Artisanal and Small-Scale Fish Trap Fisheries from Tropical and Subtropical Reefs: Targeted Species and Conservation of Fish Stocks

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ABSTRACT

Portable fish traps are a popular gear in reef fisheries, mainly in tropical and subtropical regions. As fish traps can be highly non-selective, catch composition may be composed of a variety of species. Commonly, fishers target predatory fish species of high trophic levels. However, in areas facing overfishing, there is a tendency towards a decrease in the proportion of these species in catches followed by their substitution with miscellaneous fish species of lower trophic levels, previously considered as by-catch, but nowadays marketable. In addition, some highly valuable fish species are commercially extinct and are caught rarely. In this review, we aim to shed light on the species targeted across the main trap fisheries worldwide, as well as to identify characteristics of these species that may be feasible to use as conservation tools to preserve stocks. Although a considerable number of species gain fishers' attention, we have revealed a significant lack of information regarding their population dynamics. Almost 65 % of species of high fishery interest remain unexamined, and approximately 76.5 % of those that have been examined are decreasing in biomass or (and) abundance. Further research is required for the evaluation of the dynamics of fish populations and socioeconomic factors that influence fisheries management plans and decision-making for the retained and discarded species.

Keywords: Artisanal fisheries, By-catch species, Commercial species, Fish traps, Fishing down the web, Reef fishes

INTRODUCTION

Portable fish traps are used extensively within tropical and subtropical regions, and predominantly in coral reef environments (Mahon and Hunte, 2001). The performance and efficiency of a fish trap can be heavily influenced by the trap´s physical characteristics, its location of deployment, and the peculiarities related to its mode of operation as well as the biology and behavior of targeted fish species (Fogarty and Addison, 1997; Mahon and Hunte, 2001). Since fish traps are suitable for harvesting a variety of fish species within reefs, they have become a prevalent gear used in areas where structural complexity or heterogeneity of the seabed limits the use of other gear types including beach seines, trammel nets, and bottom trawls (Gobert, 1998).

Artisanal fish traps are mainly used to harvest demersal fish stocks. Commonly, trap fisheries target fish species of higher trophic levels (predators and mobile invertebrate feeders) belonging to the families Serranidae, Lutjanidae, Lethrinidae,

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and Sparidae, among others. Nevertheless, catch composition can be very diverse and may include over 100 species (Jiménez and Sadovy, 1997). The tendency to retain or discard species in the catch is influenced by the trap selectivity and the economic forces of the market (Jones *et al*., 2018). Additionally, artisanal fisheries are diverse in terms of management of catches, and while the "target species" are the ones providing maximum economic yield, the definitions of "by-product," "by-catch" and "discarded" species might be context- and site-specific (Jones *et al*., 2018).

While target species are clearly preferred to the others due to size, quality, state and origin (Zimmermann and Heino, 2013), "by-product species" have lower commercial value but are still marketable. By-catch are fish and marine life that are caught unintentionally, and may or may not be discarded, while "discards" are fish and other marine species that are thrown away (Zeller et al., 2017). Discards are composed of unwanted species, as well as marketable target and non-target species that cannot be retained due to economic or regulatory reasons (Tingley *et al*., 2000). Although fishers tend to target larger predatory fish species, the classification of species caught is flexible and highly dependent on the availability and frequency of occurrence of a particular species and the associated costs of fishing (Salas *et al*., 2004). The proportion of by-catch species may be substantial and comprise 50 % or more of the total catch (Ferry and Kohler, 1987).

