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Original Article

Danger beyond the catches: a review of conservation threats posed by commercial and non-commercial fisheries in Guaratuba Bay, southern Brazil

P. T. C. Chaves[a]*

[a]Departamento de Zoologia, Universidade Federal do Paraná – UFPR, CP 19020, CEP 81531-980, Curitiba, PR, Brasil
*e-mail: ptchaves@ufpr.br

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Abstract

Comparisons between the implications of commercial and recreational fisheries for estuarine conservation have been a topic of debate. A review on the available data from Guaratuba Bay, Southern Brazil, identifies six threats for conservation, other than those concerning the fishing effort on target resources. Differing from the popular view that fishing for pleasure could be innocuous for the environment, the identified threats concern both commercial and non-commercial fisheries: (1) catching of reproductive individuals; (2) catch of big old fat fecund females; (3) loss and abandonment of fishing gears; (4) use of natural baits; (5) bycatch of rays, turtles and non-target finfish; and (6) bad practices associated with catch-and-release or discarding. Environmental disturbances and fauna depletion are detected as potential impacts. Recommended actions for estuary conservation include fishing closures in mangrove and shallow waters areas, release of fish larger than the critical size, and measures against abandoned, lost or otherwise discarded fishing gears.

Keywords: estuarine fisheries, fishing impacts, bycatch, ghost fishing, catch-and-release.

Perigo além das capturas: uma revisão das ameaças à conservação pelas pescas comercial e recreativa na Baía de Guaratuba, sul do Brasil

Resumo

As implicações das pescas comercial e recreativa para conservação dos estuários têm sido largamente discutidas. Uma revisão das informações disponíveis para a Baía de Guaratuba, sul do Brasil, identifica seis ameaças à conservação, que extrapolam aquelas concernentes ao esforço de captura sobre as espécies-alvo. Contrariando a visão comum de que a pesca de lazer seria inócua para o ambiente, as ameaças identificadas referem-se tanto à pesca comercial como à não-comercial: (1) captura de indivíduos em atividade reprodutiva; (2) captura de fêmeas grandes e mais fecundas; (3) perda e abandono de materiais de pesca; (4) uso de iscas naturais; (5) captura incidental de raias, tartarugas e peixes não-alvo; e (6) práticas inadequadas associadas a pesque-e-solte e descarte. Impactos potenciais são perturbações ambientais e depleção de fauna. Ações recomendadas para conservação do estuário incluem interdição de pesca no manguezal e áreas rasas, soltura de peixes com tamanho superior ao crítico, e medidas contra abandono, perda e outras formas de descarte de materiais de pesca.

Palavras-chave: pesca estuarina, impactos da pesca, captura incidental, pesca-fantasma, pesque-e-solte.

1. Introduction

How different are commercial and recreational fisheries with respect to risks for conservation? The multiple uses of estuaries and consequent risks for conservation include fishing activities, either for commercial (professional) or recreational purposes (França et al., 2012). Along the Brazilian coast, commercial landings are expressive in some bays and lagoons; however, in others, recreational catches surpass commercial ones (Freire, 2010). In fact, according to Hickley (1998), since more than two decades ago the stocks of species with a commercial interest, and the fishing effort associated to their capture, are decreasing in certain coastal and freshwater areas, being the non-commercial fisheries an important beneficiary of this new availability.

The general notion is that commercial fisheries, leading to higher catches, have stronger effects than recreational fisheries, and that commercial landings are responsible for depletion of stocks and environmental degradation. However, implications for conservation are not restrained to the volume of catches: other impacts on estuarine and inland fisheries include habitat change, reduced water quality, potential for local extinctions (Blaber et al. 2000; Alho and Sabino, 2011), or mortality of post-released individuals (Bartholomew and Bohnsack 2005); and they concern fishing for pleasure, too.

