Catch, bycatch and discards of the Galapagos Marine Reserve small-scale handline fishery

Johanna S Zimmerhackel, Anna C Schuhbauer, Paolo Usseglio, Lena C Heel, Pelayo Salinas-de-León

Fisheries bycatch is one of the most significant marine conservation issues as valuable fish are wasted and protected species harmed with potential negative ecological and socio-economic consequences. Even though there are indications that the small-scale handline fishery of the Galapagos Marine Reserve has a low selectivity, information on its bycatch never has been published. We therefore assessed the bycatch of the Galapagos handline fishery by estimating the bycatch ratio, determining species compositions of landings and bycatch, and identifying fishers' reasons for discarding certain individuals using onboard monitoring and interview data. Moreover, we used interview surveys to reveal historical trends in the bycatch ratio. The estimated bycatch ratio of 0.40 confirmed a low selectivity of this fishery. Characterisation of the catch resulted in a total of 19 target species which were dominated by groupers, and 53 non-target species, with grunts and groupers being most prominent. Most individuals were not landed for economic motivations, either because species (77.4%) or sizes (17.7%) are not marketable and to a lesser extent for regulatory reasons (5.9%). However, sharks were after grunts with 69% the second most often mentioned bycatch taxa during interview surveys. We found that small sized individuals of some of the most exploited species suffer high bycatch mortality because they are used as bait. Moreover, over half of interviewees perceived a historical decrease in bycatch ratios that was explained by a diversification of the catch composition due to the reduction in abundance of the traditionally most important target species. As some target species show signs of overfishing and to date there are no specific regulations for the finfish fishery in place, we recommend the investigation of different gear settings such as the use of different hooks and bait species. Furthermore, we suggest the integration of faster growing species to the local market as well as spatio-temporal closures, and minimum and maximum catch sizes for overexploited species in order to improve the selectivity and sustainability of the Galapagos handline fishery.

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Introduction

The role of bycatch in global fisheries has become a significant marine conservation issue, especially in areas where serious ecosystem degradation has already been observed (Harrington, Myers & Rosenberg, 2005). Bycatch is commonly referred to as the incidental catch of non-target species and is divided into the portion of the catch that is discarded because species or sizes are not marketable or of lower economic value (economic discards), and catch that is discarded due to regulatory restrictions (regulatory discards) e.g. protected species or certain sizes (Dunn, Boustany & Halpin, 2011; National Marine Fisheries Service, 2011). Bycatch, when discarded, causes significant waste of natural resources and is of particular concern when the populations of the captured species are already severely overfished or threatened (Alverson, 1994; National Marine Fisheries Service, 2011). Furthermore, bycatch has serious ecological consequences not just for the species caught, but also for entire marine ecosystems (Dayton et al., 1995; Crowder & Murawski, 1998; Dulvy, Sadovy & Reynolds, 2003; Kappel, 2005). Ecological impacts on community structure and fishery productivity are the result of increased fishing mortality of species that are important to shape the ecosystems such as species at high trophic levels (Myers et al., 2007; Shester & Micheli, 2011) which can cause alterations in species assemblages and widespread community impacts via trophic cascades (Pauly et al., 1998; Lewison et al., 2004). In marine fisheries, bycatch implications include the negative economic impacts of foregone income due to discards of undersized individuals of commercially valuable species, and the costs associated with discarding non-commercial species (Pascoe, 1997; Bjorkland, 2011; Dunn, Boustany & Halpin, 2011), negative public image of fishers for wasting resources and for bycatching certain charismatic animals such as dolphins or marine turtles (Hall, 1999). Because of the high impact of bycatch in fisheries, (Bjorkland, 2011) stated that "the ecological, economic and social costs of bycatch in fishing activities are increasingly indefensible to governments, fishing interests, marine scientists and ocean activists", making it necessary to establish appropriate measures and finding alternative gear to successfully reduce the impact of bycatch on a global scale.

Bycatch in small-scale fisheries

Most bycatch studies have focused on industrial fisheries, leaving a lack of information regarding small-scale fisheries, in particular towards effort, catch and bycatch (Lewison et al., 2004; Moore et al., 2010). Small-scale fisheries are often described as fisheries that use relatively low technologically advanced gear and have the capability for more effective local governance, which makes them more likely be more sustainable than large-scale fisheries (Shester & Micheli, 2011). In this respect, (Pauly, 2006) stated that small-scale fisheries are "our best hope for sustainable utilisation of coastal marine resources". However, recent studies show that bycatch in small-scale fisheries can have severe ecological impacts, and if scaled to per-unit of total catch they can be comparable to industrial fisheries (Shester & Micheli, 2011). As small-scale fisheries encompass 44% of the world's 50 million fishers and provide over half of the total global fisheries production (Chuenpagdee et al., 2006; Teh & Sumaila, 2013), this knowledge gap represents a major challenge to sustainable fisheries management and the conservation of threatened species, especially in tropical fisheries of developing countries (Moore et al., 2010).

The Galapagos handline fishery

The Galapagos Archipelago did not have a consistent human presence until the 1930s (Reck, 1983; Danulat & Edgar, 2002; Castrejón Mendoza, 2011). Since then, the highly productive and diverse marine ecosystems of the archipelago have been increasingly threatened by human activities, reflected by the exponential increase of the human population from 6,119 inhabitants in 1962 to 25,000 in 2010 (INEC, 2011), along with the expansion of the number of tourists, which reached over 200,000 visitors per year in 2013 (DPNG, 2014). To ensure the sustainable economic development and protect the biodiversity of Galapagos, the 133,000 km^2 Galapagos Marine Reserve (GMR) was established in 1998. While industrial fishing was banned within the reserve, fishing rights were granted exclusively to the local small-scale fishing sector. The implemented Organic Law for the Special Regimen for the Conservation and Sustainable Development of Galapagos (LOREG) includes regulations for iconic species such as sharks, marine mammals and sea horses, which are excluded from extractive activities, and if caught unintentionally, have to be returned to their natural environment. However, there is evidence that the established artisanal fishery caused major impacts upon fishing resources (Burbano et al., 2014; Schiller et al., 2014). The collapse of the sea cucumber fishery in the early 2000s represents the most severe example (Hearn, 2008; Wolff, Schuhbauer & Castrejón, 2012). The multispecies handline fishery (locally called empate) is traditionally the most important in Galapagos. Until the 1960s, fishers had no access to refrigeration and therefore preserved fish by salting and drying it. Fish were then exported to the mainland where they formed the main ingredient of "fanesca", a traditional Ecuadorian dish served at Easter. While presently the handline fishery for fresh demersal finfish occurs all year round to supply local markets, the main market still remains the exported salt-dried finfish to serve the ongoing demand for "fanesca", and is caught during the hot season (December to April). The handline fishing method has been observed to have very low selectivity for species and size ranges in some cases (Nicolaides et al., 2002; Peñaherrera & Hearn, 2008), but conversely also as fairly selective (Ruttenberg, 2001). However, to date no information on bycatch for this fishery has been published. Studies have demonstrated that the handline fishery has caused an impact on several exploited fish stocks, and revealed a dramatic shift in the volume of fish landings and in the species composition of the handline fishery (Ruttenberg, 2001; Burbano et al., 2014; Schiller et al., 2014). Despite the increasing evidence that there is a continuous trend of overexploitation of target species, until today there is no particular management plan in place for any of these species. As the fishing sector sustains fishers' livelihoods and plays a significant role for the regional culture it is crucial preventing a further decline in the key target species, such as the regional endemic sailfin grouper (*Mycteroperca olfax*)(Castrejón Mendoza 2011). A better understanding about the complete catch of this fishery, including bycatch species and their sizes, is therefore an important step towards a sustainable Galapagos handline fishery.

