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ORIGINAL RESEARCH

A diagnosis of the artisanal fishery landings in the Colombian Caribbean coast by means of indicators

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ABSTRACT. Landings of the artisanal fishery in the Colombian Caribbean from 2013 to 2021 were characterized by means of two indicators: the trophic level and the vulnerability to fishery landings. Indicators showed a statistically significant decreasing trend in vulnerability and trophic level, suggesting that the fishery is increasingly targeting species of low vulnerability and trophic level, thus moving down the food web. The overall pattern of indicators was not uniform in space. Incidence interaction of gears and species landed explained the trajectory of indicators at the scale of Departments. Fishing gears targeted different levels in the food web, with gillnets responsible for the bulk of landings. Compared to a previous study, the group of fish species supporting most of landings has changed towards species with lower vulnerability, i.e. resistant to fishing mortality due to their evolved life-history but still of predatory habits in general. A notable exception is *Mugil incilis*, a species with a low trophic level that has become third in importance of landings in the database.

Key words: Trophic level, vulnerability, fishing gear, landings.

Diagnóstico de los desembarques pesqueros artesanales en la costa del Caribe colombiano a través de indicadores

RESUMEN. Los desembarques de la pesca artesanal en el Caribe colombiano entre 2013 y 2021 se caracterizaron mediante dos indicadores: el nivel trófico y la vulnerabilidad en los desembarques de pesca. Los indicadores mostraron una tendencia decreciente significativa en la vulnerabilidad y el nivel trófico, lo que sugiere que la pesquería se dirige cada vez más a especies de baja vulnerabilidad y nivel trófico, desplazándose así hacia abajo en la trama alimentaria. El patrón general de indicadores no fue uniforme en el espacio. La interacción de incidencia de las artes y especies desembarcadas explicó la trayectoria de los indicadores a nivel de Departamentos. Las artes de pesca capturaron a diferentes niveles de la rama alimentaria, siendo las redes de enmalle responsables de la mayor parte de los desembarques. En comparación con un estudio anterior, el grupo de especies de peces que sustentan la mayoría de los desembarques ha cambiado hacia especies con menor vulnerabilidad, es decir, resistentes a la mortalidad por pesca debido a la evolución de su historia de vida, pero aún con hábitos depredadores en general. Una excepción notable es *Mugil incilis*, una especie con un nivel trófico bajo que se ha convertido en la tercera en importancia de desembarques en la base de datos.

Palabras clave: Nivel trófico, vulnerabilidad, arte de pesca, desembarques.

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INTRODUCTION

Marine fisheries in Colombia have a secondary role in economic terms. For instance, fisheries and aquaculture together represented just 0.3% of the national gross domestic product (GDP) in 2020 (Ministerio de Agricultura 2020). Artisanal fisheries, however, are paramount as a source of employment and protein for families in precarious conditions. Further, fishing surplus allows the acquisition of services and goods for their households. Diagnosing its status and looking for trends becomes a necessary step to ensure its continuity.

Given that Colombia is situated in the tropics, its artisanal fisheries are necessarily multispecific. The management of multispecific fisheries targeting a variety of species is a difficult task because any measure affects numerous species beyond those targeted for the fishery. Furthermore, it is widely recognized that fishing should be conducted in terms of the Ecosystem Approach to Fisheries Management (FAO 2003; Link 2018), which aims to manage fisheries holistically in the hope of moderating the ecological impact of fishing. These circumstances put considerable pressure on the correct administration of artisanal resources everywhere and, particularly, in Colombian waters.

In the case of the Colombian Caribbean Sea, several surveys among fishermen have indicated that fishery resources are in decline, i.e. fishermen must go further away, and spend more hours fishing in deeper waters to catch less fish than before (García 2010; Saavedra-Díaz et al. 2015). Projections of declining fishery potential for the tropics, including the Caribbean Sea related to global change, add to the concerns about the future of artisanal fisheries in the Colombian Caribbean (Cheung et al. 2010; Lam et al. 2020).

One way to explore status, trends and impact of fishing is by means of the use of indices and indicators. Numerous indicators have been proposed aiming to characterize different aspects of fisheries and their impact on the ecosystem. Such indices address a suite of aspects of human interaction with ecosystems including fisheries, biodiversity, climate, environment, and socioeconomic conditions (Breslow et al. 2016; Coll et al. 2016).

In this study, a diagnosis of the Colombian Caribbean artisanal fishery trends and status was provided using indicators reflecting the vulnerability to fishing and the trophic level of landings. We intended to contribute to proper management of fish resources in the Colombian Caribbean in the face of rapid ecological changes triggered by global warming. Likewise, we call attention to some practical aspects in the collection of fishery statistics much in need of improvement.

MATERIALS AND METHODS

Study area

Since the Colombian Caribbean Sea is located along the tropics it does not show marked seasonality. Two climatic periods can be distinguished driven by the regular migration of the Intertropical Convergence Zone (ITCZ) that influences the strength and direction of winds and precipitation, resulting in a dry season from about December to April and a rainy season during the rest of the year, with local variations in both climatic variables (Ricaurte-Villota and Bastidas-Salamanca 2017).

The coastline extends 1,642 km and faces north to east (Figure 1), which, in combination with the wind regime, promotes a seasonal upwelling phenomenon toward the north of the coast (Andrade and Barton 2005). There are several seascapes, from rocky shores to mangrove swamps, including shallow coralline reefs, extended soft-bottoms and estuaries (Vides and Sierra-Correa 2003). Artisanal fishing is practiced in all habitats and extends offshore.

