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Ecosystem-based adaptation measures for Galapagos small-scale fisheries in the context of climate change

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1. SUMMARY

Small-scale fisheries (SSF) are a strategic sector for the economy, food security, and sustainable development of the Galapagos human population. They are increasingly threatened by climatic and anthropogenic drivers of change. One of the most relevant is climate change, a global-scale perturbation that is disrupting the availability and accessibility of marine fish and invertebrates by shifting the oceanographic and climatological conditions that influence their distribution and abundance. The Galapagos Islands (Ecuador) are strongly affected by El Niño Southern Oscillation (ENSO), making this multiple-use marine protected area vulnerable to climate variability and change. It is uncertain whether ENSO will intensify or weaken under climate change. However, recent studies predict that this global climatic driver is likely to affect organisms and populations inhabiting the Eastern Tropical Pacific (ETP) region, including Galapagos, due to increasing trends in warming and acidification of surface waters, stratification and reduced productivity and upwelling/mixing of hypoxic waters into the surface layer. As climate change might result in similar, but prolonged and more intense conditions of those caused by ENSO events by the end of the 21st century, policies aimed at building resilience in small-scale fisheries (SSF) are needed to increase the adaptive capacity of fishery resources, fishing communities, and institutions to cope with and adapt to climate change.

Therefore, this program proposes three Ecosystem-based Adaptation measures (EBA) to increase the resilience and adaptive capacity of Galapagos SSF fisheries in the context of climate change. If successfully implemented, the three EBA proposed will help local fishing communities to adapt to climate change, and this in turn will yield direct and ancillary benefits in the short and long-term, resulting in positive returns on investment and ‘‘win-win’’ situations for coastal communities and marine ecosystems. However, their implementation will demand effective and enforceable regulations and economic incentives, all of which will require the political will of the Galapagos National Park Directorate and Galapagos Governing Council, as well as adequate financial and human capital.

2. INTRODUCTION

Small-scale fisheries (SSF) are increasingly threatened by anthropogenic drivers of change acting at multiple spatial and temporal scales (Hall 2011; Defeo et al. 2013b; Castrejón and Defeo 2015; Castrejón and Charles 2020). One of the most relevant is climate change, a global-scale perturbation that is disrupting the availability and accessibility of marine fish and invertebrates by shifting the oceanographic and climatological conditions that influence their distribution and abundance (Rijnsdorp et al. 2009; Hollowed et al. 2013). A decreased accessibility and availability of commercial species are serious threats because this will negatively influence a wide range of socio-economic factors, including food security, livelihoods and public health (Blasiak *et al*., 2017; Golden *et al*., 2016).

Climate change is threatening food security and livelihoods of fishing communities by exacerbating the negative effects caused by anthropogenic drivers, such as overfishing, pollution, and markets globalization (Defeo and Castilla 2012; Ortega et al. 2012; Defeo et al. 2013b). This climatic driver has increased the risk of disasters by intensifying the magnitude and frequency of natural extreme events, including hurricanes, floods, droughts, and heatwaves (van Aalst 2006; Belhabib et al. 2018). In Central and South America, 613 climatological and hydro-meteorological extreme events occurred during the period 2000–2013, resulting in 13,883 fatalities, 53.8 million people affected, and economic losses for US$52.3 billion (Barros et al. 2014). In this region, fishing communities are especially vulnerable to the social-ecological perturbations caused not only by extreme natural events but also by drastic long-term and large-scale effects of climate variability associated to climate change, including sea surface temperature anomalies, increasing wind intensity and sea-level rise (Defeo et al. 2013b). These climatic drivers affect the distribution and production of fish stocks, the risk and viability of fishing operations and livelihoods, and the economic contribution of fisheries to poverty reduction (Allison et al. 2009).

Climate change impacts fisheries through a variety of physical and chemical factors, which include changes in temperature, winds, vertical mixing, salinity, dissolved oxygen, sea level, and pH. The direct effects act on the physiology, development rates, reproduction, behaviour and survival of individuals (Brander, 2010). These impacts and their variability fluctuate according to the life cycle and latitudinal distribution of fishery resources, the characteristics of the oceanographic systems, and the inherent features of the social systems (Defeo et al. 2013b). In the Eastern Tropical Pacific (ETP), El Niño Southern Oscillation (ENSO) has a strong influence on the dynamics of coastal upwelling systems, affecting the productivity of marine ecosystems and commercial fish stocks (Wang and Fiedler 2006). El Niño (warm phase) events are characterized by high sea surface temperatures (SST), a lack of west-to-east thermal gradient across the surface of the Pacific, and a weakening of the easterly trade winds (Lui et al. 2013). In Galapagos, El Niño produces high air temperatures, sustained high SST, increased rainfall, and a longer than usual warm season, whereas La Niña (cold phase) events result in abnormally cold conditions and drought (Sachs and Ladd 2010). There is significant debate regarding whether ENSO in the ETP will intensify or weaken under climate change (Collins et al. 2010; Liu et al. 2013; Wang et al. 2017; Cai et al. 2018). However, some studies suggests that El Niño events have increased in intensity and frequency over the last two decades in the eastern Pacific due to warmer SST (Conroy et al., 2010; Rustic et al., 2015; Thompson et al., 2017).