Aims of this study

The aims of this study are to quantitatively describe the bycatch of the Galapagos handline fishery, as well as catch selectivity and bycatch ratios. This information will help to establish a knowledge baseline from which changes in bycatch ratios can be monitored and to inform decision making processes for future fisheries management plans. We then analyse the social component of this multispecies fishery by identifying the fishers' reasons for discarding certain individuals. Moreover, we hypothesize that changes in the availability of key target species have resulted in changes in the fishers' decision making process of whether to keep or discard a specimen. In order to test this hypothesis, we use interview surveys to evaluate historical trends in the bycatch ratio and reasons for potential changes in bycatch levels.

Materials and methods

Fishery observations

We monitored artisanal handline fishing trips with onboard observers from February to May 2012. The handline technique consists of a monofilament line weighted with lead and several short extensions of propylene line each with one hook (Danulat & Edgar, 2002). Fishing depths ranged from 15 to 200 m, with trip durations lasting from one to two days and an average duration of 8 hours (SD = 6.5). Departure and arrival date and time, vessel horsepower and number of fishers on board were recorded for each trip. During each fishing trip, fishers actively looked for promising bottom structure and fished for several minutes on selected sites before moving to the next. We recorded the effective fishing time at each of these sites as the interval starting when the first line was cast and ending when the last line was out of the water. Start and stop time, geographical position, number of hooks and lines in the water, number of fishers, water depth, bait and capture time were recorded at each site. The study area with all monitored fishing sites is shown in Fig. 1. Total lengths of all individuals were recorded and converted to weight using available length-weight relationships (Froese & Pauly, 2000). When no length-weight relationship was available, these were obtained by means of regression analysis on our catch data as suggested by Lima-Junior et al. (2002). Catch was categorized according to the bycatch definition of the US National Marine Fisheries Service (MSA 1996), such that all individuals that are either sold or used for personal consumption are categorized as landings, while all other individuals are bycatch. We furthermore distinguished different bycatch categories between bycatch survival (individuals that were discarded alive) and bycatch mortality (individuals that were discarded dead or used as bait). Additionally, the condition of individuals when released was recorded and their release observed. Whenever possible, the post-release mortality was noted, but could not be measured constantly for all discarded individuals.

Bycatch estimates

Landings and bycatch were expressed in numbers of individuals and biomass (kg). Additionally, for each of the defined landing and bycatch categories, biomass percentages were calculated. The bycatch ratio (BCR) is defined as the ratio of bycatch to total catch, whereby total catch equals landings plus bycatch. BCR was obtained as a function of abundance (BCR_N) and biomass (BCR_W).

Species composition

Species composition is shown as numbers of species categorized as landings or bycatch. We identified three reasons for fishers not landing an individual, and divided the bycatch accordingly into the three subcategories: species that are not lucrative because they have low or no market value were defined as “not marketable species”, small sized and therefore not lucrative individuals of otherwise marketable species were defined as “not marketable sizes”, and bycatch of protected species was defined as “regulatory discard”. We report the average Total Length (TL) of each species represented in these categories as well as the bycatch ratio of each species (BCR_S), defined as the ratio in which the number of individuals of each species belong to the bycatch.

Prediction of bycatch sizes

For exploited species for which an adequate sample size was obtained ($n \geq 100$), a logistic regression model was used to estimate the probability of a fish being landed based on its size. Fish TL was summarized into 5cm length categories. Proportion of fish considered as landed was calculated for each length category. The model followed the formula:

$$\text{Logit(p)} = \frac{p}{1-p}$$

where 1-p is the probability of that a given fish would not be landed. Confidence intervals of the parameters of the regression were estimated via bootstrapping with 100 iterations. Analyses were done using the R package FSA (Ogle, 2013a). The resulting predictive model was used to estimate the size below which a fish would have a 80% probability of becoming bycatch (b_{80}). We furthermore obtained the odds ratio of the model, which is the factor by which the probability of an individual to be landed increases with each 5 cm in TL.

Interview surveys

To obtain additional information about bycatch species and historical changes in bycatch composition and quantities, we interviewed local fishers. Because of the close relationship the fishers have with their environment, we used their experience and knowledge, as this information can fill important knowledge gaps including the abundance of fish stocks and perceived historical changes in the fishery (Johannes, Freeman & Hamilton, 2000; Murray, Neis &

Johnsen, 2006; McCluskey & Lewison, 2008). From April to May 2012, we approached fishers from Santa Cruz and San Cristobal Islands and asked them for permission to carry out in-person interviews. Because interviewers had already worked closely with fishers and guaranteed their anonymous status, it was possible to gain the fishers' trust. Therefore no fishers rejected the participation and answers are believed to be reliable. To avoid any influence on fishers' responses, interviews were carried out with one fisher at a time. Interviewed fishers were asked to suggest fellow fishers who could be interviewed, who we then approached at the fishing dock in order to ask their participation in the interview. Our use of this snowball sampling technique (Goodman, 1961) helped ensure that an adequate number of interviews ($n \geq 78$, $N = 400$, confidence level = 95% and margin of error = 10%) were completed. Interviews were designed to identify species that are commonly caught as bycatch and the reason for not landing these species. A Pearsons' chi square test was used to test for interactions among the answers given and the island of residence of the fishers.

Additionally, we asked fishers about their perceptions of historical changes regarding the amount of caught non-target species. If they perceived a change, fishers were asked to give reasons for their perception. We used an open interview as it has been proven to provide a much more detailed description of the answers provided (Jackson & Trochim, 2002). Answers about most common bycatch species, reasons for not landing these species, historical changes in bycatch and reasons for changes given by fishers were manually coded. We chose this approach because answers to open questions can vary in the description and human analysers are able to interpret the subtleties in answers to code them. We then calculated the percentages of each coded answer.

The research was approved by the Galapagos National Park under the annual research plan of the Charles Darwin Foundation (POA 2012, number 86). As the Galapagos National Park has no body in charge of ethical questions and there are no specific regulations for the study design on vertebrates or humans in the Galapagos Marine Reserve, we didn't obtain any specific approval.

Results

Bycatch estimates

A total of 22 fishing trips were conducted, resulting in 153 hours at sea and 94 hours of effective fishing time. During fishing trips, 297 sites were visited and 1279 fish with a total combined biomass of 2.1 metric tonnes. Fractions of landing and bycatch categories are shown as a function of biomass in Fig. 2. Total bycatch weighted 883kg (n = 543), resulting in a BCR_N of 0.43 and a BCR_W of 0.40.

Landing composition

We observed a total of 36 species caught by the Galapagos handline fishery. Landings were composed of 17 fish species belonging to seven families. Of these, five species were landed exclusively and the remaining 12 species were sometimes landed and sometimes discarded or used as bait. Landings were dominated by fish of the family Serranidae, which was represented by eight species and made up for 68% of the landed biomass. The Galapagos sailfin grouper (*M. olfax*) and the Camotillo (*Paralabrax albomaculatus*) were the most landed species constituting 40% and 13% of all landed biomass, respectively. Other common target species were the Ocean whitefish (*Caulolatilus princeps*) and the mottled scorpionfish (*Pontinus clemensi*) representing 13% and 10% of the landed biomass, respectively. While the first two species are fished in depth ranging from 15 to 40 m, the latter two species are targeted in deeper waters of up to 200 m. Fishers used 7% of landed biomass for their personal purposes which were represented by the five species (from highest to lowest occurrence) *C. princeps*, *M. olfax*, *P. clemensi*, *P. albomaculatus* and the starry grouper *Epinephelus labriformis*. Descriptive statistics of catch including the number of individuals per species, average size and bycatch ratios are shown in Table 1.