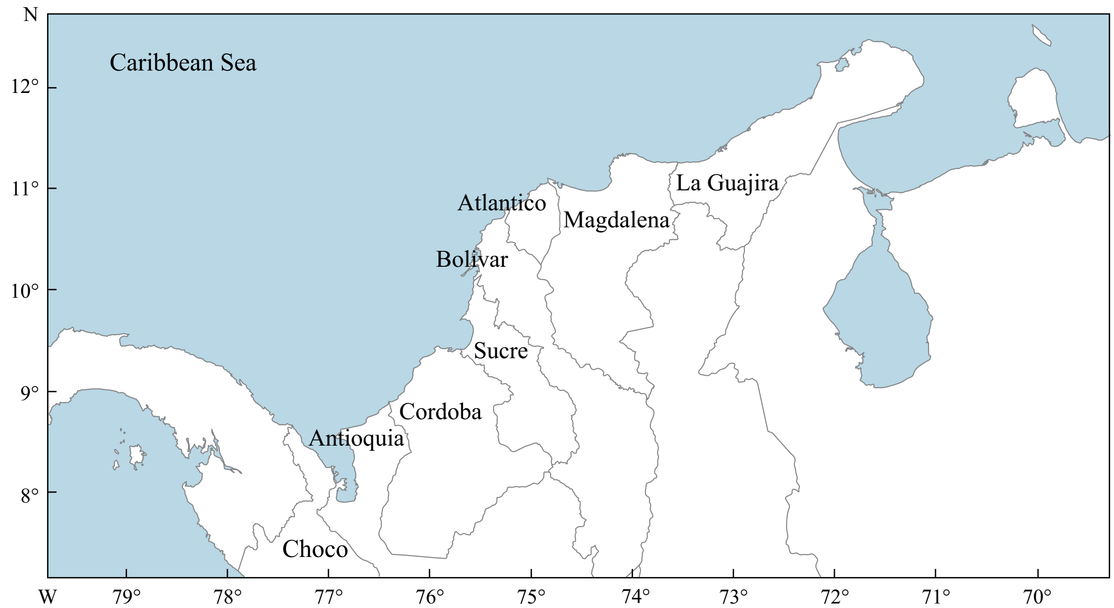

Figure 1. Position and names of Colombian Caribbean Departments. Artisanal fishery landings were accumulated at the level of Departments and analyzed at that spatial resolution.

For the sake of this study, the insular Colombian Caribbean region (San Andres and Providencia archipelago) was not considered. Estimations on the number of artisanal fishermen do not discriminate between the Pacific and the Caribbean coast. A conservative number of 50,000 has been suggested in a report by the Organization for Economic Cooperation and Development (OECD) in 2016.

The Dataset

The National Authority of Fishing and Aquaculture (Autoridad Nacional de Acuicultura y Pesca, AUNAP) monitors landings and efforts (trip days) of artisanal fishery in several ports and places along the coasts of Colombia. In the case of the Colombian Caribbean, the database provided by the fishing authority includes information of 113 landing locations covering the period 2013-2021. The original database was processed so that records could provide detailed information on the department, municipality, location, year, month, species, vulnerability, trophic level, fishing gears, estimated landing (kg) and faunal group (crustaceans, mollusks, bony fishes, sharks, and rays).

The estimated landing per species in a given location, month and gear was obtained in two steps. Firstly, the monthly effort was estimated by multiplying the mean number of trips per day by the effective number of trips in the month, and this estimated effort was then multiplied by the respective CPUE for the species (more details in Duarte et al. 2022). The dataset concerning landings at a level different than species was renamed to the closest species according to the landings in the location, month, and year. The final dataset comprised a matrix of 130,617 entries or rows by eleven columns.

Unfortunately, there were several missing values in the temporal series regarding locations, months, and years in different combinations, i.e. no data of where and when were recorded in the original database. For example, there were 108 months from January 2013 to December 2021, but there were only 86 months of data. These circumstances limited the analysis, since no formal time series analysis for landings was possible.

Indicators

The nature and availability of data led to the application of two indicators: trophic level and vulnerability of landings. Decreasing trophic levels of landings should reflect the depletion of higher trophic level species due to fishing as the fishers 'fish down the food web' (Pauly et al. 1998), and thus they suggest ecological simplification of the ecosystems with top-level predators in danger of stock collapse. Vulnerability refers to vulnerability to fishing in the sense that species with certain life-history traits (large body size, longevity, late maturation, low growth rates) are less capable of supporting high levels of fishing mortality (Cheung et al. 2005).

The trophic level of a fish is defined as one plus the weighted trophic mean level of its preys (Pauly and Palomares 2005). Vulnerability of landings, in turn, is a construct based on fish life-history traits utilizing fuzzy logic and ranges from 1 to 100 (Cheung et al. 2005; Cheung et al. 2007). Estimated local trophic levels for fish were used for calculations (García and Contreras 2011, 102 trophic levels). In case of no local estimate, the trophic level was taken from FishBase (Froese and Pauly 2023, 180 trophic levels). Vulnerability values were taken from FishBase (Froese and Pauly 2023) for all the fish species in the dataset. Both trophic levels and vulnerability values were retrieved from Fishbase with the help of the R package rfishbase (Boettiger et al. 2012). In the case of invertebrates, trophic levels and vulnerability values were taken from SealifeBase (Palomares and Pauly 2023). When values were not available for an invertebrate species, the values of the closest taxonomical species were used.

Statistical analyses were performed by weighting basic trophic levels and vulnerabilities by the landing of relevant species in the location, month, year, gear, and department to which the landing of that species belonged. The spatial-temporal analysis was conducted at the level of departments (Figure 1), i.e. aggregating location landings into their respective departments. Further, the so-called 'trophic signature' (Stergiou et al. 2007; Moutopoulos et al. 2014) of gears and vulnerabilities associated with gears was explored. Mean values of the corresponding series replaced missing data. For instance, if landing data for a given month was missing in one department, then weighted trophic level and vulnerability were set to be the mean trophic level and vulnerability of the year to which the month belonged.

Weighted means and standard errors were calculated with the help of R package Hmisc (Harrel 2023). Trends were visualized per department (all gears) and per gear (all departments). The Mann-Kendall test for linear trends (R package Kendall; McLeod 2011) was applied to construct a time series of trophic levels and vulnerabilities at monthly steps for the entire data set and period. An additional time series relating to landings was constructed as an index whereby the total landing in each month was divided by the number of locations monitored that month, so that a value representing the average landing per location was obtained.

Gear names were reduced to 9 from the original 43 names in the database by aggregating gears that work under similar principles. Graphic work was done with R packages ggplot2 (Wickham 2016) and cowplot (Wilke 2020).

RESULTS

Overview

The processed database examined 304 species, being 248 bony fishes, 24 sharks and 11 rays, reflecting the fish diversity of Colombian Caribbean fishes. As for the invertebrates, the dataset included 14 crustacean species and 8 molluscan species. Landings recorded in the period amounted to 24,020 t, of which 21,073 t corresponded to bony fish, 174 t to sharks, 494 t to rays, 1,809 t to crustaceans and 468 t to mollusks. Of these 304 species, however, a short list of species support landings, notably fishes *Caranx crysos*, *C. hippos* and *Mugil incilis* (Table 1). Thus, a great deal of behavior of trophic level and vulnerability should be associated with the presence-absence of these species in the database.

Gears played a differential role in total landing (Table 2). The bulk of landings was due to gillnets, with over 59% of landings in the period. Far behind were beach seines and handlines, with 17.7% and 9.7% of total landings, respectively. Other gears were of minor importance (Table 2). Correspondingly, gillnets were the gear most frequently mentioned in the database (Table 2). Interestingly, beach saines were less frequently mentioned than handlines but contributed much more to total landing than handlines (Table 2). The preeminence of gillnets in the database should drive trends in trophic levels and vulnerability.

There was a definite geographic distribution of indicators, with Choco showing the highest trophic level and vulnerability values (Figure 2 A and 2 B), suggesting that landings were mostly made up of species found high in the trophic web. At the other extreme was Cordoba, with the lowest vulnerability and trophic levels values among departments (Figure 2 A and 2 B), suggesting that landings were mostly made up of species found low in the food web. Notice the great dispersion of values.