FAO (2012) alerts that even recreational fisheries, although essentially a quiet and often solitary activity, can disturb wildlife. Catch records in USA (Hickley, 1998) indicated that fishing as a sport caused a heavier significant damage to some threatened marine species, landing to captures of more than 50% of over-fished species along the Gulf of Mexico and Pacific Coast. Angling in Australia, comprising biomass removal, species introduction, and impacts on habitat through bait harvesting, has been recognized as ecologically significant and broad in scope (Bartholomew and Bohnsack, 2005). Concerning recreational fisheries removal in European marine waters, Radford et al. (2018) warned that for some species inclusion in stock assessments should be routine. Abundance of snapper *Chrysophrys auratus* (Forster, 1801) within the Seal Rocks no-take area, Australia, significantly declined by 55% due to recreational vessels performing illegally fishing within this area (Harasti et al., 2019).

It is recognized, then, that recreational fisheries also affects natural environments. This study discusses the implications of fishing activities, other than the volume of catches, for conservation in an estuarine system, the Guaratuba Bay, Southern Brazil.

2. The Guaratuba Bay

Placed in the Parana state coast (25°52'S, 48°39'W; Figure 1), this estuary is a 15 km east-west long and surrounded by mangrove and salt marshes. People living close to it vary from 60,000, permanently, to 300,000, in summer. The Guaratuba Bay, hereafter referred as GB, is submitted to physical, chemical, and biological pressures that include noise pollution and erosion of margins by boat movements, input of effluents from urban origin, as well as from fertilizers and other chemicals from banana and rice plantation, and oyster farming (Chaves, 2012).

For the present study, both fishery types, commercial and recreational, were analyzed and compared, considering studies on fish and fisheries in GB and marine adjacent zone ranging from 1994-2017. Antecedents from other estuaries were taken as reference to recognize and prevent threats and potential impacts.

3. Overview on Fish and Fishing in Guaratuba Bay

3.1. Fish

More than 75 fish species inhabit GB, with high abundance of anchovies, sardines, catfishes, snooks, mullets, croakers, mojarras, puffers, and flatfishes (Chaves and Correa, 1998; Chaves and Vendel, 2001). Many of them inhabit the estuary temporarily and reach a commercial size only after they move to the sea (Chaves and Bouchereau, 2000). Behavior and distribution of fish assemblage have been studied in different sectors according to the variety of continental and marine influences they are subject to (Bouchereau and Chaves, 2003). Two distinguishable areas are recognized: a western, continental area, primarily submitted to freshwater influence; and an eastern, marine area subjected to marine influence. Fish are more abundant in the first one, where species are resident instead of migrant. However, in marine area specific richness is higher, fish being predominantly migrants or having only a sporadic occurrence (Bouchereau and Chaves, 2003).

GB margins harbour at least 50 fish species, with an impoverishment of ichthyofauna in shallow waters, from the sea towards the inner continental area (Vendel et al., 2010). In spite of the low richness, a high density of fishes and motile macroinvertebrates has been reported in inner mangrove areas, supposedly related to the greater protection afforded by vegetation. In general, aerial roots, tree trunks, and fallen branches of the mangrove forests supposedly attract fish, providing food availability and refuge against predation (Laegdsgaard and Johnson, 2001).

Ichthyofauna composition and abundance vary throughout the year, a consequence of both seasonal and