Bycatch composition and sizes

We found 31 species that were caught unintentionally, out of which 19 species were never landed. Regulatory discard included 26 juvenile sharks (23 *Carcharhinus galapagensis* and 3 *Triaenodon obesus*) as well as two sea lions (*Zalophus wollebaeki*). Protected species made up for 5.9% of all caught individuals as bycatch. Eighteen species were not landed because they were considered not marketable species constituting 77.4% of individuals. The most frequently caught not marketable species were: the burrito grunt *Anisotremus interruptus*, the peruvian grunt *Anisotremus scuderii*, *E. labriformis* and the greybar grunt *Haemulon sexfasciatum*. Twelve species representing the remaining 17.7% of the bycatch were not landed because fishers considered the size of individuals too small to be economically valuable. The amount of individuals per species caught as bycatch, average sizes and bycatch ratio are shown in Table 2.

The species *P. albomaculatus*, *C. princeps* and *P. Clemensi* were not only some of the most important target species in landings, they also were some of the most frequently caught bycatch species. Those three species made up five, four and two percent of all bycatch biomass, respectively. The biomass of *C. princeps* was mostly landed (79%), but partly used as bait (19.6%), partly discarded dead (1.2%) and to a small extent discarded alive (0.6%). Of the total biomass of *P. albomaculatus*, 76% was landed, 16.1% was used as bait, 8.0% discarded dead and only 0.9% was discarded alive. Finally, 75% of the caught biomass of *P. clemensi* was landed, 22.7% used as bait and 2.1% was discarded. No individuals of this species were discarded alive. An adequate sample size ($n \geq 100$) for these three species allowed us to apply a logistic regression model which predicted the size below which individuals have a 80% chance to become bycatch. Results of this model are indicated in Fig. 4.

Interview surveys

A total of 100 semi-structured interviews with fishers from Santa Cruz (26%) and from San Cristobal (74%) Islands were conducted representing approximately 25% of the 400 active fishers in the GMR. Fishers' ages ranged from 19 to 80 years, with an average of 43.0 years (SD = 11.9). While 42% of interviewed fishers were born in the Galapagos Islands, the remaining 58% were originally from mainland Ecuador. Of the 43 different species caught as bycatch, the reasons given for not landing 27 of these species was that they were not marketable species, whereas the other 14 were considered as bycatch when caught under a certain size to be marketable. Additionally, five of these species were discarded for both these reasons. Haemulidae (79%) and Serranidae (37%) were the most frequently mentioned families, represented by six and nine different species, respectively. The most common bycatch? species mentioned by fishers were *A. interruptus* (39%), *A. scuderii* (26%), *E. labriformis* (24%) and *Sphoeroides annulatus* (21%). Furthermore, 73% of fishers stated that they occasionally bycaught protected species. Of these, 68% identified sharks as bycatch with 29% of these were identified as *C. galapagensis,* 2% as *Carcharhinus falciformes*, 1% as *T. obesus*, while the remaining 36% did not specify the species. Rays were mentioned by 20% of fishers, turtles by 14%, sea lions by 13% and marine birds by 3%

(Fig. 3). There was no significant difference between the number of species reported by fishers of the two different islands of residence based on the Pearsons' chi square test (p=0.45)

Perception of historical changes of bycatch

Results from interviews revealed that 52% of fishers perceived a decrease in bycatch throughout their working life mostly attributed to general decreases of fish abundance (44%), shift in species composition of landings (21%) or a change in their main fishing gear (13%). On the other hand, eight percent of interviewees stated that they observed an increased amount of discards, which they explained with changes in fishing regulations. A third (31%) of fishers stated that there was no change and 9% did not answer this question.

Discussion

This study provides the first insight into the selectivity of the Galapagos handline fishery. Our results suggest that Galapagos small-scale fisheries are not necessarily more selective than industrial fisheries reported from the literature (Shester & Micheli, 2011). We found the handline fishery to bycatch a fairly diverse fish fauna where most specimens are discarded due to economic motivation, and to a lesser extent because of regulatory restrictions. Undersized individuals of some commercially exploited species suffer bycatch mortality contributing most probably to their overexploitation. Moreover, interviews revealed that the overexploitation of the commercial species caused a diversification of the catch composition which resulted in a historical change in the bycatch level towards lower bycatch ratios.

Bycatch estimates

The estimated bycatch ratio of 0.40 is are comparable to current global fisheries bycatch estimates of 40.4% (Davies et al., 2009). A study in Baja Californie, Mexico found strong varying discar rates for different artisanal fishing gears (0.11% for fish traps, 15.1% for lobster traps, 18.5% for drift gillnet and 34.4% for set gillnets) (Shester & Micheli 2011). Even though the results of these studies are due to the assessments of different fishing techniques and species, and therefore not directly comparable with our results, it is interesting to note that the bycatch ratio of the Galapagos handline fishery is similar or higher than the ratios of the other studied fisheries. The varying bycatch ratio of the different gears therefore show the importance of the type of fishing gear used, and the nature of its interactions with marine species, which should be closely observed to be able to find ways of reducing bycatch.

Species that suffered bycatch mortality were represented mostly by grunts and small sized individuals of economically valuable species. Bycatch of non marketable undersized individuals represents not only a waste of resources because specimens are being harvested before reaching their maximum yield per recruit, it also contributes to growth overfishing of the most exploited species (Alverson, 1994). This is of special concern for threatened species such as *P. albomaculatus*, which is endemic to the Galapagos and classified as endangered on the IUCN red list of threatened species (Robertson et al., 2010). For other highly exploited species like *C. princeps* and *P. clemensi*, the lack of knowledge about their biology impedes a proper risk assessment, which is necessary for their inclusion on the IUCN red list.

Individuals that are discarded alive are still vulnerable as the interaction with the fishing gear can negatively affect the survival of the fish and lead to post-release mortality (Ryer, Ottmar & Sturm, 2004). Among the reasons for this mortality are decompression sickness, deficits in swimming ability, feeding, and a higher vulnerability to predators (Davis, 2002). As delayed mortality was impossible to observe from onboard the fishing boat, the bycatch mortality might be even higher than estimated.

Species composition

The diverse catch composition of landed fish confirmed a low selectivity of this fishery and revealed that fishers consider a large part of their catch as target species. However, monitoring and previous studies on this fishery focused mainly on the Galapagos sailfin grouper and to a much lesser extent on other target and non-target species caught with this gear (Schiller et al., 2014). Given the lack of attention on other exploited species and missing management measures for any fish species in the GMR, most of the species caught are scarcely measured and poorly documented. A management plan for these species is urgently needed and should take into consideration the multispecies character of this fishery rather than focusing on single species management.

The overall bycatch of protected species recorded in this study was considerably low. However, results can be biased towards lower bycatch ratios and mortality caused by the observer effect, which occurs when fishers tend to follow a best practice fishing attitude during onboard monitoring, as opposed to un-observed fishers (Hall, 1999). Our results from both onboard observations and interview surveys confirm speculations that sharks are occasionally caught and discarded by the Galapagos handline fishery (Jacquet et al., 2008; Castrejón Mendoza, 2011). Sea lions scavenging around fishing gear increase their own susceptibility to incidental capture. The two by-caught sea lions got hooked on the fishing gear, while trying to feed on the captured fish and got injured because fishers hit them with a wooden plank with a nail attached to expel them. Even though this study did not detect any mortality of sharks and sea lions, there are indications that bycatch mortality of protected species occurs as sea lions are occasionally found dead, showing evidence of having died due to unnatural causes (Denkinger, Quiroga & Murillo, 2014). Fishers see sharks and sea lions as competitors for marine resources and therefore as a threat to their livelihood (fishers, pers. comm.). Previous studies point out that discards of protected species might be under-reported, because fishers fear negative (Pauly et al., 1998; Lewison et al., 2004)consequences when accurately reporting bycatch of these taxa (National Marine Fisheries Service, 2004; Lewison et al., 2004). However, the high number of interviewed fishers who stated that they catch protected taxa by accident, suggests that fishers answered our questions accurately.