Gears affected differentially the food web (Figure 3). Although with large dispersion, trolling lines caught species with the highest mean vulnerability and trophic levels (Figure 3 A and 3 B), i.e. top predators, while otter trawls captured species with the lowest vulnerability, while hand collection captured species with the lowest trophic levels (Figure 3 A and 3 B), i.e. low in the food web. In general, gears whose mode of capture was dependent on hooking captured species found high in the food web, while other gears using entangling tended to capture species found low in the food web (Figure 3 A and 3 B).

Table 1. Species representing over 60% of cumulative fish landings in the Colombian Caribbean artisanal fishery dataset (2013 to 2021). Notice that the database includes 304 species. Frequency rank refers to the rank of the species according to the number of species mentions in the dataset.

Species	Landing (%)	Trophic level	Vulnerability	Frequency rank
Caranx crysos	11.9	4.5	34.3	3
Caranx hippos	9.5	4.2	41.4	2
Mugil incilis	7.8	2.2	23.6	13
Haemulon plumieri	5.6	3.8	62.0	14
Xiphomenaeus kroyeri	4.9	3.4	10.0	64
Euthynnus alletteratus	3.7	4.5	40.6	15
Opisthonema oglinum	2.5	3.4	23.8	28
Katsuwonus pelamis	2.3	4.0	38.1	98
Centropomus undecimalis	2.3	4.1	45.7	4
Trichiurus lepturus	2.2	4.5	45.0	11
Scomberomorus brasiliensis	2.1	4.5	66.6	5
Bagre marinus	2.1	3.6	47.6	8
Sciades proops	2.0	3.8	37.9	9
Scomberomorus cavalla	1.5	4.4	69.1	6

Table 2. Importance and incidence of gears (frequency of gear mentions in percentage) in total fish landings in the Colombian Caribbean artisanal fishery for the period 2013-2021.

Gear	Gear acronym	Incidence	Landing (t)	Landing (%)
Gillnets	GN	51.2	14,201.3	59.1
Beach seines	BS	8.1	4,270.2	17.7
Handlines	HD	20.8	2,344.9	9.7
Set long lines	SL	6.2	730.6	3.0
Cast nests	CN	4.4	647.1	2.6
Harpoons	HP	4.5	567.1	2.3
Hand collection	HC	0.2	391.7	1.6
Traps	TP	2.0	386.5	1.6
Otter trawls	OT	0.3	256.1	1.0
Trolling lines	TR	1.9	224.6	0.9

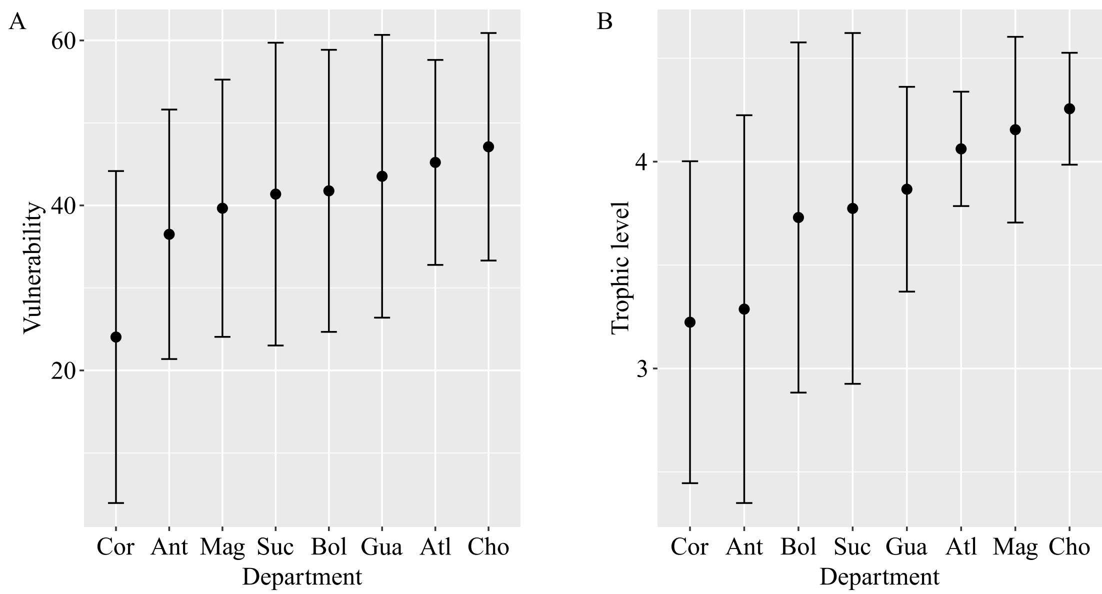

Figure 2. Rank order of mean monthly vulnerability (A) and trophic level (B) of artisanal fishery landings by Department in the Colombian Caribbean in the period 2013-2021. Ant: Antioquia, Cor: Cordoba, Suc: Sucre, Bol: Bolivar, Gua: La Guajira, Mag: Magdalena, Atl: Atlantico, Cho: Choco. Weighted mean plus weighted standard error.

Time series

Departments

Some series appeared to be trendless in the period. For instance, no trend in vulnerability of landings was distinguishable for Antioquia, Choco, Cordoba and Magdalena (Figure 4 A, 4 D, 4 E and 4 G), while Atlantico, Bolivar and Sucre showed a decreasing trend (Figure 4 B, 4 C and 4 H), and Guajira showed an increasing trend in vulnerability at least until 2018 (Figure 4 F). The decreased vulnerability of landings suggested a movement