While in some trap fisheries, appropriately placed regulations have succeeded in maintaining the resilience of harvested fish species and prevented overfishing, the collapse of fish stocks in others has caused a complete reorganization of local fish communities and ecosystem degradation in general (Freire and García-Allut, 2000; Hawkins and Roberts, 2004; Marshak *et al*., 2007). Current levels of fishing mortality in multiple fish stocks exceed the mortality at maximum sustainable yield (Tuda and Wolff, 2015; Colloca *et al*., 2017), which has led to the reduced abundance and biomass of fish species regardless of their commercial value, and to selective removal of larger fish individuals of all trappable species. Declines in abundance of primary target species and fishing down and through the food web has changed the perception of a "target" and "by-catch" species considerably during the past decades (Hawkins and Roberts, 2004; SAGARPA, 2012). Persistent changes in catch composition have resulted in a switch to targeting species formerly with no fishery interest. For instance, yellowtail snapper (*Ocyurus chrysurus*, Lutjanidae) had been considered as a by-catch in a specialized snapper fishery for *L. campechanus* in Mexican waters, but the exploitation of this species increased considerably after the decline of the primary stock (SAGARPA, 2012). In addition, rates of overfishing in some regions can be so high that fisheries collapse, e.g., the decline in key target grouper species in Bermuda led to a complete ban on the use of fish traps in 1990 (Burnett-Herkes and Barnes, 1996). Fish stocks in Jamaica and other Caribbean islands are overexploited to such an extent that fishers catch whatever is available and any fish larger than 10 cm is a target (Hawkins and Roberts, 2004). Nevertheless, redirection of fishing effort towards more resilient species of lower trophic levels (e.g., smaller and faster-growing herbivores and omnivores) does not necessarily reduce the pressure from the overfished populations. This is particularly common in developing countries, where poor enforcement and lack of compliance inclines fishers to exceed the quotas or maximum bag limits, especially if potential profit surpasses the potential fines (Luckhurst and Trott, 2015).

We herein compile the available information on coastal fish trap fisheries from tropical and subtropical reefs to: (i) identify the preferred fish species and families targeted in each ecoregion; (ii) determine their functional group; and (iii) check the conservation status and population dynamics of targeted fish stocks.

MATERIALS AND METHODS

Regardless of the great variety of gear referred to as a "fish trap", we herein focus on portable fish traps that specifically target coastal fish species; the gear is deployed to the seabed for a particular soak time and then recovered. This research is based on the analysis of scientific papers and relevant publications, including fishery reports and statistics from the National Oceanic and Atmospheric Administration (NOAA) and the Food and Agriculture Organization of the United Nations (FAO), published from 1980 to 2018. The list of target species given below (Table 1) was obtained from papers that analyzed current commercial fishing operators and from scientific surveys, if the fishing practices used in these surveys were the same as the ones applied by local fishers.

The areas presented herein (US Atlantic Coast, Caribbean, Australia, Canary Islands, Arabian Gulf, African East Coast and India) were chosen as the ones that had more full and comprehensive research on local fish trap fishing in the open-access journals. Although fish traps are extensively used on the South American coasts and in the Indo-Pacific, we did not include these areas because the published information regarding the target species and catch composition from local fish trap fisheries was too indeterminate, if present at all.

This study continues the research presented in Vadziutsina and Riera (2020) that compiled 297 papers dedicated to fish traps. Here we cover a subset of the compilation covering 58 papers that met our criterion that the authors stated the primary and secondary target fish species within the catch composition. In the case of the Caribbean region, due to the continuous extensive research and a great faunistic variability presented, only the species that were repeatedly stated as "preferred targets" or "of higher commercial importance" were included. Highly commercial species from the earliest papers (e.g., Nassau and Goliath groupers for the Caribbean) were included in the analysis even if their harvest was prohibited afterwards. Similarly, the final fish trap compilation included research on the species targeted in the US South Atlantic despite the fact that most research refers to Florida State waters, where trap fishing is banned today. Both primary and secondary target species were included in the analysis. Thereafter, mean trophic level and functional group of fish species as well as their conservation status and population dynamics were identified according to FishBase.org (Froese and Pauly, 2019) and the IUCN Red List (IUCN, 2020).

RESULTS

Target species

The identification of a target species within multispecies fisheries can be challenging, since fishers are able to modify fishing effort to emphasize species that would provide higher economic opportunities in a certain period. The high diversity of targeted and landed fish species as well as their limited spatial distributions, coupled with a lack of available information regarding by-catch and discards, did not allow us to conduct comparative analysis. However, at the family level, the similarity between the main targeted species was unquestionable (Figures 1 and 2).

Caribbean region

The Caribbean demersal trap fishery is the most diverse worldwide, with 14 fish families being targeted. However, the proportion of landings of fish with high commercial interest, e.g., snappers and groupers (Lutjanidae and Serranidae), is insignificant (Marshak *et al*., 2007). Fishers switched to targeting previously less desirable herbivorous and omnivorous species, such as grunts (Haemulidae), parrotfishes (*Sparisoma* spp. and *Scarus* spp.), surgeonfishes (Acanthuridae), and goatfishes (Mullidae). In some regions, fish belonging to Balistidae, Holocentridae, Ostraciidae, Chaetodontidae, Sparidae, Labridae, Carangidae and Pomacanthidae are also targeted (Wolff *et al*., 1999; Gobert, 2000).