Historical changes of bycatch

Our results about historical changes of bycatch levels support signs of negative impacts on exploited species imposed by this handline fishery, which already go back to the 1980s (Reck, 1983; Nicolaides et al., 2002; Burbano et al., 2014; Schiller et al., 2014). The consequences are characterized by an alteration of the species assemblages in form of a strong decline in abundance and average size of apex-level fish, such as the targeted groupers (Reck, 1983; Bustamante, 1998; Nicolaides et al., 2002; Edgar et al., 2010; Schiller et al., 2014), which drives fishers to target more species and smaller sized fishes. Besides, consequences of the decline of top predators also affects marine communities as sites with high fishing pressure show a lower variability in the fish community structure indicating significant changes in the functioning of coastal marine environments of the archipelago (Ruttenberg, 2001). Diversification of fishing gear and an increasing demand for fresh fish for local consumption are also reasons for the diversification of target species and the decreasing fraction of groupers caught with handlines within the finfish fishery of Galapagos (Castrejón Mendoza, 2011). This is supported by seven percent of fishers who stated that their bycatch ratio decreased because they changed their fishing gear. Species like mullets (e.g. *Xenomugil thoburni* and *Mugil galapagensis*) caught with beach seine nets and pelagic species (e.g. *Thunnus albacares* and *Acanthocybium solandri*) caught trolling that were only occasionally caught in the late 1970s now make up 58% of total landings with an increasing trend (Schiller et al., 2014).

Management suggestions

As multispecies fisheries target many different species, the general goal of increasing the selectivity of a fishery may not always be appropriate. Instead, the focus may rather be on reducing the bycatch on overexploited, threatened and protected species (Gillett, 2011). Furthermore, negative effects such as post release mortality on threatened bycatch species should be minimized and measures should involve adequate implementation costs and should not affect fishing operations negatively (Sales et al., 2010). Here, we suggest management regulations towards a more sustainable Galapagos multispecies handline fishery.

Unravelling the problem of fisheries' selectivity is often associated with the improvement of gear settings (Broadhurst, 2000; Bache, 2003). For example, the use of certain bait species was found to influence the bycatch of cod in the Northwest Atlantic haddock fishery (Ford, Rudolph & Fuller, 2008). Fishers from the Galapagos handline fishery stated that bait species are not equally selective and that the use of yellowfin tuna (*Thunnus albacares*) as bait seems to be related to the bycatch of sharks (Zimmerhackel, unpublished data). Also larger hook sizes have been proven to be more effective in capturing larger size classes of targeted fish (Ralston, 1990) and post-release mortality of groupers were found to be significantly lower when using circle hooks instead of J-hooks (Burns & Kerr, 2008). We therefore recommend experimental investigations about distinctive hook types, hook sizes and bait species in order to determine a gear setting that reduces the catch of unwanted species, sizes and post-release mortality, without negatively affecting the target catch.

Contrary to a common concern raised by the fishermen, the reduction of fishing pressure on threatened target species does not necessarily have to be accompanied by a reduction of income. For example, integrating more resilient, faster growing non-target species in landings was successfully adopted in a number of fisheries worldwide (Lobo et al., 2010; Rodríguez-Preciado, Madrid-Vera & Meraz-Sánchez, 2012). In the Mexican Pacific, bycatch species of the family Haemulidae such as *Pomadasys panamensis* have become an important part of the commercial catch from the fisheries (Rodríguez-Preciado, Madrid-Vera & Meraz-Sánchez, 2012). The fact that many species which presently are commonly consumed in the Galapagos handline fishery were often discarded during last decades indicates a certain flexibility and ability by the fishing sector and the consumer community to adapt to changes in their environment. This demonstrates that there is hope that new target species such as grunts (which together made up 51.1% of the bycatch biomass) could be accepted by both the fishers and consumers. However, the integration of new target species should ideally be accompanied by stock assessments on harvested species to prevent overfishing and all potential management alternatives should be evaluated on an ecological and socio-economic basis by including the main stakeholders and fishers in the solution finding process (Usseglio, Schuhbauer & Friedlander, 2014).

Unfortunately, the lack of specific biological knowledge about the most exploited species of this fishery impedes a proper assessment of their population status. Critical life stages and spawning grounds of the main target species *C. princeps*, *M. olfax, P. albomaculatus* and *P. clemensi* should be assessed and if necessary protected as this could effectively reduce the impact on threatened species (Beets & Friedlander, 1999; Lester & Halpern, 2008; Afonso, Fontes & Santos, 2011). As groupers were proven to have a high post-release survivorship (Burns & Kerr, 2008) and mainly suffered bycatch mortality because undersized individuals were used as bait, we suggest the implementation of minimum and maximum catch sizes and temporal closures that can effectively reduce their bycatch mortality. The suggested measures should be accompanied by plans to raise fishers' awareness about bycatch related concerns and their implications for the sustainability of fish stocks.

Conclusions

This information about bycatch of the Galapagos handline fishery revealed that this fishery targets a fairly high number of species and is not selective for species or size classes. Most individuals are not landed due to economic motivations, either because the species or the fish sizes are not marketable. Regulatory discards were observed to a lesser extent, indicating that protected species are not discarded very frequently. However, more than two thirds of interviewed fishers mentioned incidental catch and release of sharks. A more concerning result was the high number of small sized individuals of some target species, which mostly suffer bycatch mortality mainly because they are used as bait, which increases their overall fishing mortality. Moreover, interviews revealed a historical change in the bycatch level towards lower bycatch ratios that was explained by a diversification of the catch composition due to the overexploitation of some commercial species. As it becomes more evident that the most exploited target species of this fishery are overfished (Burbano et al., 2014; Schiller et al., 2014) and to date there are no regulations for any target species in place, our results demonstrate the need to integrate management measures (such as the ones we recommend) in future management plans in order to minimize the fishing pressure on threatened and protected species.

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References

Afonso P, Fontes J, Santos RS. 2011. Small marine reserves can offer long term protection to an endangered fish. *Biological Conservation* 144:2739–2744.

Alverson DL. 1994. *A Global Assessment of Fisheries Bycatch and Discards*. Food & Agriculture Org.

Bache SJ. 2003. Bycatch mitigation tools: selecting fisheries, setting limits, and modifying gear. *Ocean & Coastal Management* 46:103–125.

Beets J, Friedlander A. 1999. Evaluation of a conservation strategy: a spawning aggregation closure for red hind, Epinephelus guttatus, in the U.S. Virgin Islands. *Environmental Biology of Fishes* 55:91–98.

Bjorkland RH. 2011. An Assessment of Sea Turtle, Marine Mammal and Seabird Bycatch in the Wider Caribbean Region. DUKE UNIVERSITY.

Broadhurst MK. 2000. Modifications to reduce bycatch in prawn trawls: A review and framework for development. *Reviews in Fish Biology and Fisheries* 10:27–60.