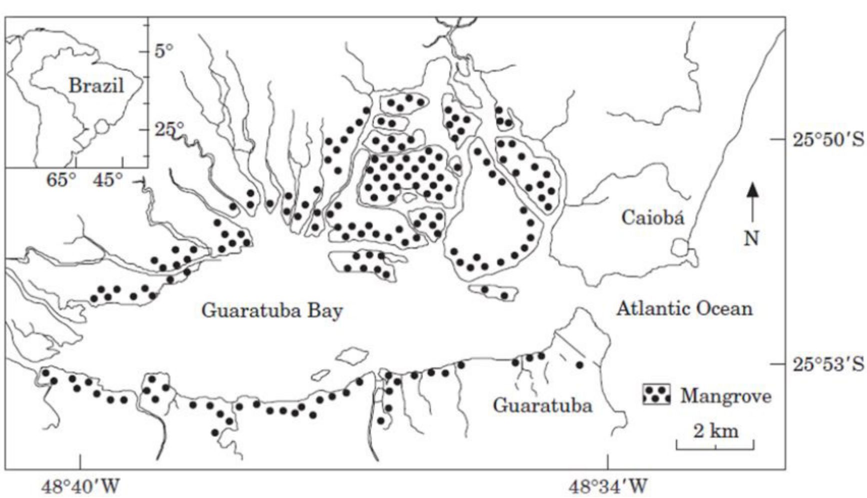

Figure 1. Map of Guaratuba Bay, Southern Brazil.

casual movements as well as of demographic oscillations in birth/mortality rates (Chaves and Bouchereau, 1999). Such strategies seem to allow fish species to cohabit the estuary, each one of them adapted enough to regular fluctuations in environmental conditions. As stated by Blaber and Barletta (2016), in South America estuaries connectivity is a well documented fact, and environmental impacts can reflect on fish assemblages of neighbor zones, continental or oceanic.

3.2. Fisheries

Subsistence fisheries occur in GB headwaters, where residents perform agriculture, subsistence fisheries, and offer fishing guide services. Commercial and recreational fisheries, however, are much more common, and constitute the source of knowledge exposed below.

3.3. Commercial fisheries

In GB, small-scale fishermen mostly employ wooden canoes 6-10 m long, equipped with 25 HP engines (Chaves et al., 2002). Paddle-propelled canoes <5 m are also utilized. Two types of fishing gear are common: gillnets and cast nets. Gillnets have a 70-140 mm mesh opening and a height of 2-3 m, with a total extension >200 m. They work on the bottom and surface, in a semi-circular design, and are mobile, moving slowly with tidal currents. Fishermen remain close to the nets, making sounds in water by starting the motors or beating the paddles in water and on the boat; this stimulates fish movement and their entrapment. Other gillnets are fixed. Cast nets are used to catch fish and small shrimps; shrimps are sold as live bait to recreational fisheries. Specifically for shrimps, fishermen also employ the '*gerival*', a conical net with 30 mm mesh opening and 3 m diameter opening. A non-motorized canoe, moved by natural currents, drags the '*gerival*' (Table 1). Although motorized trawling is prohibited inside GB, and gillnet fishing in contributing rivers, infringements have been reported.

Table 1. Fishing gears employed in commercial and recreational fisheries in Guaratuba Bay, and correspondent main target resources.

Fisheries type	Fishing gears	Target resources
Commercial	gillnets cast nets passive trawling	fish for sale shrimps for bait
Recreational	line and hooks	for food for pleasure for tournaments

Chaves et al. (2002) have also found that commercial fisheries is a familiar tradition, and most of the fishermen use their own boat. Fish market is organized directly by the families, either in markets organized by the village or in their own homes. At home, native or farmed shrimps (Henke and Chaves, 2017) are stored in floating semi-submerged boxes along the estuary margins until their purchase.

Fishermen search for marketable fish, which belong mainly to 12 species (Table 2). According to Chaves et al. (2002), seven of these species show an occasional occurrence in GB, inhabiting the estuary in an irregular non-predictable manner; four others are migratory and are caught in the estuary during some stage of their life cycle; only a catfish is known as an estuarine resident, completing its life cycle in the estuary.

Table 2. The 12 main fish species subject of commercial fisheries in Guaratuba Bay, with local common name, according to their status of occurrence in the estuary: occasional, migratory or resident.