Table 1. Summary of primary target species subdivided according to region, feeding guild, conservation status and population dynamics.

Family	Species	IUCN status	Feeding group	Population trend
US Atlantic				
Balistidae	*Balistes capriscus*	**VU**	MI	decreasing
Haemulidae	*Haemulon plumierii*	LC	MI/P	decreasing
	Haemulon aurolineatum	LC	MI/P	decreasing
Lutjanidae	*Rhomboplites aurorubens*	**VU**	MI/P	decreasing
	Lutjanus campechanus	**VU**	MI/P	decreasing
	Lutjanus griseus	LC	MI/P	unknown
Serranidae	*Centropristis striata*	LC	MI/P	stable
	Mycteroperca phenax	LC	P	stable
	Epinephelus morio	**NT**	MI/P	decreasing
	Epinephelus niveatus	**VU**	MI/P	decreasing
	Mycteroperca microlepis	LC	MI/P	decreasing
Sparidae	*Pagrus pagrus*	LC	MI/P	unknown
	Calamus nodosus	LC	MI	unknown
Australia				
Carangidae	*Pseudocaranx dentex*	LC	MI/P	unknown
Cheilodactylidae	*Nemadactylus douglasii*	NE	MI	unknown
Glaucosomatidae	*Glaucosoma scapulare*	NE		unknown
Kyphosidae	*Scorpis lineolatus*	NE		unknown
Labridae	*Bodianus unimaculatus*	LC		unknown
	Bodianus vulpinus	LC		unknown
Lethrinidae	*Lethrinus nebulosus*	LC	MI/P	unknown
	Lethrinus lentjan	LC	MI/P	unknown
Lutjanidae	*Lutjanus sebae*	LC	MI/P	decreasing
	Pristipomoides multidens	LC	MI/P	unknown
	Lutjanus malabaricus	NE	MI/P	unknown
	Pristipomoides multidens	LC	MI/P	unknown
	Lutjanus russelli	LC	MI/P	unknown
	Lutjanus bitaeniatus	NE		unknown
	Lutjanus vitta	LC	MI/P	unknown
	Pristipomoides typus	LC	MI/P	unknown
Monacanthidae	*Nelusetta ayraudi*	NE	MI	unknown
Serranidae	*Epinephelus multinotatus*	LC	MI/P	decreasing
	Epinephelus bilobatus	DD		unknown
	Plectropomus maculatus	LC	MI/P	decreasing
	Epinephelus bleekeri	**NT**	MI/P	decreasing
	Epinephelus areolatus	LC	MI/P	unknown
Sparidae	*Rhabdosargus sarba*	LC	MI	stable
	Acanthopagrus australis	NE	MI	unknown
	Pagrus auratus	LC	MI/P	decreasing

Table 1. Cont.

Family	Species	IUCN status	Feeding group	Population trend
Arabian Gulf				
Ariidae	*Arius thalassinus*	NE	MI/P	unknown
Carangidae	*Carangoides bajad*	LC	MI/P	unknown
	Gnathanodon speciosus	LC	MI/P	unknown
Haemulidae	*Plectorhynchus pictus*	NE		unknown
	Diagramma pictum	NE	MI	unknown
	Pomadasys kaakan	NE	MI/P	unknown
Lethrinidae	*Lethrinus nebulosus*	LC	MI	unknown
	Lethrinus lentjan	LC	MI/P	unknown
Lutjanidae	*Lutjanus gibbus*	LC	MI/P	unknown
	Lutjanus fulviflamma	LC	MI	unknown
	Lutjanus malabaricus	NE	MI/P	unknown
Sciaenidae	*Otolithes argenteus*	NE	MI/P	unknown
Serranidae	*Epinephelus tauvina*	DD	P	unknown
	Epinephelus coioides	**NT**	MI/P	decreasing
Sparidae	*Acanthopagrus latus*	DD	MI	unknown
	Argyrops spinifer	LC	MI	stable
	Acanthopagrus bifasciatus	LC	MI	unknown
India				
Latidae	*Psammoperca waigiensis*	NE	MI/P	unknown
Lethrinidae	*Lethrinus nebulosus*	LC	MI	unknown
Lutjanidae	*Lutjanus argentimaculatus*	LC	MI/P	unknown
	Lutjanus malabaricus	NE	MI/P	unknown
	Lutjanus rivulatus	NE	MI/P	unknown
	Lutjanus stellatus	NE	MI/P	unknown
Scaridae	*Scarus ghobban*	LC	H	unknown
Serranidae	*Epinephelus coioides*	**NT**	MI/P	decreasing
Siganidae	*Siganus canaliculatus*	LC	H	unknown
	Siganus javus	LC	H	unknown
Africa				
Haemulidae	*Diagramma pictum*	NE	MI	unknown
Lethrinidae	*Lethrinus mahsena*	NE	MI/P	unknown
	Lethrinus miniatus	LC	MI/P	unknown
	Lethrinus lentjan	LC	MI/P	unknown
	Lethrinus harak	LC	MI/P	unknown
	Lethrinus olivaceus	LC	MI/P	unknown
Mullidae	*Parupeneus macronemus*	LC	MI	unknown
	Parupeneus berberinus	LC	MI	unknown
	Parupeneus indicus	LC	MI	unknown
Scaridae	*Leptoscarus vaigiensis*	LC	H	unknown
Siganidae	*Siganus sutor*	NE	H	unknown
Sparidae	*Pterogymnus laniarius*	LC	MI	stable