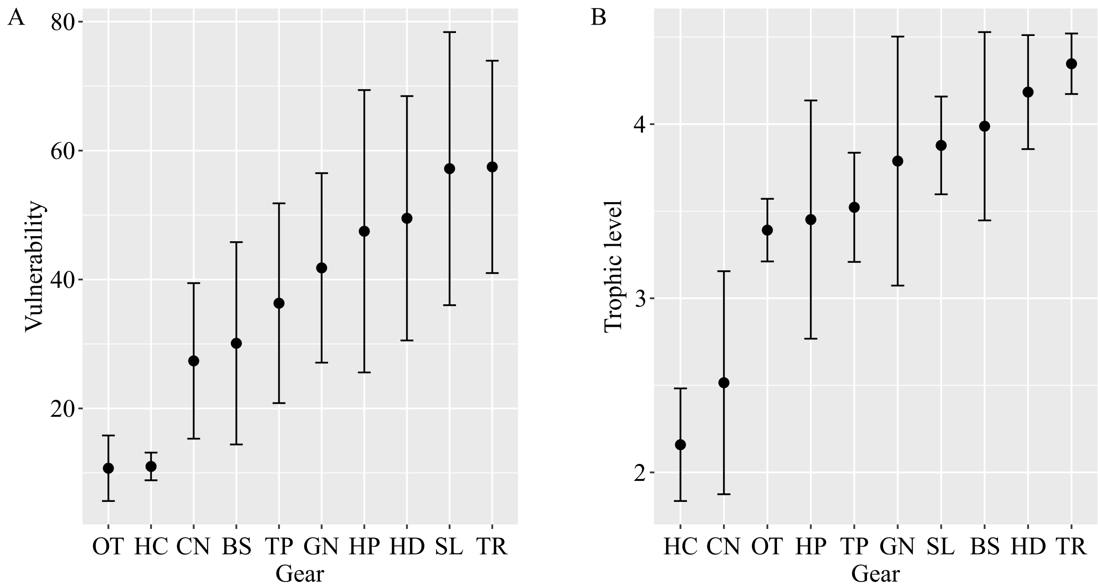

Figure 3. Rank order of mean vulnerability (A) and trophic level (B) of artisanal fishery landings per fishing gear in the Colombian Caribbean in the period 2013-2021. TR: trolling, SL: set lines, HD: hand lines, HP: harpoons, GN: gillnets, BS: beach seines, TP: traps, CN: cast nets, OT: otter trawls, HC: hand collection. Weighted mean plus weighted standard error.

towards fishing down the food web. In the case of Guajira, the increasing vulnerability trend may suggest a process of spatial expansion of the fishery (Kleisner et al. 2014) that reached a limit in terms of depleted predators stocks in 2018, with a subsequent decline in the vulnerability of landings. Globally, the vulnerability showed marked changes with an increasing period until 2016 and a decreasing period towards 2021 (Figure 4 F), signaling again spatial expansion and posterior depletion of top predator's stocks.

The behavior of trophic levels partially matches that of vulnerabilities. Thus, Antioquia, Choco, Guajira and Sucre appeared to be trendless in the period (Figure 5 A, 5 D, 5 F and 5 H), while Atlantico and Bolivar showed a decreasing trend, and Cordoba and Magdalena exhibited an increasing trend in trophic level (Figure 5 E and 5 G). Atlantico and Bolivar fishery appear to have moved down the food web in the period while Cordoba and Magdalena fishery appear to have moved up in the food web, although with no trend in vulnerability (Figure 4 E and 4 G). The period 2013-2016 showed trophic levels above the global mean with a rapid decline afterwards (Figure 5 I).

Gears

Trolling lines, harpoons, and otter trawls showed no trend in the period for vulnerability (Figure 6 A, 6 D, 6 I) whereas set lines, traps and hand collection displayed an increasing tendency in vulnerability value (Figure 6 B, 6 G and 6 J). In contrast, hand lines, gillnets, beach seines and cast nets showed a decreasing trend (Figure 6 C, 6 E, 6 F and 6 H). Increasing trends in vulnerability suggested that fishers had broaden the spectra of species to catch top predators. A decreasing trend suggested depletion of top predators such that gears were affecting increasingly a suite of species found low in the food web.

Most gears showed no trend in trophic levels (Figure 7 A, 7 B, 7 C, 7 F and 7 G). Otter trawls and hand collection, in turn, exhibited an increasing trend (Figure 7 I and 7 J), while harpoons, gillnets and cast nets showed a marked decreasing trend (Figure 7 D, 7 E and 7 H). Notably, gillnets

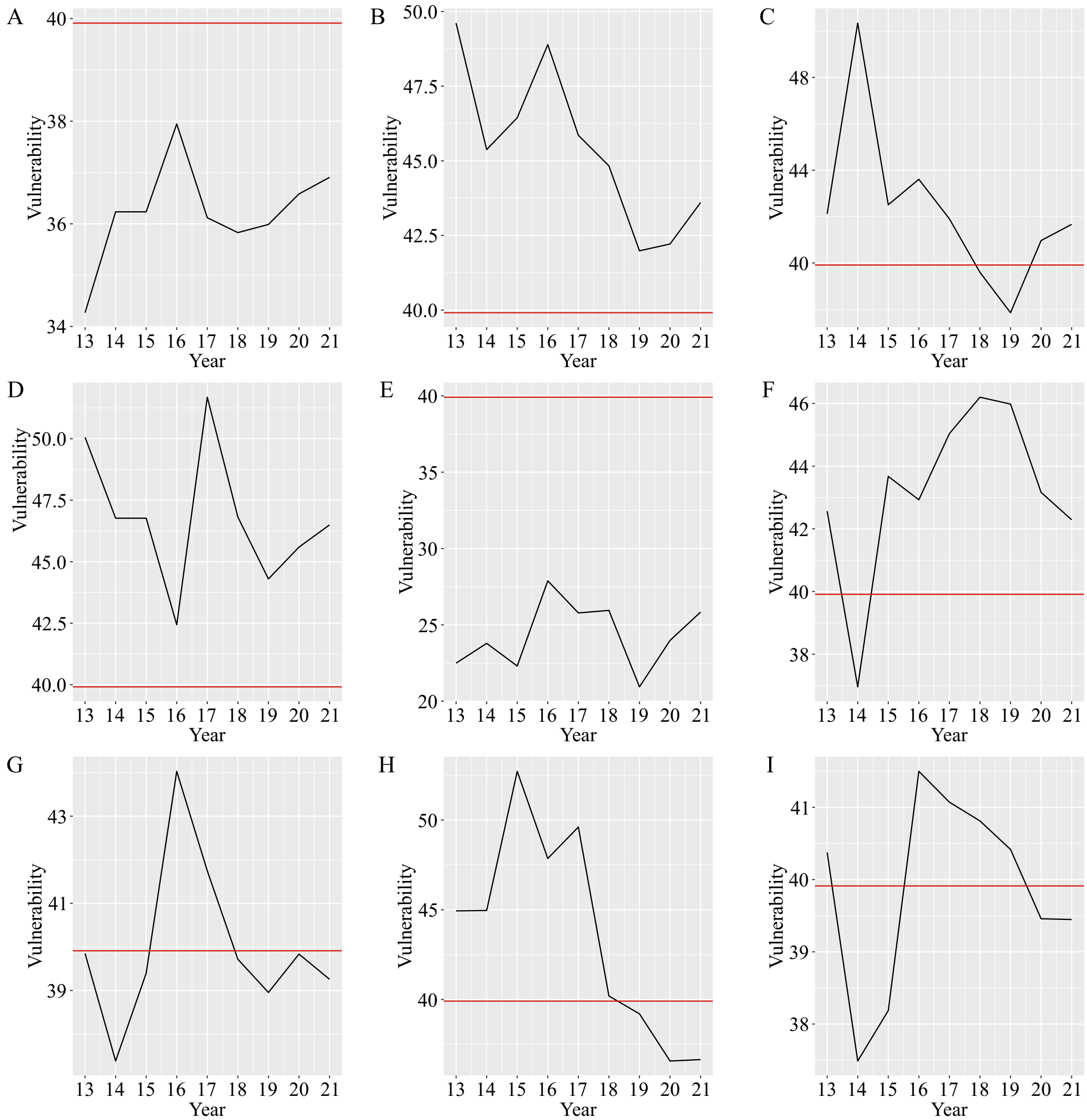

Figure 4. Time series of annual vulnerability of artisanal fishery landings by Department in the Colombian Caribbean in the period 2013-2021. A) Antioquia. B) Atlantico. C) Bolivar. D) Choco. E) Cordoba. F) La Guajira. G) Magdalena. H) Sucre. I) All landings. The red line is the global average vulnerability in the dataset.

responsible for the bulk of landings in the dataset (Table 2) performed marked declines both in vulnerability and trophic level in the period, suggesting depletion of top predators, thus forcing fishers to fish at lower levels in the food web.