Occasional	Migratory	Resident
Pomatomus saltatrix[1] (Linnaeus, 1766) anchova	*Centropomus parallelus*[1] Poey, 1860 robalo peva	*Genidens barbus*[2] (Lacépède, 1803) bagre
Cynoscion acoupa[1] (Lacépède, 1801) pescada amarela	*Centropomus undecimalis*[1] (Bloch, 1792) robalo flecha	
Cynoscion leiarchus[1] (Cuvier, 1830) pescada branca	*Mugil liza*[3] Valenciennes, 1836 tainha	
Isopisthus parvipinnis[1] (Cuvier, 1830) pescadinha	*Mugil platanus*[3] Valenciennes, 1836 parati	
Menticirrhus americanus[1] (Linnaeus, 1758) betara		
Micropogonias furnieri[1] (Desmarest, 1823) corvina		
Trichiurus lepturus[1] Linnaeus, 1758 espada		

[1]Perciformes; [2]Siluriformes; [3]Mugiliformes. Source: Chaves et al. (2002).

3.4. Recreational fisheries

Personal observations have found that metal boats equipped with 25 HP engines are employed by fishermen in competitive tournaments or during leisure times. Rods are authorized and baits can be bought at local commerce outlets (penaid shrimps) or obtained in sandy beaches close to the Bay (mole crabs and small Thalassinidea crustaceans) (Henke and Chaves, 2017). Shrimps vannamei, *Litopenaeus vannamei* (Boone, 1931), originated from the Pacific Ocean and largely cultivated in Brazil (Loebmann et al., 2010), are also used as natural bait in GB.

The most common recreational catches are Perciformes, mainly snooks, kingcroaker, whitemouth croaker, mojarras, largehead hairtail, black drum, pompano and black margate (Table 2); Siluriformes and Pleuronectiformes of uneatable species. Daily yield ranges from 0 to 30 units per angler; in competitive tournaments along 2016, snooks were the most common fish registered in number. Whether to release after catching depends on the fish variety, individual size, and catch abundance (Henke and Chaves, 2017).

Unlike commercial fisheries, recreational fisheries includes small-sized species. Most of them are estuarine residents.

4. Fishing Threats and Potential Impacts

Recreational fishermen declare fish abundance in GB is decreasing, and attribute it to a supposedly excessive effort with commercial aims (Henke and Chaves, 2017). Historical records on size and age composition, or total biomass per species, are not available for GB. Data provided by Iate Clube Guaratuba (2019; personal observation) concerning the common snook, *Centropomus undecimalis* (Bloch, 1792), caught by anglers in annual tournaments, show that the mean individual weight has declined by 15% from 2012 to 2016 (Figure 2). It coincides with an expressive increase in number of participants, which, *a priori*, would increase the chance of catching large-size individuals. In fact, in these five tournaments the largest snook caught each year reached, respectively, 6,190, 3,585, 3,170, 3,010 and 6,280 g; but, relatively to the number of participants (92, 72, 154, 542 and 716), these values corresponded to 67, 49, 21, 6 and 9 g/angler, respectively. It means that, proportionally to the number of anglers, the largest snooks are shortening.

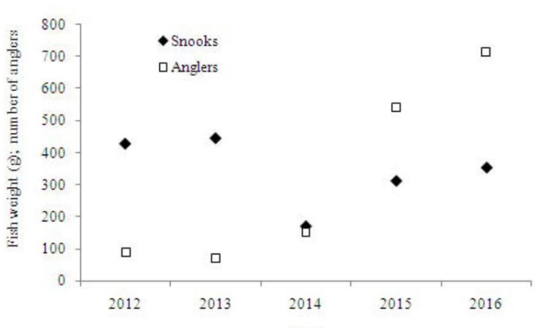

Figure 2. Mean weight of snooks, *Centropomus undecimalis*, caught by anglers in annual tournaments in GB, period 2012-2016, and number of participants having caught snooks. For each angler, only the largest individual was considered. Source of data: Iate Clube Guaratuba (2019).

In this study, six threats for conservation associated to fishing practices have been examined, considering their commercial or recreational objective. They show how, at the present, routine events, other than the catching effort by itself, can be concerned in this presumed reduction of fish availability in GB.

