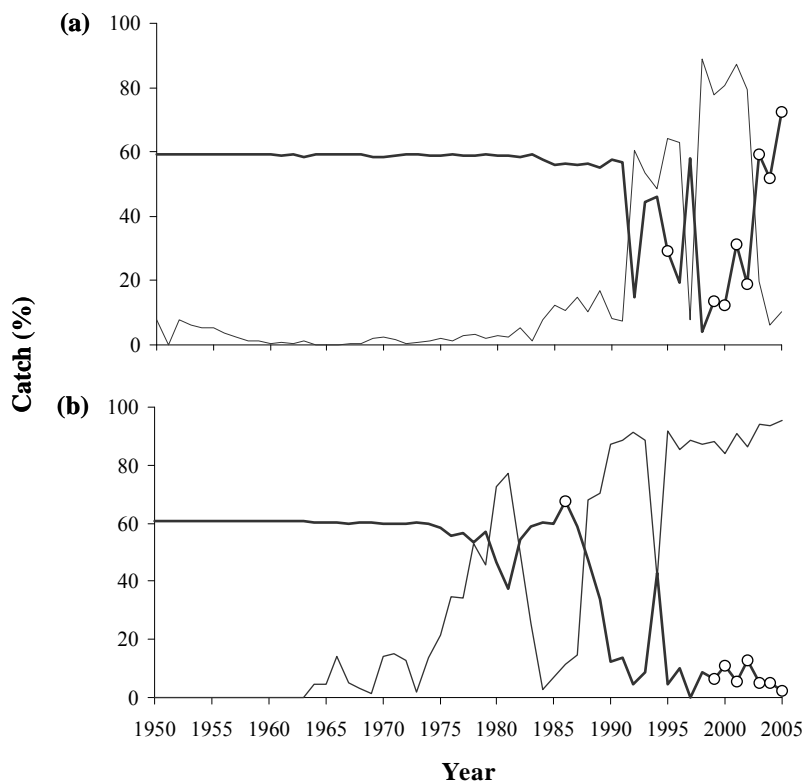
approximately 59% of the variation in the differences in total landings for 1988-2004 ( $r^2=0.591$ ,  $F=21.67$ ,  $P<0.01$ ).

Before the intensification of tuna fishing, the small-scale sector contributed more than half of the total reported landings in the Caribbean and Pacific Oceans (Figure 5).

During years of low fishing by the industrial fleet, the small-scale sector still contributes substantially to the total catch (Figure 5). However, the industrial fleet has contributed with more than 80% of the catch during some recent years.

There are noticeable differences between the officially-reported landings and the reconstructed total catch estimates, and discrepancies were generally larger in the Atlantic than in the Pacific (Figures 6 and 7). The unreported by-catch and the discards from shrimp trawling were the largest components of unreported catch in both oceans, and they generally represented a larger proportion in the Atlantic than in the Pacific (Figure 7).