A decreasing trend was noticeable for vulnerability (Figure 8 A) and trophic level (Figure 8 B). For the latter, the linear trend was statistically significant (Mann-Kendall test, $p < 0.05$). The same vulnerability analysis, excluding invertebrates, re-

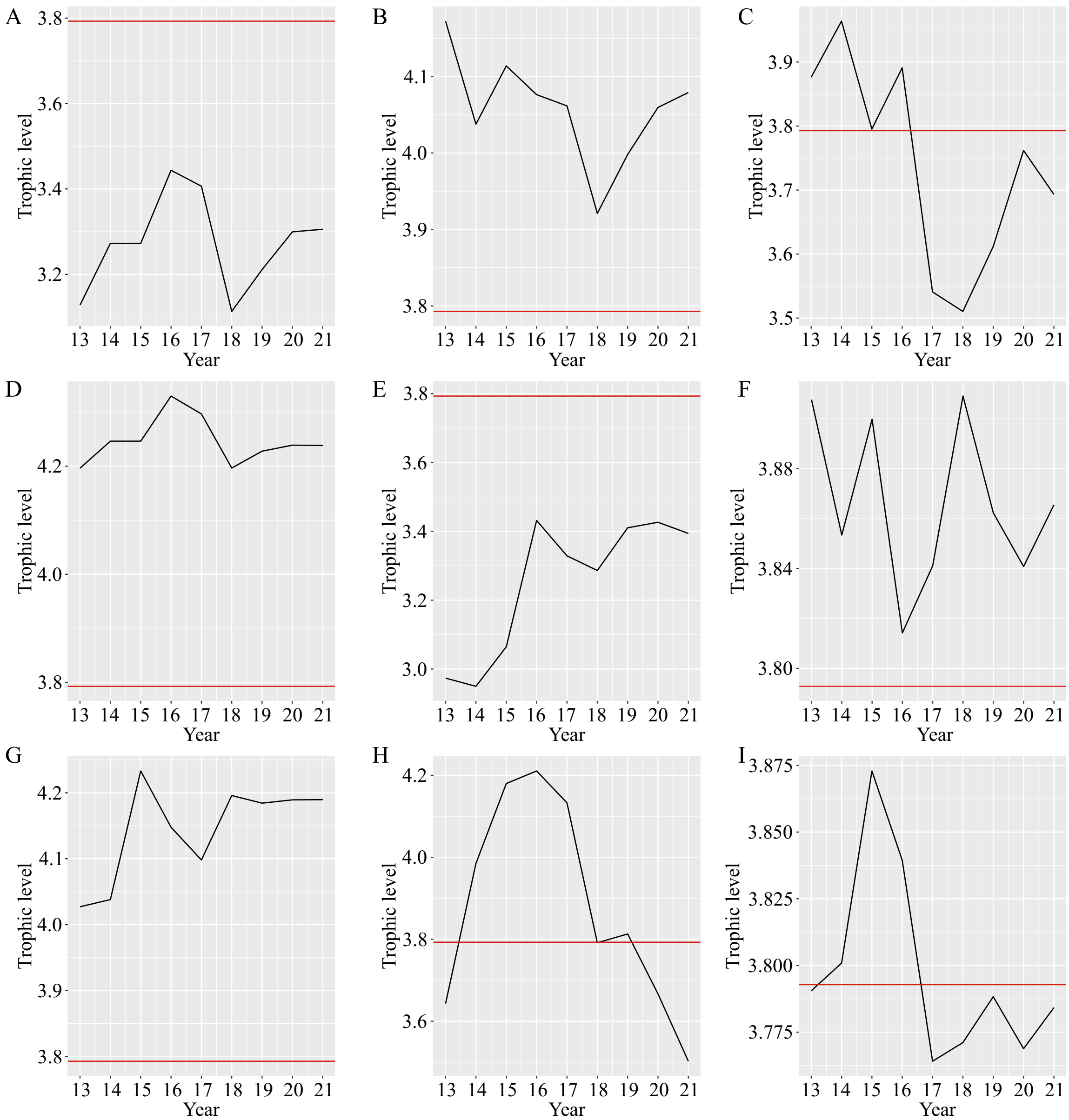

Figure 5. Time series of annual trophic level of the artisanal fishery (fishes) landings by Department in the Colombian Caribbean in the period 2013-2021. A) Antioquia. B) Atlantico. C) Bolivar. D) Choco. E) Cordoba. F) La Guajira. G) Magdalena. H) Sucre. I) All landings. The red line is the global average trophic level in the dataset.

vealed a statistically significant decreasing linear trend for fish (Mann-Kendall test, $p < 0.05$). Thus, globally, the fishery has shifted from fishing at higher levels to fishing at lower levels in the food web, increasingly targeting species resistant to fish mortality. Relative landings had a decreasing trend (Figure 8 C), but it was not statistically significant (Mann-Kendall test, $p > 0.05$).