4.1. Catching of individuals in reproductive activity

Excepted for catfish *Genidens barbus* (Lacépède, 1803) and snooks, *Centropomus parallelus* Poey, 1860 and *C. undecimalis* (Bloch, 1792), all species exploited by commercial fisheries in GB spawn in marine waters (Chaves and Bouchereau, 1999). In this sense, the impact of fisheries on reproduction would be limited. However, mature individuals of many species use the estuary temporarily: e.g. largehead tail, *Trichiurus lepturus* Linnaeus, 1758; shortfin corvine, *Haemulopsis corvinaeformis* (Steindachner, 1868); and croacker, *Micropogonias furnieri* (Desmarest, 1823); it makes catches a major threat to their reproductive cycle (Chaves and Bouchereau, 2000). Recreational fisheries applies a lesser fishing effort, but it also targets small-sized species. Chaves and Bouchereau (2000) estimated that about 40% of species found in the mangrove area use this habitat as spawning sites. Small-sized species are particularly vulnerable to recreational fisheries.

Species maturing and spawning in GB are mostly r-strategists, *sensu* Winemiller (1992). They are multiple spawners and produce numerous small eggs (Chaves and Bouchereau, 2000). Parental care is not reported, except for catfishes, mouthbreeders with large eggs and low fecundity. It is argued that under increased mortality due to fisheries pressure, species that mature at a smaller size and younger age are more successful than fish that postpone reproduction (Van Overzee and Rijnsdorp, 2014). In *G. barbus*, commonly found in all types of fisheries, spawning peaks concentrate in spring-summer (Chaves, 1994), but in many groups reproductive activity, including maturation, extends throughout the year. Thus, whenever fisheries take place in GB, a potential impact on fish reproduction exists. Even effects concerning noise produced by fishing vessels or gears are not negligible, once they interfere on fish aggregation (Robertis et al., 2010) and with the sounds produced by species during courtship (Van Overzee and Rijnsdorp, 2014).

Beside catches of maturing individuals, impacts on reproduction can include habitat destruction and a higher chance of capture of the larger age classes, particularly in species that form aggregations (Van Overzee and Rijnsdorp, 2014).

4.2. Catching of BOFFFs: Big Old Fat Fecund Females

Length at first maturation is currently used as a fisheries management tool in policies that recommend minimum sizes for capture. Catching of big individuals is usually favored. Chaves et al. (2017) studied the relationships between fecundity and body size, and fecundity relative to the gonad weight and fecundity in 17 species occurring in GB and adjacent marine zone. Results showed that fecundidty increases with fish size and an inverse relationship between fecundity and gonad weight, indicating that species with high fecundidty have smaller oocytes than species with low fecundidty. Strategic sizes for stock conservation correspond to sizes with maximum fecundity. One of the outputs of this study was to recognize that fecundity values are very different between individuals within a certain species (Figure 3), primarily depending on fish size.

In South Carolina estuaries, McDonough et al. (2003) found a high degree of variability in the length at age relationship, and stated that a stronger relationship of fecundity to fish size allowed a much better predictive model for potential fecundity. No retention of the largest individuals can increase the reproductive capacity of stock. For the giant perch, *Lates calcarifer* (Bloch, 1790), which reaches 1200 mm total length, minimum and maximum sizes for capture are recommended to be 550 mm and 800 mm, respectively, in Australian estuaries (Australia, 2018). In GB, maximum size is applied to the fat snook, *C. undecimalis*, a hermaphroditic species, only.