Burbano DV, Mena CF, Guarderas P, Vinueza L, Reck G. 2014. Shifting Baselines in the Galapagos White Fin Fishery, Using Fisher's Anecdotes to Reassess Fisheries Management: The Case of the Galapagos Grouper. In: Denkinger J, Vinueza L eds. *The Galapagos Marine Reserve*. Social and Ecological Interactions in the Galapagos Islands. Springer International Publishing, 227–246.

Burns RJ, Kerr GN. 2008. Observer effect on fisher bycatch reports in the New Zealand ling (Genypterus blacodes) bottom longlining fishery. *New Zealand Journal of Marine and Freshwater Research* 42:23–32.

Bustamante RH. 1998. *The artisan fishing sector of the Galápagos and the 1997 fishing season.* Quito, Ecuador: WWF.

Castrejón Mendoza. 2011. *Co-Manejo Pesquero en la R eserva Marina de Galápagos: Tendencias, Retos y Perspectivas de Cambio*. Fundación Charles Darwin.

Chuenpagdee R, Liguori L, Palomares MLD, Pauly D. 2006. Bottom-up, global estimates of small-scale marine fisheries catches.

Crowder LB, Murawski SA. 1998. Fisheries Bycatch: Implications for Management. *Fisheries* 23:8–17.

Danulat, Edgar. 2002. *Marina de Galápagos. Línea Base de la Biodiversidad*. Santa Cruz, Galápagos, Ecuador: Fundación Charles Darwin, Parque Nacional Galápagos.

Davies RWD, Cripps SJ, Nickson A, Porter G. 2009. Defining and estimating global marine fisheries bycatch. *Marine Policy* 33:661–672.

Davis MW. 2002. Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Sciences* 59:1834–1843.

Dayton PK, Thrush SF, Agardy MT, Hofman RJ. 1995. Environmental effects of marine fishing. *Aquatic Conservation: Marine and Freshwater Ecosystems* 5:205–232.

Denkinger J, Quiroga D, Murillo JC. 2014. Assessing Human–Wildlife Conflicts and Benefits of Galápagos Sea Lions on San Cristobal Island, Galápagos. In: Denkinger J, Vinueza L eds. *The Galapagos Marine Reserve*. Social and Ecological Interactions in the Galapagos Islands. Springer International Publishing, 285–305.

DPNG. 2014. *Informe anual de visitantes que ingresaron a las áreas protegidas de Galápagos 2013*. Puerto Ayora, Santa Cruz, Galapagos, Ecuador: Parque Nacional Galápagos, Ministério del Ambiente.

Dulvy NK, Sadovy Y, Reynolds JD. 2003. Extinction vulnerability in marine populations. *Fish and Fisheries* 4:25–64.

Dunn DC, Boustany AM, Halpin PN. 2011. Spatio-temporal management of fisheries to reduce by-catch and increase fishing selectivity. *Fish and Fisheries* 12:110–119.

Edgar GJ, Banks SA, Brandt M, Bustamante RH, Chiriboga A, Earle SA, Garske LE, Glynn PW, Grove JS, Henderson S, Hickman CP, Miller KA, Rivera F, Wellington GM. 2010. El Niño, grazers and fisheries interact to greatly elevate extinction risk for Galapagos marine species. *Global Change Biology* 16:2876–2890.

Ford JS, Rudolph T, Fuller SD. 2008. Cod bycatch in otter trawls and in longlines with different bait types in the Georges Bank haddock fishery. *Fisheries Research* 94:184–189.

Froese R, Pauly D. 2000. Fishbase 2000. *Fishbase 2000: concepts, design and data sources. WorldFish*.

Gillett R. 2011. Bycatch in small-scale tune fisheries: a global study.

Goodman LA. 1961. Snowball Sampling. *The Annals of Mathematical Statistics* 32:148–170.

Hall MA. 1999. Estimating the ecological impacts of fisheries: what data are needed to estimate bycatches?

Harrington JM, Myers RA, Rosenberg AA. 2005. Wasted fishery resources: discarded by-catch in the USA. *Fish and Fisheries* 6:350–361.

Hearn A. 2008. The rocky path to sustainable fisheries management and conservation in the Galápagos Marine Reserve. *Ocean & Coastal Management* 51:567–574.

INEC. 2011. Proyecciones-poblacionales. *Instituto Nacional de Estadísticas y Censos*.

Jackson KM, Trochim WMK. 2002. Concept Mapping as an Alternative Approach for the Analysis of Open-Ended Survey Responses. *Organizational Research Methods* 5:307–336.

Jacquet J, Alava JJ, Pramod G, Henderson S, Zeller D. 2008. In hot soup: sharks captured in Ecuador's waters. *Environmental Sciences* 5:269–283.

Johannes R e., Freeman M m. r., Hamilton R j. 2000. Ignore fishers' knowledge and miss the boat. *Fish and Fisheries* 1:257–271.

Kappel CV. 2005. Losing pieces of the puzzle: threats to marine, estuarine, and diadromous species. *Frontiers in Ecology and the Environment* 3:275–282.

Lester SE, Halpern BS. 2008. Biological responses in marine no-take reserves versus partially protected areas. *Marine Ecology Progress Series* 367:49–56.

Lewison RL, Crowder LB, Read AJ, Freeman SA. 2004. Understanding impacts of fisheries bycatch on marine megafauna. *Trends in Ecology & Evolution* 19:598–604.

Lobo AS, Balmford A, Arthur R, Manica A. 2010. Commercializing bycatch can push a fishery beyond economic extinction. *Conservation Letters* 3:277–285.

McCluskey SM, Lewison RL. 2008. Quantifying fishing effort: a synthesis of current methods and their applications. *Fish and Fisheries* 9:188–200.

Moore JE, Cox TM, Lewison RL, Read AJ, Bjorkland R, McDonald SL, Crowder LB, Aruna E, Ayissi I, Espeut P, Joynson-Hicks C, Pilcher N, Poonian CNS, Solarin B, Kiszka J. 2010. An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. *Biological Conservation* 143:795–805.

Murray G, Neis B, Johnsen JP. 2006. Lessons Learned from Reconstructing Interactions Between Local Ecological Knowledge, Fisheries Science, and Fisheries Management in the Commercial Fisheries of Newfoundland and Labrador, Canada. *Human Ecology* 34:549–571.

Myers RA, Baum JK, Shepherd TD, Powers SP, Peterson CH. 2007. Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean. *Science* 315:1846–1850.

National Marine Fisheries Service. 2004. Evaluating bycatch: A national approach to standardized bycatch monitoring programs. *U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-66*:108.

National Marine Fisheries Service. 2011. *U.S. National Bycatch Report*. National Oceanic and Athmospheric Administration.

Nicolaides F, Murillo JC, Toral MV, Reck G. 2002. Capitulo 7: Bacalao. In: *Reserva Marina de Galápagos: Linea Base de la Biodiversidad*. Fundación Charles Darwin, Parque Nacional Galápagos, 146–165.

Ogle DH. 2013a. FSA: Fisheries Stock Analysis. R package version 0.3.5.

Pascoe S. 1997. Bycatch management and the economics of discarding.

Pauly D, Christensen V, Dalsgaard J, Froese R, Torres F. 1998. Fishing Down Marine Food Webs. *Science* 279:860–863.

Pauly D. 2006. Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. *Maritime Studies* 4:7–22.

Peñaherrera C, Hearn A. 2008. *Toward an ecosystem-based approach to fisheries: a risk analysis*. Puerto Ayora, Santa Cruz, Galapagos, Ecuador: Charles Darwin Foundation.

Ralston S. 1990. Size Selection of Snappers (Lutjanidae) by Hook and Line Gear. *Canadian Journal of Fisheries and Aquatic Sciences* 47:696–700.