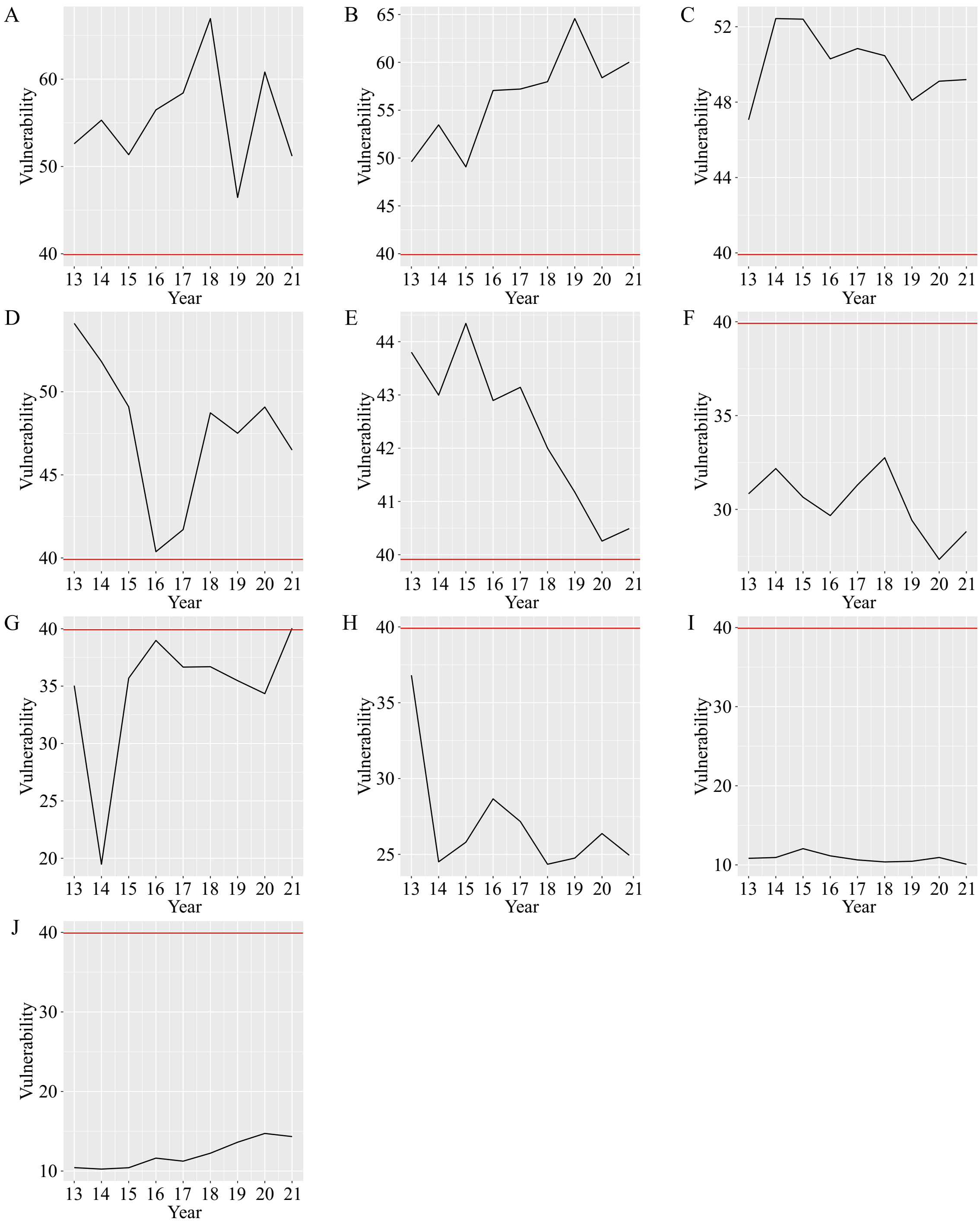

Figure 6. Time series of annual vulnerability of the artisanal fishery landings per fishing gear in the Colombian Caribbean in the period 2013-2021. A) Trolling lines. B) Beach seines. C) Hand lines. D) Harpoons. E) Gillnets. F) Beach seines. G) traps. H) Cast nets. I) Otter trawls. J) Hand collection. The red line is the global average vulnerability in the dataset.

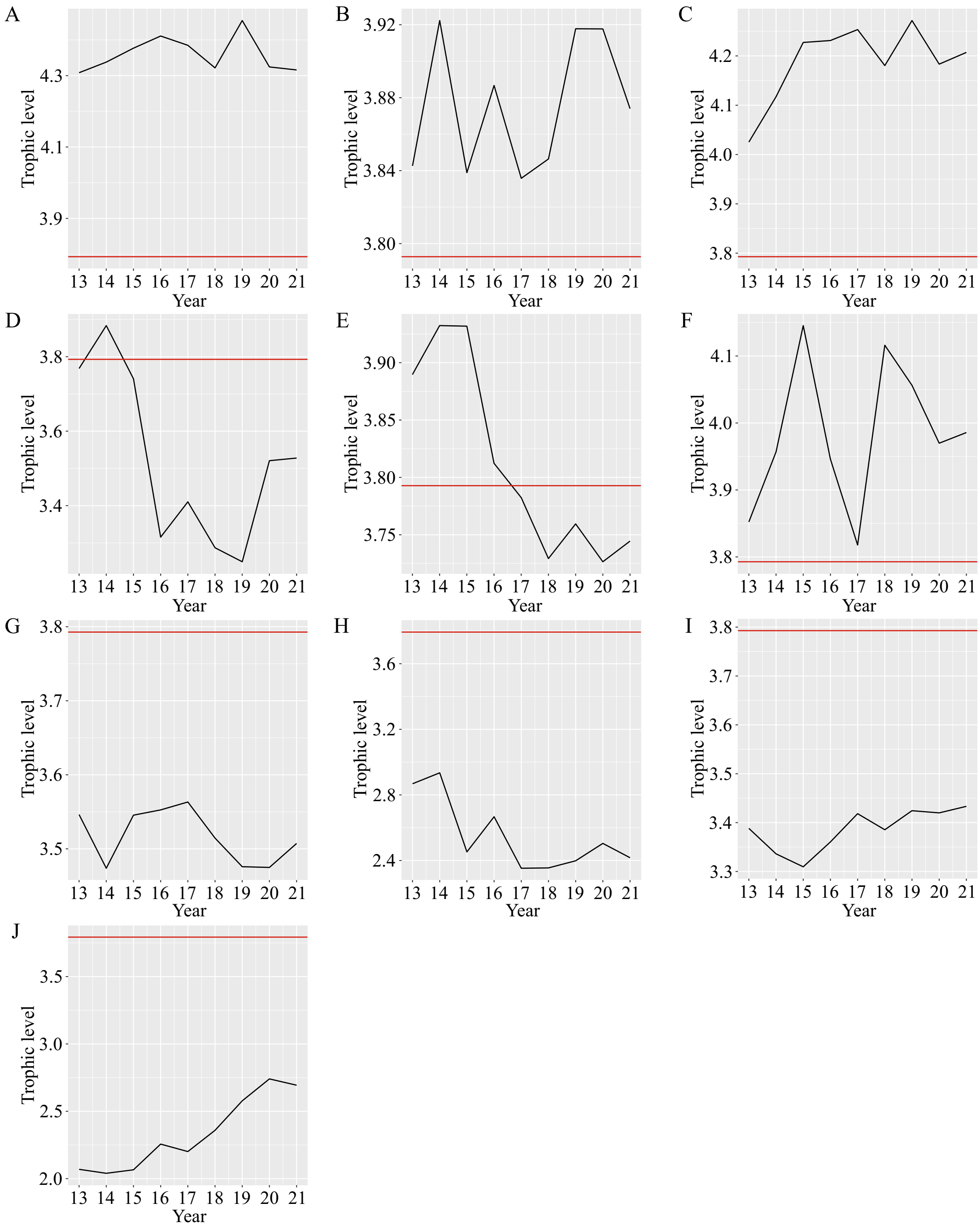

Figure 7. Time series of annual trophic level of the artisanal fishery (fishes) landings per fishing gear in the Colombian Caribbean in the period 2013-2021. A) Trolling lines. B) Beach seines. C) Hand lines. D) Harpoons. E) Gillnets. F) Beach seines. G) traps. H) Cast nets. I) Otter trawls. J) Hand collection. The red line is the global average trophic level in the dataset.