4.3. ALDFGs: Abandoned, Lost and Otherwise Discarded Fishing Gears

In GB, gillnets of commercial fisheries are frequently moved out, attached to continental and estuarine debris and mangrove trees loaded from margins during periodic floods (Chaves and Robert, 2009). Under these circumstances, derelict fishing gears give risk to ghost fishing, with detrimental impacts on fish stocks, endangered species, and the benthic environment. Although FAO (2012) states that the ability of *ALDFG*s to continue fishing is a problem mainly confined to large-scale commercial fisheries operations, it also concerns recreational fisheries. In GB, 12 fishing gears on average are lost per day, comprising hooks, metallic weights, floaters, and luminous baits (Henke and Chaves, 2017). Losses occur mainly at rocky zones, where fishing lines are more susceptible to be cut. Risks of ingestion by fish persist, as proposed by Ferreira et al. (2018) who studied an estuarine predator fish in Northeastern Brazil,

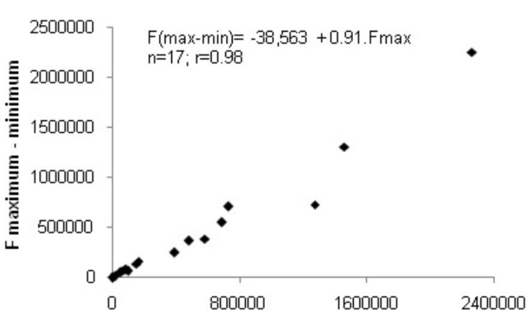

Figure 3. Values of difference between maximum and minimum fecundity (F) in 17 finfish species of Guaratuba Bay, plotted according to the maximum F (Fmax) found in each one. Source: Chaves et al. (2017).

with several types of microplastics found in gut contents, including possible fishing line fragments.

*ALDFG*s are a subject underexplored in Brazilian estuaries. In Chesapeake Bay, 20% of the approximately 800,000 fished hard crab pots become derelict each year, and may self-bait and ghost fish for several year (Scheld et al., 2016). Besides fishing gears, other discards originated from fishing activities can affect the estuarine environment. This is the case of soft plastics, as reported by Henke and Chaves (2017) during recreational fisheries activity in GB. Discarded plastic bags can swell in water, and can be ingested by fish (Ferreira et al., 2018) and other animals (Bugoni et al., 2001).

4.4. Use of natural baits

In GB, use of natural baits is preferred by anglers instead of artificial ones (Henke and Chaves, 2017), the artificial baits being almost restrict to tournaments. Natural baits can cause environmental disturbance as result of stock depletion in autochthonous populations of invertebrates, excessive influx of natural matter, and new genotypic introduction; the risks are discussed below.

I. Stock depletion of autochthonous populations. The most common native baits used in GB are: white shrimps *Litopenaeus schmitti* (Burkenroad, 1936), extracted by commercial fishermen using cast nets; mud shrimps (‘corruptos’, Thalassinidea), extract by digging or pumping; and mole crabs, the ‘tatuíras’, *Emerita brasiliensis* (Schmitt, 1935), being *Emerita* extracted by recreational fishermen themselves. Fishermen declare that at the local beaches adjacent to GB up to 300 ‘corruptos’ are collected 30 minutes before fishing. They also afirm that their availability is decreasing. Regarding meiofauna extraction, FAO (2012) cites risks of habitat disturbance and interaction with non-target species;

II. Influx of organic matter by fish attractor devices (*FAD*). In GB headwaters, local people use to install small *cevas*, an intentional deposition of organic materials in water aiming to attract fish. This practice is mentioned by FAO (2012) as another possible source of environmental problems by deterioration of water quality and reduction in benthic fauna;

III. Use of non native species. *Litopenaeus vannamei* (Boone, 1931) is a penaid shrimp originated from Pacific Ocean and introduced in Brazilian aquaculture (Loebmann et al., 2010). It is produced under confinement in inland farms and sold to be used as live bait. As stated by Nathan et al. (2014), with respect to Great Lakes, a potential exists for non native species introduction to be accidentally captured during bait harvests and, due to imperfect detection capabilities, to be sold unknowingly to anglers.

4.5. Bycatch

Incidental catch is a problem of fisheries worldwide, particularly in tropical environments due to their highly diversified fauna. In GB, bycatch concerns fisheries of commercial and recreational types. In autumn, commercial fisheries catches mullets (*Mugil* spp.), which form dense aggregates inside the bay. Gillnets and cast nets present low selectivity and catch charismatic species, such as rays and turtles, and non-target finfish (Pina and Chaves, 2005). Recreational fishermen are less specific while choosing their catches, and normally all species are accepted. Even so, rays, small fish, and non-edible ones, as flatfish and puffer fish, are often released immediately after catching. Although alive, freed fish hardly recover, as discussed below, in *Bad practices of catch-and-release*.