Reck GK. 1983. The coastal fisheries in the Galapagos Islands, Ecuador. Descriptions and Consequences for Management in the Context of Marine Environmental Protection and Regional Development. Kiel, Germany: Christian-Albrecht-Universität Kiel.

Robertson R, Allen G, Dominici-Arosemena A, Edgar GJ, Rivera F, Merlen G. 2010. Paralabrax albomaculatus. *IUCN Red List of Threatened Species*.

Rodríguez-Preciado JA, Madrid-Vera J, Meraz-Sánchez R. 2012. Size Structure and Biomass of the Panama Grunt (Pomadasys panamensis) from Bycatch in the Southeastern Gulf of California. *Open Journal of Marine Science* 2:1–7.

Ruttenberg BI. 2001. Effects of Artisanal Fishing on Marine Communities in the Galápagos Islands. *Conservation Biology* 15:1691–1699.

Ryer CH, Ottmar ML, Sturm EA. 2004. Behavioral impairment after escape from trawl codends may not be limited to fragile fish species. *Fisheries Research* 66:261–269.

Sales G, Giffoni BB, Fiedler FN, Azevedo VG, Kotas JE, Swimmer Y, Bugoni L. 2010. Circle hook effectiveness for the mitigation of sea turtle bycatch and capture of target species in a Brazilian pelagic longline fishery. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20:428–436.

Schiller L, Alava JJ, Grove J, Reck G, Pauly D. 2014. The demise of Darwin's fishes: evidence of fishing down and illegal shark finning in the Galápagos Islands. *Aquatic Conservation: Marine and Freshwater Ecosystems*:n/a–n/a.

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

Teh LCL, Sumaila UR. 2013. Contribution of marine fisheries to worldwide employment. *Fish and Fisheries* 14:77–88.

Usseglio P, Schuhbauer A, Friedlander A. 2014. Collaborative Approach to Fisheries Management as a Way to Increase the Effectiveness of Future Regulations in the Galapagos Archipelago. In: Denkinger J, Vinueza L eds. *The Galapagos Marine Reserve*. Social and Ecological Interactions in the Galapagos Islands. Springer International Publishing, 187–202.

Wolff M, Schuhbauer A, Castrejón M. 2012. A revised strategy for the monitoring and management of the Galapagos sea cucumber Isostichophus fuscus (Aspidochirotida: Stichopodidae). *International Journal of Tropical Biology* 60:539–551.

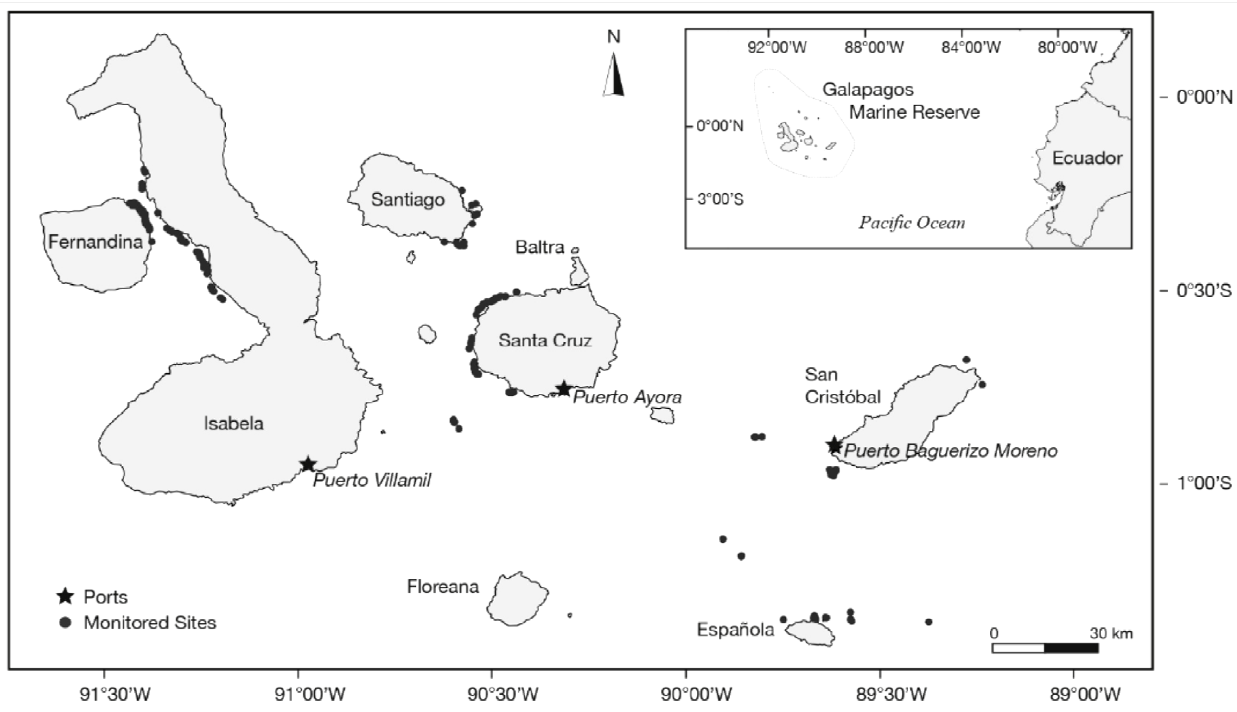

Figure 1: Geographic position of the Galapagos Marine Reserve; study site with the fishing ports (stars) and the monitored fishing sites (dots).

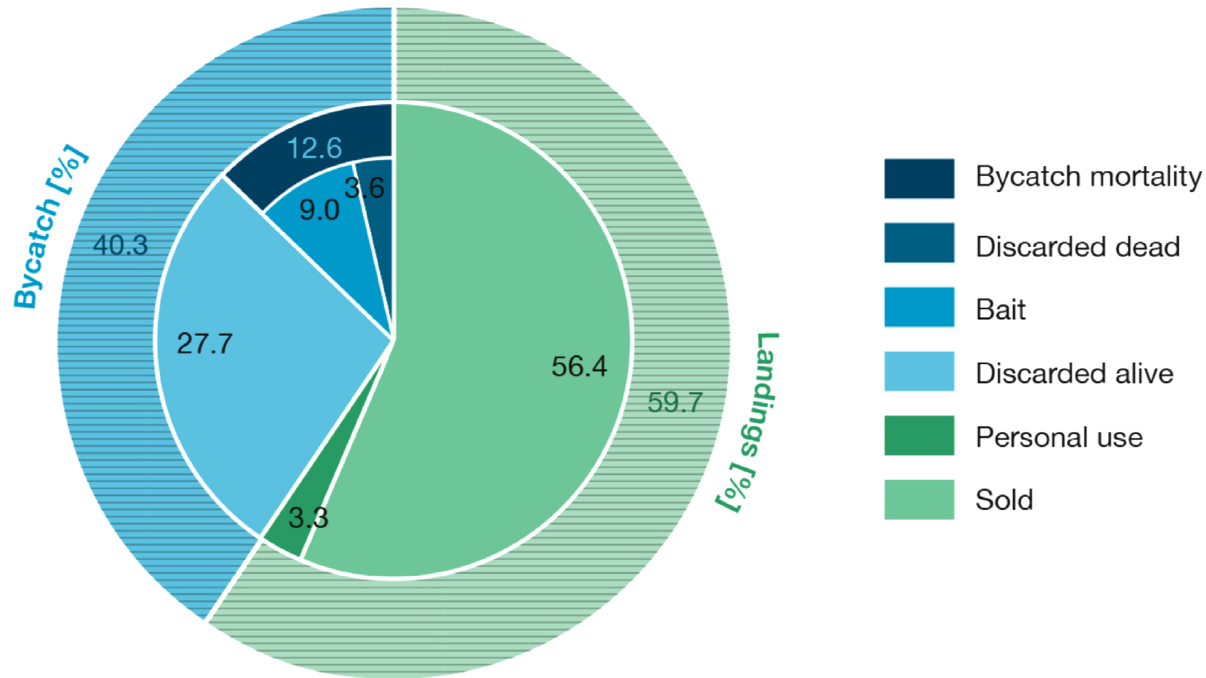

Figure 2: Fraction of the total biomass for landings and bycatch (outer circle) and the fractions of the according subcategories for landings (dashed green): personal use (dark green) and sold (light green), and for bycatch (dashed blue): bycatch mortality (dark blue) and discarded alive (light blue). The bycatch mortality is divided by the fraction discarded dead and the fraction used as bait.