Table 1. Cont.

Family	Species	IUCN status	Feeding group	Population trend
Canary Islands				
Mullidae	*Mullus surmuletus*	LC	MI	unknown
Scaridae	*Sparisoma cretense*	LC	H	unknown
Serranidae	*Mycteroperca fusca*	**EN**	MI/P	decreasing
	Epinephelus marginatus	**EN**	MI/P	decreasing
Sparidae	*Dentex gibbosus*	LC	MI/P	unknown
	Pagrus pagrus	LC	MI/P	unknown
	Pagellus acarne	LC	O	unknown
	Pagellus erythrinus	LC	O	unknown
	Sarpa salpa	LC	H	stable
Caribbean				
Acanthuridae	*Acanthurus bahianus*	LC	H	stable
	Acanthurus coeruleus	LC	H	stable
Balistidae	*Balistes vetula*	**NT**	MI	decreasing
Carangidae	*Caranx ruber*	LC	P	unknown
Haemulidae	*Haemulon album*	DD	MI	decreasing
	Haemulon plumierii	LC	MI/P	decreasing
Holocentridae	*Holocentrus rufus*	LC	MI	unknown
	Holocentrus adscensionis	LC	MI	unknown
Lutjanidae	*Lutjanus analis*	**NT**	MI/P	decreasing
	Lutjanus synagris	**NT**	MI/P	decreasing
	Ocyurus chrysurus	DD	MI	decreasing
	Lutjanus buccanella	DD	MI/P	unknown
	Lutjanus vivanus	LC	MI/P	decreasing
	Rhomboplites aurorubens	**VU**	MI/P	decreasing
Ostraciidae	*Acanthostracion polygonius*	LC	SI	unknown
Scaridae	*Sparisoma viride*	LC	H	unknown
	Scarus taeniopterus	LC	H	unknown
	Sparisoma aurofrenatum	LC	H	unknown
Serranidae	*Cephalopholis fulvus*	LC	MI/P	decreasing
	Epinephelus guttatus	LC	MI/P	decreasing
	Epinephelus striatus	**EN**	MI/P	decreasing
	Epinephelus adscensionis	LC	MI/P	decreasing

Note: (IUCN status: NE = Not Evaluated; DD = data deficient; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; the conservation status of near threatened, vulnerable, and endangered species are in bold); Feeding group: P = piscivore; MI/P = mobile invertebrate feeder/piscivore; MI = mobile invertebrate feeder; O = omnivore, H = herbivore