On the other hand, based on IPCC projections related to the business-as-usual/high greenhouse gas emission scenario (called the Relative Concentration Pathway- RCP 8.5 scenario), Monnier et al. (2020) predicts an average increase in sea surface temperature of 3.5 °C in the EEZ off the Ecuadorian continental coast and 3.9 °C in and around the Galapagos Islands EEZ by the end of this century. In contrast, changes in pH are projected to be lower. Such changes are likely to affect organisms and populations inhabiting the ETP region due to increasing trends in warming and acidification of surface waters, stratification and reduced productivity, and upwelling/mixing of hypoxic waters into the surface layer (Glynn et al. 2017; Manzello et al. 2017). The precise impacts and direction of climate-driven change for fisheries are still developing. However, research suggests fisheries are likely to lead to either increased economic hardship, or missed opportunities for development in countries that depend upon this sector but have limited capacity to adapt (Allison *et al*., 2009).

Furthermore, although Galapagos is a sanctuary for several marine species, the overexploitation, incidental catch, and illegal fishing, produced by Ecuadorian and foreign industrial fleet established along Galapagos boundaries (Boerder et al., 2017), pose a threat to commercial species (Alava et al., 2017; Alava and Paladines, 2017; Castrejón 2020a) and SSF. Species targeted by SSF show signs of over exploitation (e.g. bass and groupers) (Danulat and Edgar, 2002; Schiller et al., 2014; Usseglio et al., 2016), while others have already collapsed due to overfishing (i.e. sea cucumber on 2006) (Hearn and Toral-Granda, 2007, Hearn et al., 2005; Purcell et al., 2011; Toral-Granda, 2008; Wolff et al., 2011). Intensive fishing coupled with the potential impacts of climate change threatens both the conservation-sustainability of SSF and Galapagos livelihoods, which highlights the need to better understand the impacts of climate change in this region.

As climate change might result in similar, but prolonged and more intense conditions of those caused by ENSO events by the end of the 21st century (Cha et al. 2018), research efforts in the ETP are needed to evaluate the long-term ENSO variability coupled with ongoing climate change and its observed and predicted impact on high ecological value areas (HEVAS)[1], marine ecosystems and SSF.

The ENSO affects the function and structure of Galapagos marine ecosystems, the abundance and distribution of fishery resources, disrupting their availability and accessibility, leading to changes in fisher´s behaviour (Castrejón 2020b). Despite more than 65 species are commercially exploited in Galapagos (Castrejón 2011), there is only empirical information about the impact of ENSO for less than 6.1% of Galapagos fishery resources (Castrejon 2020b). This a matter of great concern because pelagic and demersal finfish species, such as yellowfin tuna (*Thunnus albacares*) and sailfin grouper (*Mycteroperca olfax*), are fundamental for the economy and food security of Galapagos human population. In consequence, policy-makers lack of information to guide and prioritize decisions about investments and initiatives needed to increase the resilience and adaptive capacity of the small-scale fishing sector in the context of climate change.

[1] High ecological value areas (HEVA) are defined as areas highly sensitive and exposed to drivers of environmental change. These areas are key for environmental services provision, including fisheries, freshwater, and nature-based tourism activities (Escobar et al. under review).

3. PROJECT IMPLEMENTATION AREA

The Galapagos archipelago comprises approximately 234 islands, islets, and rocks with a total land area and coastline of ca. 7 985 km^2 and 1667 km, respectively (DPNG, 2014), which are enclosed in a multiple-use area (MPA) of nearly 138,000 km^2, the Galapagos Marine Reserve (GMR) (Fig. 1) (Heylings et al., 2002). The GMR is divided into five marine bioregions, referred to as far-Northern, Northern, South-Eastern, Western and Elizabeth – the latter being a bioregion located in the Western part of Isabela Island, whose proportion of endemic species is anomalously high (Edgar et al., 2004a; Fig. 1). Each bioregion has distinctive reef fish and macro-invertebrate assemblages, whose abundance and distribution are strongly affected by El Niño Southern Oscillation (ENSO), making Galapagos an exceptional case study for assessing the effect of natural extreme events on marine biodiversity and SSF (Edgar et al. 2004a; Edgar et al. 2010; Defeo et al. 2013b).