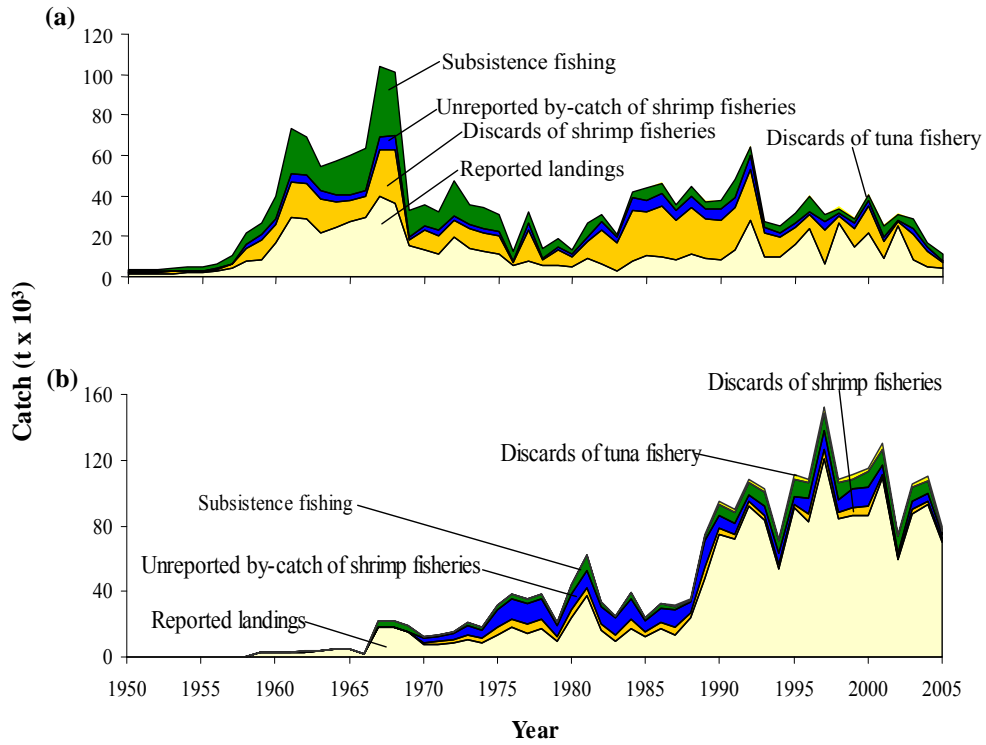
Our results suggest that for the period 1950-2004, fisheries catches in the Colombian Atlantic may have been 2.9 times higher than the reported landings presented by FAO on behalf of Colombia (Figure 8). In the Colombian Pacific, catches may have been 1.4 higher than the landings presented by FAO. For the country as a whole, total fisheries catches may have been more than 1.8 times higher than the landings reported by FAO (Figure 9).



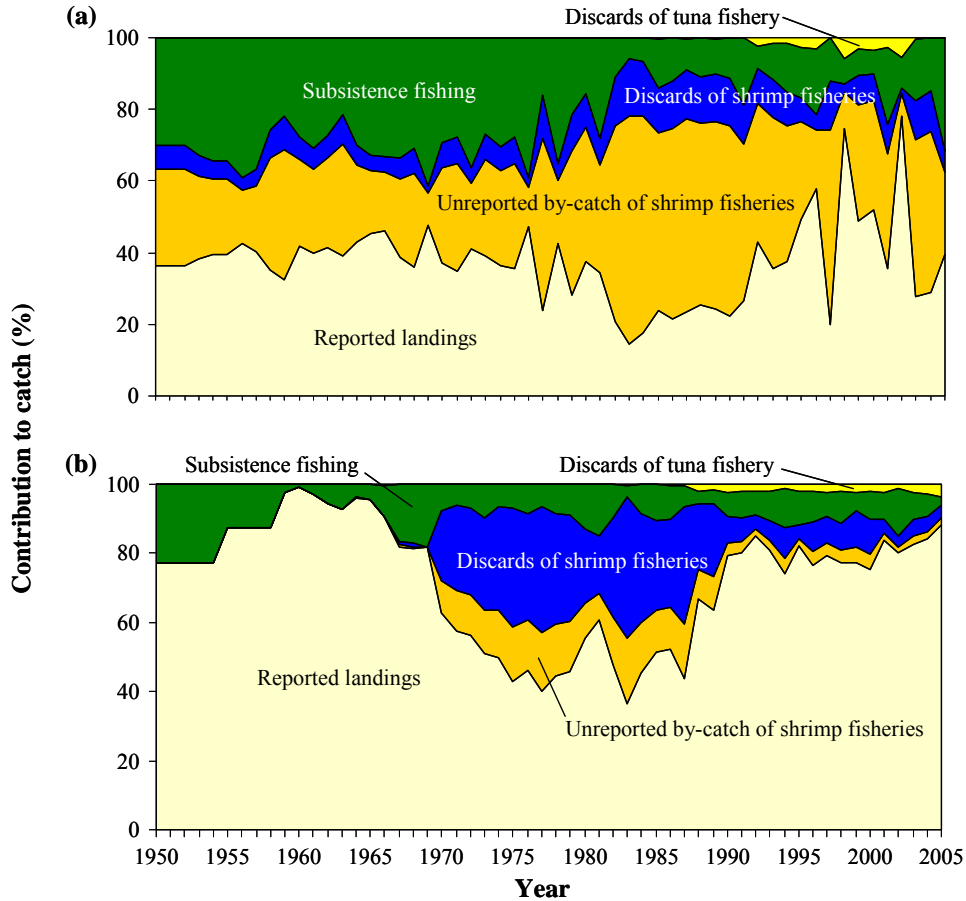
**Figure 5.** Percent contribution of small-scale fisheries (dark line) and tuna, clupeid, spiny lobster, and queen conch landings (light line) to total catches in the Colombian (a) Atlantic and (b) Pacific Oceans for 1950-2005. Open circles correspond to the values in Table 2. The remaining data points were estimated by using the regression equations of percent contribution vs. industrial landings (see text for details).