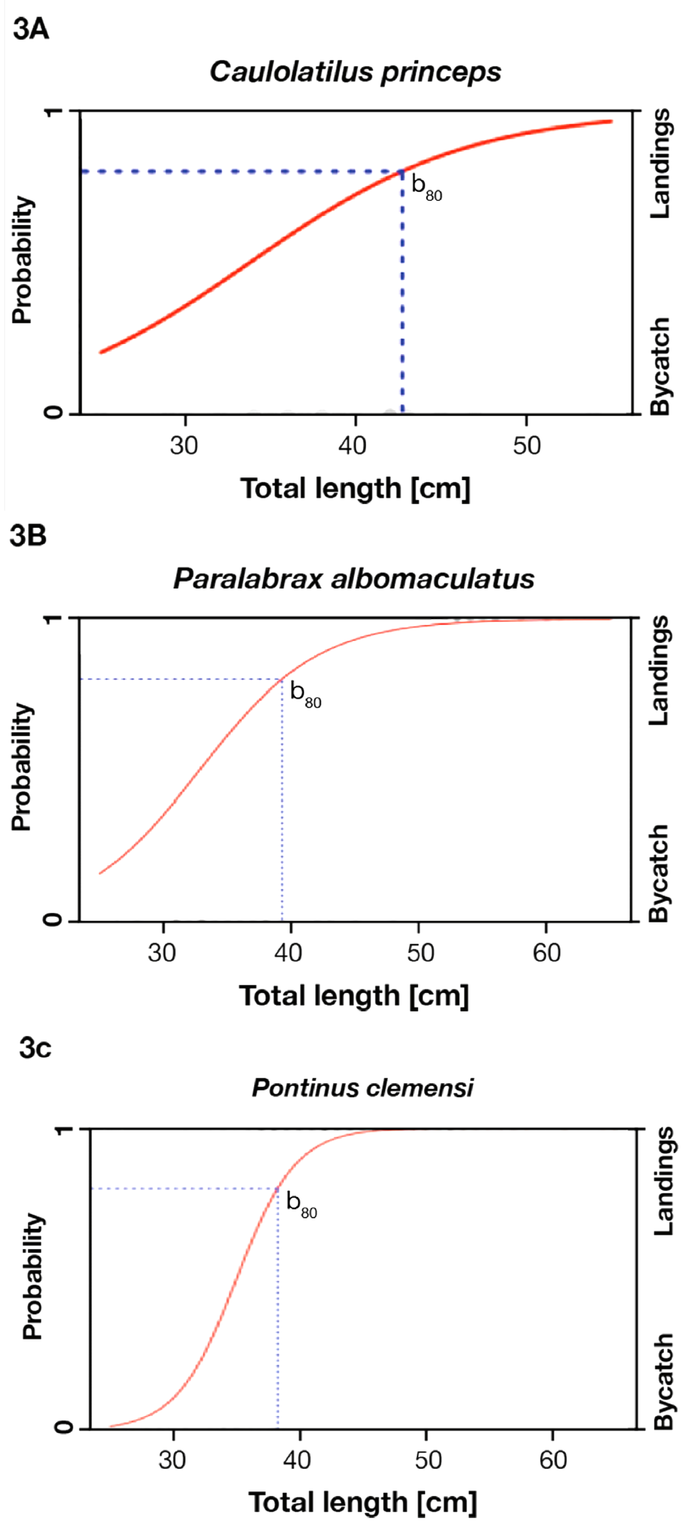

Figure 3: Logistic regression model results showing the probability of an individual to belong to bycatch (0) or to landings (1) depending on the individuals' total length. The dashed blue line indicates the b_{80} for the species: A) *C. princeps* (n = 112, b_{80} = 38.2 cm TL, odds ratio = 1.16); B) *P. albomaculatus* (n = 112, b_{80} = 39.2 cm TL, odds ratio = 1.24); C) *P. clemens* (n = 141, b_{80} = 35.2 cm TL, odds ratio = 3.25e-7).

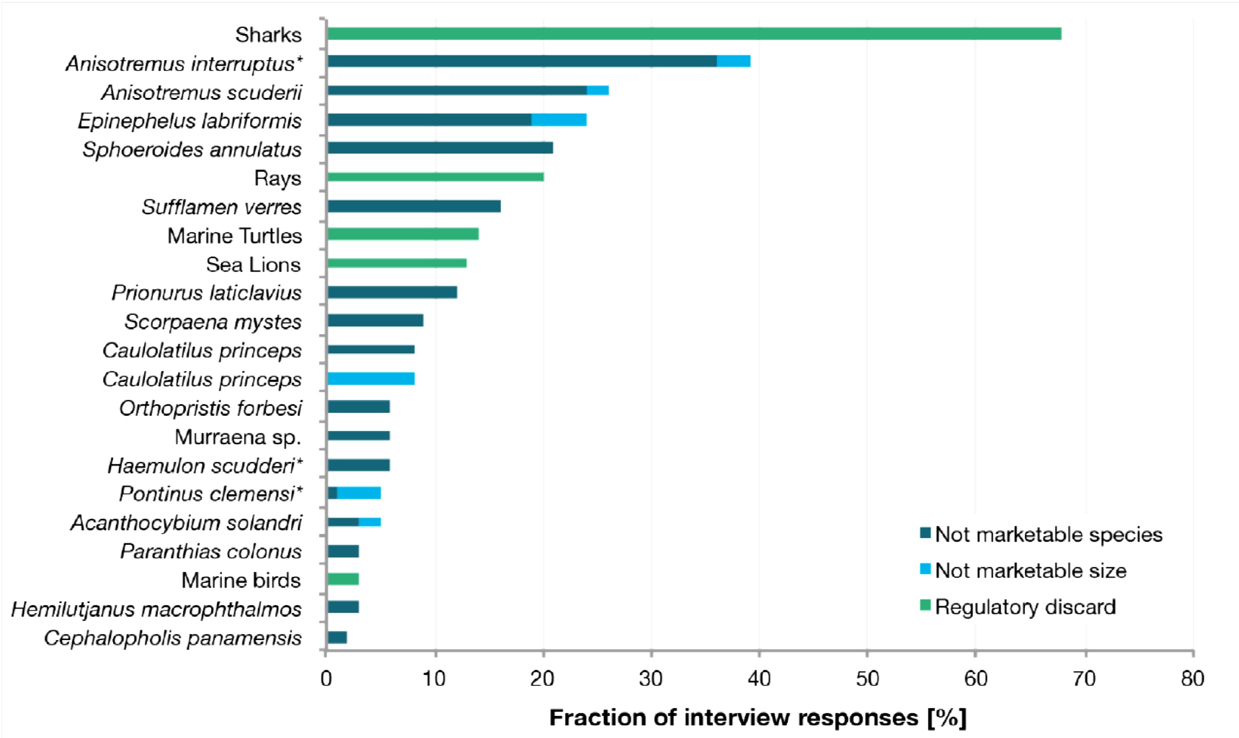

Figure 4: Percentage of responses of interviewees (n = 100) for each mentioned taxa as well as the reasons of fishers to not land these taxa. Not marketable species (dark blue), not marketable size (light blue) and regulatory discard (green).