Bycatch is a global problem in estuaries. In pink shrimp fisheries using fixed nets in West African lagoons and estuaries, vast numbers of non-marketable juvenile fishes that use estuaries as nursery grounds are caught (Blaber et al., 2000). In Australian estuaries, incidental captures by gillnets depend on the fisheries focus (Gray et al., 2003): when fisheries aim the dusky flathead, all other organisms apart from it and the mud crab (e.g. sea mullet and yellowfin leatherjacket) must be discarded. On the other hand, in multispecies fisheries, the discards, comprising species with little commercial value, include undersized individuals of several target species.

4.6. Bad practices of catch-and-release

Mandatory or voluntary releases are common in recreational fisheries, but fish freedom does not mean that the fish are alive. The main risks are barotrauma, hook ingestion, mouth injuries and stress during manipulation (Chaves and Freire, 2012). Although only recreational fisheries are concerned by formal *catch-and-release* (hereafter C&R), in commercial ones many animals with no commercial interest are returned to water alive. Landings do not accurately reflect total mortality, and post-release mortality represents a considerable portion of total fishing mortality (Bartholomew and Bohnsack, 2005). Summing both commercial and recreational categories and the high intensity of fishing in an estuary, the mortality of non-retained fish can causes serious implications for conservation.

In GB, fish like puffers (*Sphoeroides* spp. e *Chilomycterus spinosus* (Linnaeus, 1758)) and small flatfish (Pleuronectiformes) are often caught in cast nets. A survey with 77 anglers in GB (Henke and Chaves, 2017) showed the reasons they consider while deciding whether to release their catch. A total of 79% of anglers release part of their catches, and 13% release them integrally. In general, the decision for releasing depends on: fish size (53%), benefiting those individuals with a small size, the illegal sizes here included; fish type (8%), releasing individuals with a lesser culinary interest; or mixing both abundance and size (5%), in order to avoid retention of a small number of individuals, mainly when they have a small size.

For recreational fisheries, Bartholomew and Bohnsack (2005) found post-releasing mortality rates to be 18% for salmonids, similar between marine and freshwater species. According to Hickley (1998), for a fisheries management, common sense would suggest that further application of C&R encourages the biological, economic, and social sustainability of recreational fisheries. However, actually, by C&R fish are not released, but harvested. FAO (2012) states that the ability in recreational fisheries to take care of individual captured fish, also in the process of rapid kill, represents a major difference to commercial fisheries (e.g. fish dying slowly due to hypoxia after trawling or in gillnets) and allows recreational fisheries to reduce the amount of harm induced to the absolute minimum.

The survival rates post-discarding concern commercial fisheries as well. In Australian estuaries, survival of some fish species originated from gillnet bycatch reached 82%, although several important species such as tailor and mulloway displayed low rates of survival, less than 58% (Gray et al., 2003). Authors note that survival rates vary between periods of warm and cold water.

Other fishing-related sources of impact, not commented above, are known in estuaries, like eutrophication by way of discharge of fish-processing wastewater (Blaber et al., 2000), and microplastics (Azevedo-Santos et al., 2019), including those originated from fragmentation of fishing gears (Ferreira et al., 2018). Both are applied to GB, and the second one concerns to non-commercial fisheries, too.

5. Conclusions and Recommendations

In the estuary, commercial and non-commercial fisheries share similar threats for conservation, in addition to the effort on the target species itself. They comprehend impacts on fish reproduction, removal of strategic sizes, production of fishing-related debris, an unsuitable use of baits, occurrence of incidental captures and bycatch, and losses following post-capture/angling discard or release. A summary is provided in Table 3. Also non-commercial fisheries is concerned, differing from the popular view that fishing for pleasure would be innocuous for the environment.