## DISCUSSION

Our catch reconstruction suggests that the retained, but unreported by-catch and the discards of the shrimp fisheries are the most important components of the unreported catches in the Colombian Atlantic and Pacific Oceans. The antiquated equipment used by the industrial fishery and the artisanal methods employed by the small-scale fishery are non-selective and result in unreported by-catches that are approximately 3 times larger than the shrimp catches in the Pacific Ocean, and 12 times larger than the shrimp catches in the Caribbean. These results are in agreement with FAO reports indicating that the mean discards/shrimp ratio of shrimp trawling in the Caribbean is 12.1, which is one of the highest discard rates of any fishery worldwide (Alverson *et al.* 1994). The lower contribution of discards to total catch in the Pacific may be associated with the higher number of commercially-important species in this area compared to the Caribbean (Table 1). The discard rate in the Colombian Pacific (0.89) is substantially lower than the rates reported for the industrial shrimp trawls in Ecuador and Perú (3.78 and 4.26, respectively, Kelleher 2005).



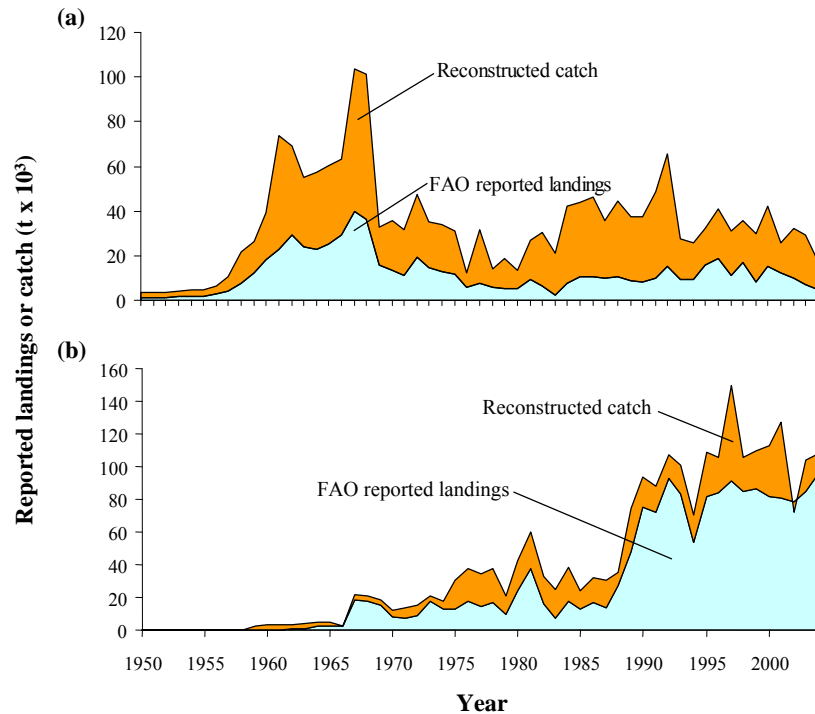
**Figure 6.** Reconstructed total catch estimates for the Colombian (a) Atlantic and (b) Pacific Oceans for 1950-2005. The reconstruction includes retained but unreported by-catch, discard, and subsistence components.