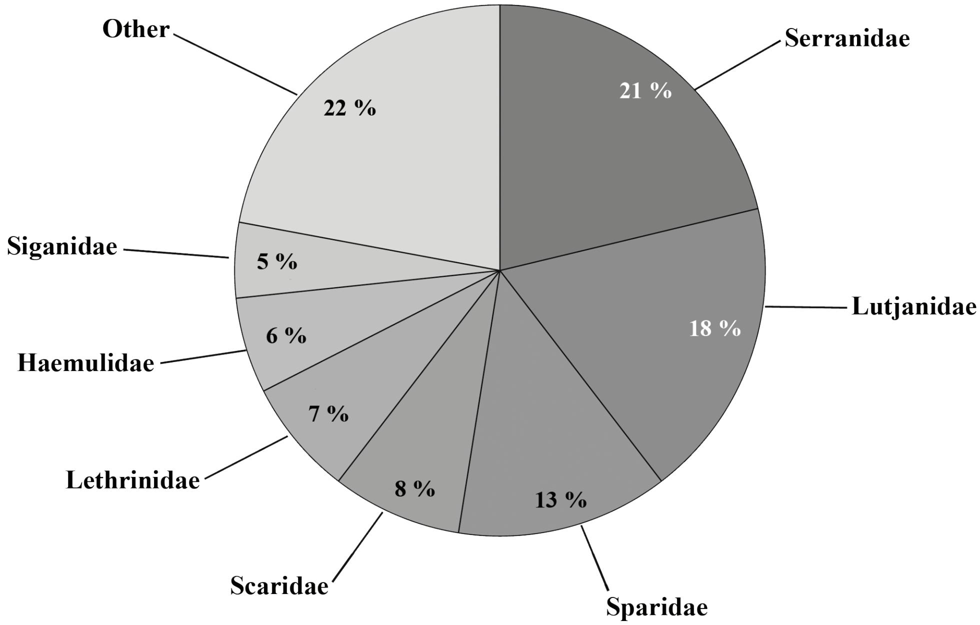

Figure 1. Main fish families targeted in trap fisheries.

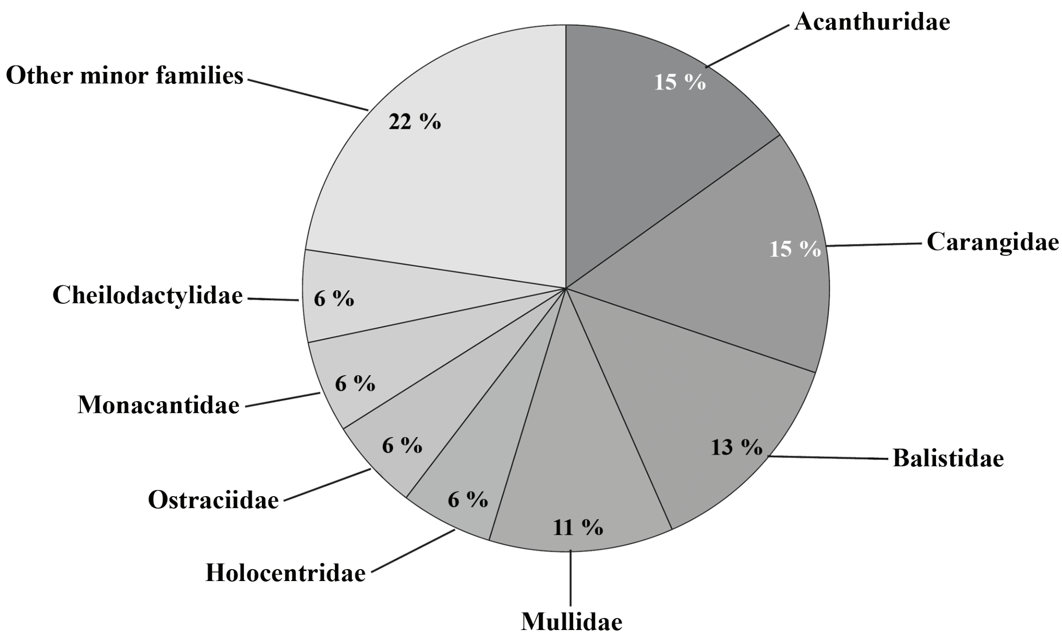

Figure 2. Secondary fish families targeted in trap fisheries.

US Mid and South Atlantic

In the demersal fisheries of the Mid-Atlantic Bight, black sea bass (*Centropristis striata*) is the main target species, for which proportion in the overall catch may reach 96 % (Eklund and Targett, 1991). Commercial fisheries in southeast US shelf waters are more diverse, and in addition to black sea bass, target the snapper-grouper complex and other species, of which vermillion snapper (*Rhomboplites aurorubens*, Lutjanidae), northern red snapper (*Lutjanus campechanus*, Lutjanidae), red porgy (*Pagrus pagrus*, Sparidae), grey triggerfish (*Balistes capriscus*, Balistidae), and scamp (*Mycteroperca phenax*, Serranidae) are among the most important (Bacheler *et al*., 2014; Bacheler and Smart, 2016).