Table 1: Marketable species that were landed during onboard monitoring, numbers of specimens landed (N), their average total length with its' standard deviations (Av. TL ± SD) and the bycatch ratio of each particular species (BCRs). Asterisks denote endemic species to Galapagos.

Family	Scientific Name	Common Name	N	Av. TL ± SD [cm]	BCRs
Serranidae	*Mycteroperca olfax**	Galapagos sailfin grouper	368	45.9 ± 8.5	0
Serranidae	*Cratinus agassizi*	Grazery threadfin seabass	16	59.8 ± 11.5	0
Serranidae	*Epinephelus mystacinus*	Misty Grouper	2	83.0 ± 5.0	0
Carangidae	*Caranx caballus*	Green jack	1	49.0 ± 0.0	0
Lutjanidae	*Hoplopagrus guentheri*	Barred Snapper	1	72.0 ± 0.0	0
Labridae	*Semicossyphus darwini*	Galapagos sheephead wrasse	37	51.4 ± 7.4	0.08
Malacanthidae	*Caulolatilus princeps*	Ocean whitefish	88	42.5 ± 5.0	0.21
Serranidae	*Paralabrax albomaculatus**	Camotillo	85	44.9 ± 7.5	0.24
Scorpaenidae	*Pontinus clemensi**	Mottled scorpionfish	106	45.3 ± 7.4	0.25
Sparidae	*Calamus taurinus**	Galapagos porgy	6	38 ± 4.1	0.25
Malacanthidae	*Caulolatilus affinis*	Bighead tilefish	2	48.5 ± 3.5	0.33
Serranidae	*Hemilutjanus macrophthalmos*	Grape eye seabass	3	58.3 ± 1.3	0.4
Carangidae	*Caranx sexfasciatus*	Bigeye trevally	1	46.0 ± 0.0	0.5
Serranidae	*Epinephelus cifuentesi*	Olive grouper	2	64.5 ± 21.5	0.6
Serranidae	*Epinephelus labriformis*	Starry grouper	6	38.7 ± 3.0	0.89
Haemulidae	*Anisotremus scuderii*	Peruvian grunt	6	31.3 ± 3.1	0.93
Haemulidae	*Anisotremus interruptus*	Burrito grunt	3	32.3 ± 2.1	0.98

Table 2: Not marketable species, not marketable sizes and regulatory discards that were recorded during onboard monitoring, numbers of specimens (N), their average total length with its' standard deviations (Av. TL ± SD) and the bycatch ratio of each particular species (BCRs). Asterisks denote endemic species to Galapagos.

Family	**Scientific name**	**Common name**	**N**	**Av. TL [cm] ± SD**	**BCRs**
Not marketable species					
Haemulidae	*Haemulon sexfasciatum*	Greybar grunt	29	30.0 ± 4.9	1
Lutjanidae	*Lutjanus viridis*	Blue and gold snapper	19	26.2 ± 3.6	1
Serranidae	*Paranthias colonus*	Pacific creolefish	17	30.6 ± 4.3	1
Sphyraenidae	*Sphyraena idiastes*	Pelican barracuda	11	59.3 ± 9.9	1
Haemulidae	*Haemulon scudderi**	Grey grunt	6	32.0 ± 3.5	1
Balistidae	*Balistes polylepis*	Finescale triggerfish	5	45.6 ± 1.0	1
Balistidae	*Sufflamen verres*	Orangeside triggerfish	5	37.4 ± 5.2	1
Scorpaenidae	*Scorpaena mystes*	Pacific spotted scorpionfish	2	28.0 ± 0.0	1
Synodontidae	*Synodus lacertinus*	Banded lizardfish	2	34.0 ± 7.0	1
Kyphosidae	*Girella freminvilli*	Dusky chub	1	35.0 ± 0.0	1
Muraenidae	*Murraena sp.*	Moray eel	1	60.0 ± 0.0	1
Scombridae	*Scomberomorus sierra*	Pacific Sierra	1	90.0 ± 0.0	1
Scorpaenidae	*Scorpaena histrio*	Bandfin scorpionfish	1	33.0 ± 0.0	1
Serranidae	*Serranus psittacus*	Barred serrano	1	13.0 ± 0.0	1
Tetradontidae	*Sphoeroides annulatus*	Bullseye puffer	1	27.0 ± 0.0	1
Haemulidae	*Anisotremus interruptus**	Burrito grunt	191	33.2 ± 5.0	0.98
Haemulidae	*Anisotremus scuderii*	Peruvian grunt	81	32.2 ± 2.9	0.93
Malacanthidae	*Caulolatilus affinis*	Bighead tilefish	3	45.7 ± 4.5	0.33
Not marketable size					
Serranidae	*Dermatolepis dermatolepis*	Leather bass	1	46.0 ± 0.0	1
Serranidae	*Epinephelus labriformis*	Starry grouper	51	36.2 ± 3.8	0.89
Serranidae	*Epinephelus cifuentesi*	Olive grouper	3	35.0 ± 4.1	0.6
Carangidae	*Caranx sexfasciatus*	Bigeye trevally	1	43.0 ± 0.0	0.5
Serranidae	*Hemilutjanus macrophthalmos*	Grape eye seabass	2	49.0 ± 1.0	0.4
Scorpaenidae	*Pontinus clemensi**	Mottled scorpionfish	35	31.2 ± 5.3	0.25
Sparidae	*Calamus taurinus**	Galapagos porgy	2	36.5 ± 6.5	0.25
Serranidae	*Paralabrax albomaculatus**	Camotillo	27	36.2 ± 6.1	0.24
Malacanthidae	*Caulolatilus princeps*	Ocean whitefish	24	38.3 ± 6.1	0.21
Labridae	*Semicossyphus darwini*	Galapagos sheephead wrasse	3	43.0 ± 5.0	0.08
Regulatory discard					
Carcharhinidae	*Carcharhinus galapagensis*	Galapagos shark	23	74.4 ± 8.4	1
Carcharhinidae	*Triaenodon obesus*	Whitetip reef shark	3	110.0 ± 0.0	1
Otariidae	*Zalophus wollebaeki*	Californian sea lion	2	n.a.	1

Annex 1

Fitting parameters (a and b) and the number of individuals (n) of the length-weight relationship for species where these information were not available in literature.

Species	**a**	**b**	**n**
Hemilutjanus macrophthalmos	*0.07*	*2.54*	*95*
Pontinus clemensi	*0.01*	*3.21*	*120*
Semicossyphus darwini	*0.11*	*2.50*	*96*

Annex 2

List of bycatch species that were mentioned by interviewed fishers once.

Species	**Not marketable species**	**Not marketable size**
Caulolatilus affinis	1	
Caranx caballus	1	
Dermatolepis dermatolepis		1
Epinephelus cifuentesi		1
Eucinostomus dowii	1	
Euthynnus lineatus	1	
Haemulon sexfasciatum	1	
Lutjanus sp.		1
Mugil galapagensis		1
Murraena sp.	1	
*Mycteroperca olfax**		1
Myrichthys tigrinus	1	
*Paralabrax albomaculatus**		1
Semicossyphus darwini	1	
Sphyraena idiastes	1	
Thunnus albacares		1
Xenichthys sp.	1	