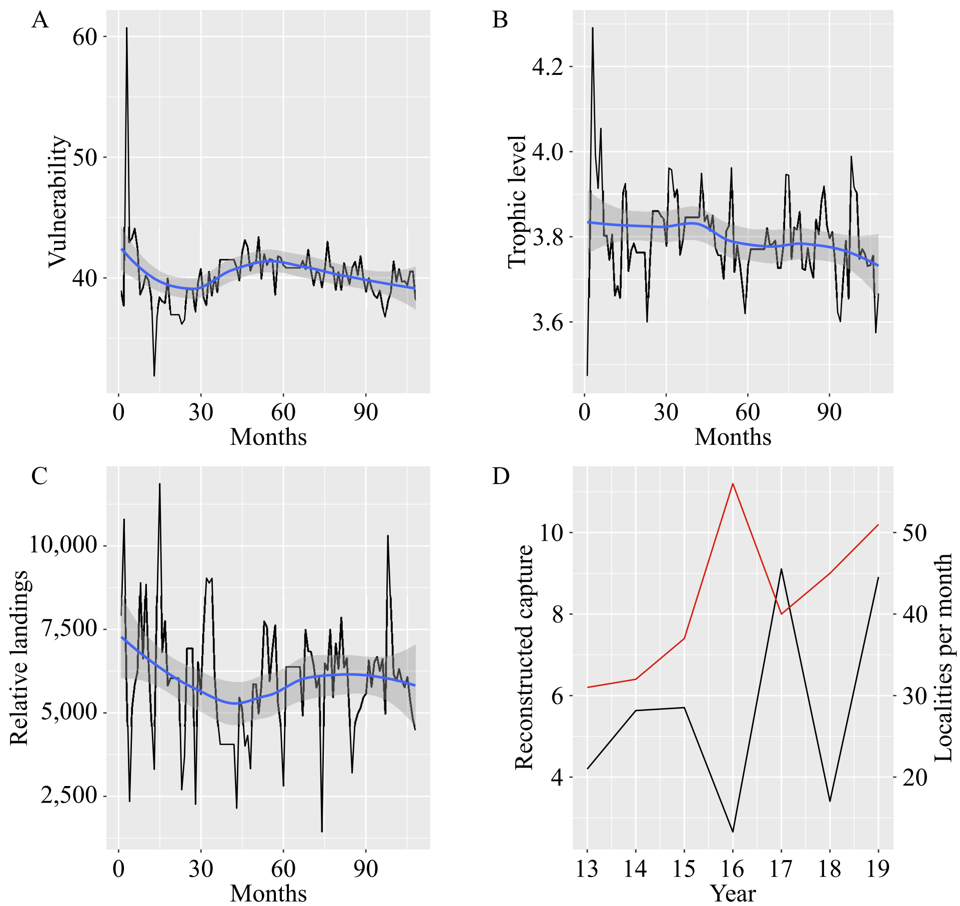

Figure 8. Constructed time series of vulnerability (A), trophic level (B), relative landings (month-site, C) at monthly intervals, and reconstructed catch (artisanal plus subsistence) from the Sea Around Us website versus mean number of locations with data in the database (D). The red line is the mean number of locations with data in the database and the black line is the reconstructed catch.

DISCUSSION

Total fish landing of the artisanal fishery reported here is a sub-estimation of actual catches in the Colombian Caribbean in the studied period. Not only because of blanks in the dataset, but also because there are no estimates of illegal fishing, and much fishing is unreported and unregulated. For instance, fishing for forage fish, for the local tourist industry, for commercial oceanariums, sport fishing and discards goes largely unnoticed (Duarte et al. 2013). Similar results are seen in catch reconstructions (see Pauly and Zeller 2016) for the Colombian Caribbean. Thus, according to Wielgus et al. (2010) for the period 1950-2004, there was 2.8 times higher total catch than officially reported in the Colombian Caribbean, while Lindop et al. (2015) estimated that that catch for the country, i.e. including the Pacific Ocean, was 2.3 times higher than reported. Updates are available to 2019 (Page et al. 2020; Pauly et al. 2020).

To test for the effect of irregular monitoring in the Colombian Caribbean on reconstructed catches corresponding to the artisanal fishery and subsistence, catch categories or types, were recovered from the Sea Around Us project website (Pauly et al. 2020). Thus, catches per year in the period 2013-2019 were calculated. As an indication of irregular monitoring, the mean number of locations per month with data in the dataset in each year of the same period was obtained, and both data were plotted in the same graph (Figure 8 D). The line match is not perfect, in particular for the year 2016 when the highest monthly mean number of locations was monitored, while the reconstructed catch shows its minimum, which looks anomalous. Nevertheless, the positive trend in both lines suggests that at least partial discordance between official catch reports and catch reconstruction is due to the rough number of monitoring locations per year not accounted for in official reports. To what extent this affects the accuracy of reconstructed catches is an open question.

The Sea Around Us website also offers a time series of trophic levels weighted by reconstructed catches in different forms but not disaggregated by type of fishery, which precludes a comparison. It may be interesting to signal, however, that while the trophic level of catches seems to have increased from 2010 to a peak in 2015, and then decreased to 2019 (Pauly et al. 2020), the trophic level of landings showed a significant decreasing linear trend from 2013 to 2021, which suggests coincidence.

Both trophic level and vulnerability of landings in the dataset decreased linearly in the period 2013-2021, corroborated by the Kendal test with the caveat that blanks in the series were filled with mean values. This means that the artisanal fishery globally is moving to fish down in the food web, i.e. either more species low in the food web are being targeted or landings of high trophic level and vulnerable species are reducing, causing the low trophic level and low vulnerable species to predominate in landings, or both. This worrisome finding should be counteracted by a correct administration of fishery resources allowing for catches of economic value while pursuing preservation of ecosystem integrity.