Indian Coast and Seychelles

The families Serranidae, Siganidae, Lethrinidae and Scaridae are the most important in the catch of artisanal fishers on the Indian coast. The orange-spotted grouper (*Epinephelus coioides*, Serranidae), spangled emperor (*Lethrinus nebulosus*, Lethrinidae), white-spotted and streaked spinefoot (*Siganus canaliculatus* and *S. javus*, Siganidae) and blue-barred parrotfish (*Scarus ghobban*, Scaridae) are considered to be of high importance (Mariappan *et al*., 2016; Varghese *et al*., 2017), followed by the snappers *Lutjanus malabaricus*, *L. argentimaculatus* and *Pristipomoides filamentosus* (Lutjanidae) (Murugan *et al*., 2014).

Arabian Gulf

The orange-spotted grouper (*Epinephelus coioides*) and painted sweetlips (*Diagramma pictum*, Haemulidae) have been reported as key species in the United Arab Emirates (Grandcourt *et al*., 2011), followed by emperors (*Lethrinus lentjan* and *L. nebulosus*, Lethrinidae), porgies (*Argyrops spinifer* and *Acanthopagrus bifasciatus*, Sparidae) and jacks (*Gnathanodon speciosus* and *Carangoides bajad*, Carangidae). Similar target species were reported from Kuwait: *E. coioides* (Serranidae), *L. malabaricus* (Lutjanidae), *L. nebulosus* (Lethrinidae), and *Acanthopagrus latus* (Sparidae) (Chen *et al*., 2012).

African East Coast

One of the most important species along Eastern Africa is *Siganus sutor* (Siganidae). It comprises around 85% of total trap catches in Tanzania (Kamukuru, 2009) and is one of the most abundant species landed by the Kenyan trap fishery (Hicks and McClanahan, 2012). Among the other important species listed are *Lethrinus harak*, *L. lentjan*, *L. mahsena*, *L. miniatus* (Lethrinidae), *Leptoscarus vaigiensis* (Scaridae), and *Parupeneus macronemus* (Mullidae). Landings for the most commercially important species in this region were reported to have declined, while landings of other fish families (Scaridae, Acanthuridae, etc.) increased, followed by an increase in their market value (Kaunda-Arara *et al*., 2003).

Australia

Snappers and emperors are the main target species of the Pilbara region, in particular: *Pristipomoides multidens*, *Lethrinus hutchini*, *L. nebulosus*, *Lutjanus erythropterus*, *L. malabaricus* and *L. sebae*, followed by *Epinephelus multinolatus*, and *E. bilobatus* (Serranidae) (DEHA, 2004; Newman *et al*., 2008; Langlois *et al*., 2015). Targeted species clearly differ in New South Wales, since fisheries are composed of rubberlip morwong (*Nemadactylus douglasii*, Cheilidactylidae), silver trevally (*Pseudocaranx dentex*, Carangidae), ocean leatherjackets (*Nelusetta ayraudi*, Monacanthidae), pearl perch (*Glaucosoma scapulare*, Glaucosomatidae), and such sparids as tarwhine (*Rhabdosargus sarba*), silver seabream (*Pagrus aurata*), and yellowfin bream (*Acanthopagrus australis*), among others (Stewart and Ferrell, 2002; Stewart and Hughes, 2008).

Canary Islands

Fish stocks around the Canary Islands are considered to be overexploited (García-Mederos *et al*., 2015), thus only a limited number of species belonging to Scaridae, Sparidae, Monacanthidae, Pomacentridae and Mullidae can provide relatively high revenue. Specifically, the species *Sparisoma cretense* (Scaridae), *Mullus surmuletus* (Mullidae), *Dentex gibbosus*, *Pagellus* spp., *Diplodus* spp.

(Sparidae) and some others are of pivotal importance for artisanal fishermen (García-Mederos *et al*., 2015).

Conservation status and population dynamics

The present review reveals the significant lack of information concerning the state of fish populations (Table 1). Of 96 species included in the list of species of higher fishery interest, 62 (64.6 %) had no information on their current population trend. At the same time, from the remaining 34 species for which population dynamics was assessed, only eight were stable, while 76.5 % were decreasing (or 27 % of the total number of target species). Except for several species belonging to Haemulidae, Balistidae and Sparidae, the decreasing trend was strongly associated with Serranidae and Lutjanidae: 72 % and 35 %, respectively, of all the species listed as declining (Froese and Pauly, 2019; IUCN, 2020). The population trends of other targeted Lutjanidae species still remain unexplored. However, two serranid species (*Centropristis striata* and *Epinephelus tauvina*) are fished within the sustainable limits and thus maintain stable populations.