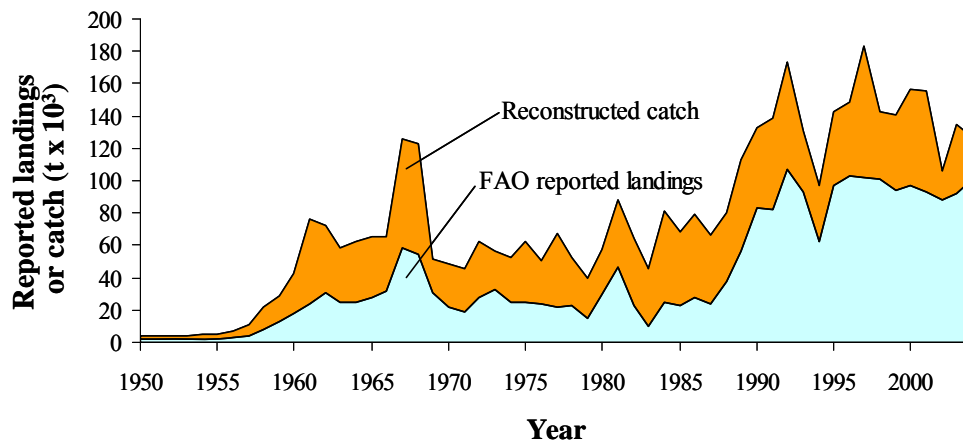
**Figure 7.** Percent contribution of the different catch components to the reconstructed total catch in the Colombian (a) Atlantic and (b) Pacific Oceans for 1950-2005.

Subsistence fishing is an important component of unreported fishing in the Colombian Atlantic and Pacific Oceans. Colombia has one of the highest numbers of internally-displaced people worldwide (between 2 to 3 million people according to UNHCR 2007), and food security is a critical issue in many areas of the country that have been affected by violence, including parts of the Caribbean and Pacific coasts. Fish is an important component of the diet of coastal communities, and during recent years, the number of people involved in artisanal fishing has increased as part of the displaced population seeks alternative means of sustenance and income (Beltrán-Turriago and Villaneda-Jiménez 2000).

Difficulties with the collection of landings data have been pervasive in Colombia, and it likely that large fluctuations in landings between certain years are partly associated with unreliable landings data. Impediments to data collection in the country have been the result of the frequent transfer of management responsibilities between different agencies and the resulting changes in data collection procedures; the logistical difficulties involved in obtaining information from distant and geographically isolated communities; and the reduced number of staff of the fishery management agencies (Sáenz 1962; Ciardelli 1968; WCAFC 2000). These problems with data collection and management may help to explain the discrepancies between the official data held by INCODER and the data reported by FAO on behalf of Colombia. However, fluctuations in landings data are also likely associated with overfishing, as discussed above for the shrimp fisheries, and with environmental factors. In 1973 and 1983, for example, decreases in shrimp landings in the Pacific coincided with strong El Niño events (Mora-Lara 1987). Similarly, fluctuations in tuna catches in the Pacific during the 1980s and 1990s have been correlated with changes in sea-surface temperatures (Pedraza and Díaz-Ochoa 2006).



**Figure 8.** Reconstructed total catch estimates in the Colombian (a) Atlantic and (b) Pacific Oceans, and reported landings data as presented by FAO on behalf of Colombia, for 1950-2004.



**Figure 9.** Reconstructed total catch estimates in Colombia (Atlantic and Pacific Oceans combined), and reported landings data as presented by FAO on behalf of Colombia, for 1950-2004.

In addition to the uncertainty in the reliability of the reported landings, our reconstruction may have underestimated total catches in Colombia because it did not include the following extractive activities which have been reported, but not quantified. Colombia has a limited ability to enforce fishing regulations (UNEP 2006), and the use of illegal fishing methods such as dynamite and fish poisons, which have a large impact on non-target species, has been observed in both coasts (Giudicelli 1979, Friedemann and Arocha 1984, Pérez-Ramírez 1986). Deficient enforcement has also resulted in recurrent illegal fishing by Honduran and Nicaraguan boats in the San Andrés Archipelago. Colombia has granted fishing rights to the United States in these waters<sup>2</sup>, but United States vessels must provide records of their catches to the Colombian fisheries management authorities. However, we could not find any information indicating that these records have been provided.

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<sup>2</sup> The Vásquez-Saccio Treaty between Colombia and the United States was signed in 1972. Under this treaty, the United States gives up any claims over the islands of Quitasueño, Roncador, and Serrana and the surrounding waters, and Colombia grants it fishing rights, under certain conditions. The text of the treaty is available at [www.armada.mil.co/tratados/tratcol-usa.doc](http://www.armada.mil.co/tratados/tratcol-usa.doc).

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