Particularly in ecosystems very susceptible to disturbances, like estuaries, fishing activities require an accurate management. In GB, attempting to reach commercial and non-commercial purposes, recommended actions to minimize threats for conservation are: (i) fishing closures in mangrove and shallow waters areas, mainly in spring and summer; (ii) releasing of the largest individuals in each species; (iii) adoption of preventive and mitigating measures against ALDFG, including removal derelict gear programs; (iv) incentive for using artificial baits instead of natural ones; (v) improvement of technological and educational measures to minimize capture and mortality of non-target species and illegal sizes; and (vi) adoption of measures to increase survival of the discarded/released individuals.

Table 3. Six threats derived from fishing activities in Guaratuba Bay, the potential impacts they generate, and procedures recommended for threat prevention and impact reduction.

Threats, fisheries type concerning	Potential impacts	Recommended procedures
1- Impacts on reproduction Mature (C,R) and pre-spawning (R) fish capture	Stock depletion	Fishing closures in mangrove and shallow waters areas, mainly in spring and summer, can help to protect maturing and spawning individuals. Van Overzee and Rijnsdorp (2014) add that such action may reduce risk of over-exploitation in species forming large spawning aggregations and effects on spawning habitats, as noise and chemical pollution, which affect egg survival and newborns welfare.
2- Removal of strategic fish sizes Capture of individuals with higher fecundity (C,R)	Stock depletion	No-retention of small fish is usual in fishing routines, and law enforcement acts in this sense. However, in 2012 a new Brazilian policy was adopted, which aimed to protect the best reproducers. Moreover, research on strategic sizes to be released after catching is stimulated.
3- *ALDFG*s Gillnets (P); hooks, weights, floaters, luminous baits (R)	Water pollution; stock depletion	Educational campaigns are efficient in reducing abandonment and discards of fishing gears. Recreational fishermen must be persuaded to avoid rocky zones, and commercial fishermen, to keep derelict gears in appropriate dispensers. Scheld et al. (2016) recommend a combination of preventative and mitigating measures; mitigating measures include removal of derelict gear programs.
4- Natural baits Shrimp extraction (C); crustacean extraction from sandy beach; non native species introduction (R)	Genotype introduction; stock depletion	Artificial baits are more expensive than natural ones, but their use may reduce beach fauna extraction and use of vannamei. Additionally, artificial baits are recognized by fish during catch-and-release, and their rejection increases fish survival (Bartholomew and Bohnsack, 2005; Chaves and Freire, 2012).
5- Bycatch Rays, turtles, non-target finfish (C); rays and small, non-edible fish (R)	Stock depletion	Apart from spatial and temporal fishing closures, solutions include the development of more selective nets and fishing practices that minimize the capture and mortality of non-target species and undersized individuals of the target ones. Discard levels may be lower and subsequent mortalities of fish may also be reduced because of the decreased soak times. Based on gillnet fisheries in Australian estuaries (Gray et al., 2003), larger mesh sizes can result in fewer bycatch.
6- Post-discard or post-release mortalities Undersized fish and protected fauna (C,R), fish with no commercial value (C)	Stock depletion	Action must be taken to increase survival of animals discarded/released. Examples are decline in the time taken by anglers to place fish into bucket, use of barbless hooks (Hickley, 1998), and avoid of C&R during reproductive period (FAO, 2012). For tournaments, Mannheim et al. (2018) suggest improving angler knowledge, behavioral modelling, rewards and penalties. Delimitation of exclusive areas for recreational fisheries can improve survival rates post-releasing, avoiding fish exposure to commercial, intensive effort (Bartholomew and Bohnsack, 2005). In commercial fisheries, reduction of the permitted maximum setting time (overnight) of gillnets can increase survival rates of bycatch post-discarding (Gray et al., 2003).

C = commercial fisheries; R = recreational ones.

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