Although most of the species targeted by trap fisheries (62.5 %) are marked as “Least concern” in the Red List of Threatened Species, this category integrates species both with stable and decreasing population trends. Nevertheless, 41 out of 60 species within this category have not yet been assessed. Nassau grouper (*Epinephelus striata*, Serranidae) was the only species considered endangered, and 12 species, belonging to the families Balistidae, Serranidae and Lutjnidae, had “Vulnerable” or “Near Threatened” conservation status.

DISCUSSION

Over a hundred species may enter fish traps (Varghese *et al*., 2017), however only a limited number of species gain fishers´ attention. Among the examined small-scale fisheries, the number of primary and secondary target species ranged from nine (Canary Islands) to 25 (Australia), mostly consisting of piscivores and mobile invertebrate feeders (Table 1). We herein observed that, in some areas, fish trap fisheries highly depend on a single target species (e.g., *Centropristis striata* in US Mid-Atlantic, *Siganus sutor* in Seychelles, Kenya and Tanzania) (Kamukuru, 2009; Robinson *et al*., 2017; Samoilys *et al*., 2017).

High availability of *Centropristis striata* in the US Mid-Atlantic could be due to heavy management and particular biological characteristics, as well as overfishing of its direct predators, namely striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), and bluefish (*Pomatomus saltatrix*), that allows the species to withstand high fishing pressure and maintain a significant proportion in local catches (Robinson *et al*., 2017). As for *Siganus sutor*, Samoilys *et.al*. (2017) stated that the prevalence of this species was due to a drastic switch in catch composition due to high fishing pressure, where only the most resilient species survived; within a couple of decades a number of targeted fish species have gone commercially extinct and the previously highly multi-species artisanal fishery is now dominated by 2-3 herbivorous species regardless of the gear used.

While in some areas (e.g., Australia and Western Africa) the desired fish stocks can withstand high fishing pressure (Stewart and Hughes, 2008; Cullen and Stevens, 2017), other areas have experienced extensive declining trends in catches of the preferred species (Kaunda-Arara *et al*., 2003; Hawkins *et al*., 2007; Marshak *et al*., 2007; Chen *et al*., 2012). Long-term unsustainable harvesting may result in the depletion of fish species that are most susceptible to trapping (Hawkins *et al*., 2007). It was noted that a variety of target species of high trophic levels (e.g., Serranidae, Lutjanidae) are almost non-existent in catches in the Canary Islands, Kenya and the Caribbean (Hawkins and Roberts, 2004; García-Mederos *et al*., 2015; Samoilys *et al*., 2017). The problem of the absence of predatory species formerly of high abundance in real landings was particularly acute in the Caribbean, where, after the economic extinction of the primary target species (i.e., Nassau grouper, *Epinephelus striatus* and Goliath grouper, *E. itajara*, among others), local trap fisheries suffered a complete reorganization (Butler *et al*., 1993). In Jamaica and Puerto Rico, the reported rates of overfishing are so high that fishers catch whatever is available, rather than target a particular species (Hawkins and Roberts, 2004; Marshak *et al*., 2007).

Fish populations are subjected to significant fluctuations due to high fishing pressure and ecological contingencies (Bishop *et al*., 2008). Tromeur and Loeuille (2017) observed that the moderate removal of predators increases the resilience of the ecosystem and may promote the productivity of the fishery, while high fishing pressure abruptly destabilizes the ecosystem and slows down its recovery. Further, Hawkins and Roberts (2004) stated that in heavily fished areas non-target species did not increase in abundance despite the removal of its predators. Nevertheless, the impact of fisheries on the non-targeted fish species and their population trends in multispecies fisheries remains highly unexamined (Catchpole *et al*., 2005; Batista *et al*., 2009).