Evidence of change in the relative composition of catches relates to the importance of fish in time. Most species of importance to fishers during 2006-2007 (see table 14 from García 2010) did not reach the top ten in the dataset (Table 3). Common species in both lists are few: *Caranx crysus*, *C. hippos*, *Haemulon plumiery* (probably mentioned in the fisheries survey as Haemulidae; see table 14 from García 2010), and *Centropomus undecimalis*. Fish species from landings in the Colombian Caribbean artisanal fishery tend to have high trophic levels but low vulnerability (below 50, with few exceptions). Thus, fishermen are increasingly targeting fish species that, although predatory, show low vulnerability, i.e. sustain high levels of fishing mortality. The case of *Mugil incilis*, a species with low trophic level and vulnerability is notable, since it has gained central importance in the artisanal fishery, at least according to the dataset. Interestingly, *M. incilis* was used mostly as bait according to the 2006-2007 survey (see table 13 from García 2010). Another notorious case is that of the shrimp *Xiphopeneus kroyery*, a species caught as bait in the 2006-2007 survey (see table 13 from García 2010) that then became one of the most landed species in the period studied (Table 3).

Further evidence of harm to fish populations come from García and Ramírez (2016), who found evidence that heavy fishing on *Lutjanus synagris* has reduced its total length and concomitantly its length at first maturity, which is a sign of population deterioration. The fact that this species, the most important in the 2006-2007 survey (see table 14 from García 2010), has become a secondary item in the database, reinforces the inference of decadent stocks in this species (Table 3). Duarte et al. (2018) stated that the mean size of capture for *Caranx crysus* has diminished in the period 2013-2018, while Salazar-Pérez et al. (2020) reported marked differences in the composition of gillnet landings in 2008 and 2013.

In accordance with its global predominance, gillnets landings disaggregated by department showed the same pattern of dominance (Table 4). Excep-

Table 3. Comparison of ranking of species importance given by fishermen (2006 to 2007) (see table 14 from García 2010) to ranking of landing (Table 1) in the Colombian Caribbean artisanal database (2013 to 2021). Note that fishermen may refer with a single name to various species and that a species may have several names. Note that the shrimp *Xiphopenaeus kroyeri* was not mentioned in table 14 from García (2010) as important for the fishery.

Fish group (in Spanish)	Importance in García (2010)	Importance in landings
Pargo/pargo rayado/pargo chino	*Lutjanus synagris*	*Caranx crysos*
Sierra/carito/carite	*Scomberomorus regalis*, *S. cavalla*	*Caranx hippos*
Cojinua	*Caranx crysos*, *C. bartholomei*, *C. rubber*	*Mugil incilis*
Jurel	*Caranx hippos*, *C. latus*	*Haemulon plumieri*
Not mentioned	Not mentioned	*Xiphopenaeus kroyeri*
Robalo	*Centropomus undecimalis*, *C. ensiferus*	*Euthynus alletteratus*
Saltona/rubia	*Lutjanus analis*, *Ocyurus chrysurus*	*Ophistonema oglinum*
Mero	*Ephinepehlus* spp.	*Katsuwonus pelamis*
Bocacolora/ronco/conroncoro	*Haemulidae* spp.	*Centropomus undecimalis*
Sabalo	*Tarpon atlanticus*	*Trichiurus lepturus*
Raya/chucho	*Dasyatis americana*, *Aeobatis narinari*	*Scomberomorus brasiliensis*

tions are Choco, Cordoba and Magdalena, where handlines and beach seines are responsible for most landings (Table 4). The trophic level and vulnerability values time trajectories by departments are explained by the interplay of a differential suit of species landed by gear and the incidence of gears in each department. For instance, Antioquia shows the second lowest average values for vulnerability and trophic level among departments, which are very close to the average vulnerability and trophic level values of gillnets. Gillnets account for over 95% of Antioquia landing in the dataset (Table 4). Cordoba has the lowest level in average vulnerability and trophic level associated with high percentage contribution in landings of cast nets and hand collection (Table 4) that show low vulnerability values and trophic levels among gears.

In general, close monitoring, characterization and regulation of gillnets is the way to follow if sustainability of the artisanal fishery in the Colombian Caribbean is to be achieved with better revenues for fishers. The intervention, however, must be done considering the characteristics of each location and department that as demonstrated here behave differently. Neglecting other gears and fishing methods should be avoided. As shown here, gears using hooks tend to fish species with high vulnerability and trophic level (handlines, harpoons, set lines, trolling). In contrast, gears that fish by entangling (beach seines, cast nets, gillnets, otter trawls, traps) tend to fish species with low vulnerability and trophic levels. This fact should be considered.

Particular attention should be given to *Caranx crysus*, *C. hippos* and *Mugil incilis* populations that currently represent a significant proportion of landings in the dataset. Genetic, demographic, and ecological studies on these species are necessary to preserve its role in the Colombian Caribbean artisanal fishery.

Indicators used here have provided a valuable diagnosis of current situations of the artisanal fishery in the Colombian Caribbean and the impact of gears on the ecosystem by characterizing trophic levels and vulnerability to fishing of the suite of species they capture. However, a battery of auxiliary indicators would provide a complete and more contrasted picture, including indicators based on animal length. More research on ontogenic chang-

Table 4. Artisanal fish landings (%) per gear by Department in the Colombian Caribbean database.

Gear	Antioquia	Atlantico	Bolivar	Choco	Cordoba	La Guajira	Magdalena	Sucre
Gillnets	95.4	80.3	43.5	10.8	22.7	81.9	27.9	41.2
Beach seines	0	0.4	16.6	0	37.2	4.9	48.6	8.2
Handlines	0.8	10.7	22.7	88.6	7.8	2.2	9.7	33.3
Set long lines	0.8	7.6	0.6	0	1.7	3.0	5.2	3.1
Cast nests	< 0.1	0.1	12.4	0.1	8.1	0	< 0.01	7.6
Harpoons	2.9	0	0.9	< 0.1	1.7	3.6	0.8	5.6
Hand collection	0	0	0.7	0	16.7	0	< 0.1	< 0.1
Traps	0	< 0.1	< 0.1	0	1.9	4.0	< 0.1	0.2
Otter trawls	0	0	0	0	1.7	< 0.1	4.3	0
Trolling lines	0	0.6	2.1	0.3	< 0.1	< 0.1	2.9	0.3

es in fish diets and associated changes in trophic level is needed. Changes in trophic levels and vulnerability caused by heavy fishing that dwarf fish (Hollings et al. 2018) are a phenomenon to be considered. Thus, periodic reassessment of trophic levels and vulnerabilities of species will provide more realistic time trends than considering trophic levels and vulnerabilities as invariants.

An effort by the AUNAP should be made so that missing data becomes exceptional triggering the construction of long time series. Fishing gear names should be standardized and reduced to a more compact set of names in the dataset. Audits on taxonomic names assigned by monitoring personnel should be conducted regularly reducing potential bias in considering the high fish diversity in Colombian Caribbean waters.

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Author contributions

Camilo B. García: conceptualization, writing-original draft, writing-review and editing. Luis O. Duarte: data curation, writing-review and editing.

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