Declining trends in catches coupled with the decline in the number of species, especially in areas characterized by poverty and food insecurity, poses a real threat. Given the growing scarcity of fisheries resources, more attention should be paid to by-catch and discarded species. Exploiting currently discarded species is a strategy that potentially can compensate for a decline in revenues of the principal target species due to lower catches and contribute to economic sustainability of fisheries (Batista *et al*., 2009). In numerous trap fisheries facing overfishing, a sequential addition of previously less desirable species of lower trophic levels does occur. As catch composition and the corresponding discard composition fluctuates considerably due to changing socio-economic and environmental factors, it ultimately reflects economic incentives and management regulations (Catchpole *et al*., 2005). Tingley *et al*. (2000) stressed that "*lack of acceptability and marketability may be a local phenomenon; in other regions or at other times, the discarded species might be highly prized*." Salas *et al*. (2004) additionally pointed out that, on a small scale, fishers switch between alternative target species, depending on the monetary incentives and resource availability.

In subsistence trap fisheries from developing countries, species of little or no commercial value are not discarded but taken for domestic consumption (Gomes *et al*., 2014). In commercial small-scale fisheries in Sri Lanka, highly discarded species have little to moderate dietary importance at the household level (Jones *et al*., 2018). Batista *et al*. (2009) stated that some by-catch species (e.g., skates and flatfish) that were marketable but could not be sold with a good price due to low numbers in catches, were retained for personal consumption. Although the two examples mentioned above are from artisanal fisheries that use a different gear type (e.g., trammel, fyke and trawl nets), there is no reason to believe that a similar approach is not being applied by fish trap fishers.

The complexity of trap fisheries regarding their context and site specificity makes it difficult to assess the connections between the fishing pressure subjected to a particular species and its feeding guild or mean trophic level. The accurate evaluation of the population dynamics and conservation status are available for only a limited number of species of high commercial value (primarily larger piscivores and invertivores). Nevertheless, it is peculiar that none of the targeted herbivorous species herein considered were in decline, in contrast to predatory fish species. We are aware of the limitations of our approach regarding the population dynamics and conservation status of the examined fish species, as it is hardly possible to build on information provided exclusively by the IUCN Red List and FishBase.org. However, we could demonstrate once again the scarcity of data available regarding the state of fish stocks. Nevertheless, although on the global scale, stock assessments of particular species are often unavailable, local population trends of primary target species, namely *Siganus sutor* in Kenya, *Centropristis striata* in USA, *Lutjanus sebae* and *Pristipomoides multidens* in Australia, usually are well-documented as they gain significant attention from managers and the scientific community.

Traditional fishery management (e.g., gear restrictions, system of quotas, temporal and spatial closures) help to achieve a wide range of both fishery and conservation objectives (Hilborn and Ovando, 2014). Placement of marine reserves, no-take areas and their networks is a key strategy for marine conservation and should be widely incorporated into fisheries management plans (Bellwood *et al*., 2004; Roberts *et al*., 2005). Valdivia *et al*. (2017) claimed that abundance (and biomass) of larger predatory fish species, i.e., apex predators and piscivore-invertivores, is positively correlated with the absence of anthropogenic activities and reef complexity, while other environmental factors, such as temperature and ocean productivity had little or no effect. Nevertheless, it was stated that in the Caribbean marine protected areas, the actual predator biomass was as low as 10-40 % of the potential supporting capacity, demonstrating the rates of overexploitation (Valdivia *et al*., 2017).

Conservation of fish stocks and recovery of collapsed fish populations are paramount for ecologists and fishery managers. Despite investment of huge sums of money in conservation (James *et al*., 2001) and sophisticated management plans applied, globally the catches continue to decline (Pauly and Zeller, 2016), while collapsed and depleted fish stocks demonstrate little or slow recovery (Hutchings, 2000; Neubauer *et al*., 2013). Nevertheless, Hilborn and Ovando (2014) stated that scientifically assessed and well managed fisheries are stable or recovering rather than declining, proving that the lack of stock assessment and consequent lack of management is what drives fisheries to overexploitation.

Further research should be implemented for evaluation of fish stocks, switching focus from a single or several species of commercial interest to the entire local community. Monitoring community dynamics enables detection of early warning signs of a regime shift and allows prompt implementation of management measures to prevent the collapse of fish stocks and the ecosystem in general (Pedersen *et al*., 2017). Additionally, the development of new ecological theories and paradigms based on more complex and less predictive models that include anthropogenic and ecological contingences is needed, as actual ones fall short of expectations (Ale and Howe, 2010). Less deterministic ecological models will allow estimating the levels of sustainable harvest of fisheries resources with more precision, and reduce the probability of management failures that lead to further decline of the targeted fish stock and phase shifts of local communities (Ale and Howe, 2010).

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