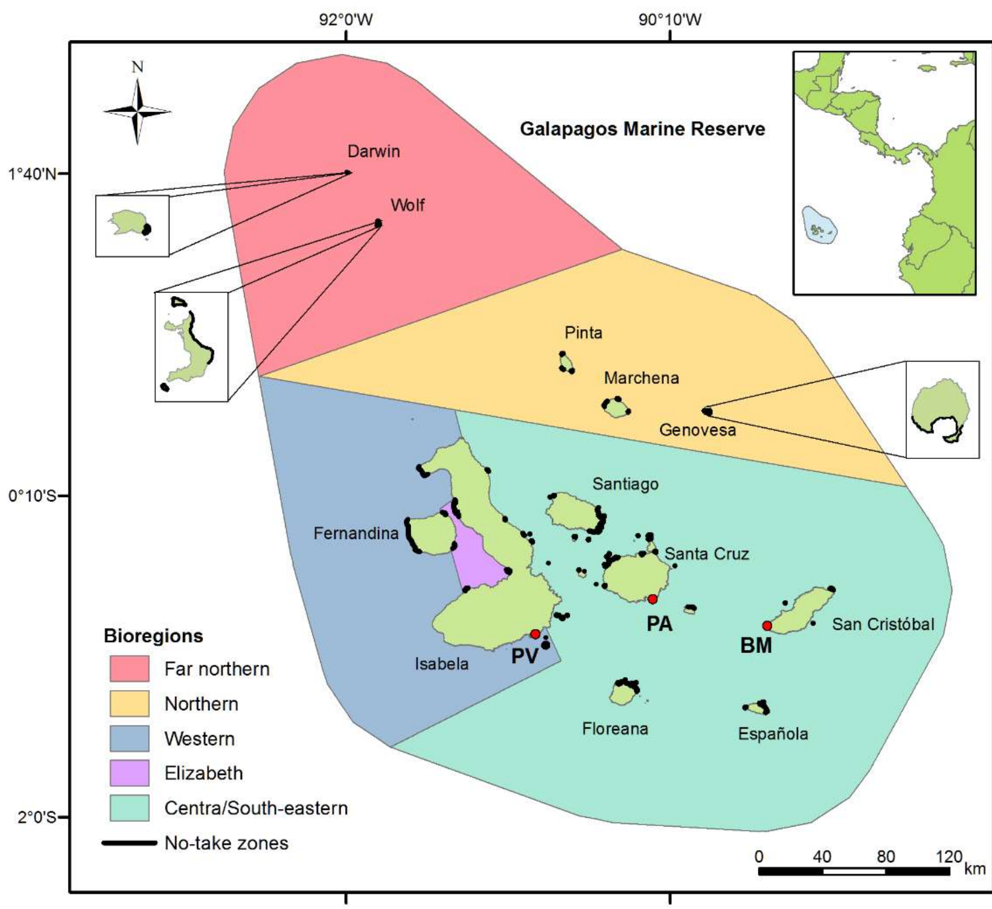

Figure 1. Bioregions, islands, ports and no-take zones, according to the 2000 marine zoning, from the Galapagos Marine Reserve. Source: Castrejón and Charles (2020).

Only 4% of the total land area is inhabited by ca. 25 144 residents distributed in five islands (Santa Cruz, Baltra, San Cristobal, Isabela, and Floreana). The remaining land area is natural protected area. There are three main fishing ports, (1) Baquerizo Moreno (San Cristóbal), (2) Puerto Ayora (Santa Cruz) and (3) Puerto Villamil (Isabela) (Fig. 1). Fishers are organized into four fishing cooperatives, most with low levels of organization, social cohesion and leadership. There are 1084 license holders and 416 vessels registered in Galapagos, although only 37% of them remain active (Castrejón and Charles 2020). Each fishing license provides to its owner the right to fish any type of shellfish and finfish species commercially permitted. Approximately 97% of active vessels are smaller than 9.6 m long (fiber glass or wooden made) and equipped with outboard engines (15–200 HP). Only 13% consist of wooden large boats (8 to 18 m long) equipped with inboards engines (30-210 HP). Large boats are used as storage, resting and towing units for up to four small vessels. Most harvesting activities usually last one or two days, although large boats are able to operate for a maximum of 12 days.

Approximately, 68 shellfish and finfish species from 27 families species are commercially harvested by ca. 400 small-scale fishers (Castrejón 2011; Schiller et al. 2013; Castrejón and Charles 2020). The most important fishery resources, after the collapse and total closure of the sea cucumber (*Isostichopus fuscus*) fishery occurred in 2006 (Defeo et al. 2016), are spiny lobsters (*Panulirus penicillatus* and *P. gracilis*), slipper lobsters (*Scyllarides astori*), yellowfin tuna (*Thunnus albacares*) and several benthic and demersal fish species, including the Galapagos sailfin grouper (*Mycteroperca olfax*), the mottled scorpionfish (*Pontinus clemensi*), the whitespotted sandbass (*Paralabrax albomaculatus*), and the misty grouper (*Hyporthodon mystacinus*) (Castrejón 2011; Schiller et al. 2014; Defeo et al. 2016; Marin and Salinas-de-León 2018).

4. PROBLEM CONTEXT AND ANALYSES

Climate change is a global driver that, in combination with overexploitation and illegal, undeclared and unregulated (IUU) fishing, will exacerbate the degradation of the resilience and adaptive capacity of Galapagos marine ecosystems, fishery resources, and human coastal communities. The COVID-19 crisis can be used as an analogy to comprehend this problem. A marine ecosystem is like a person. A healthy person will have more probabilities to withstand infection by COVID-19 than a person with pre-existing conditions, such as diabetes and hypertension. In the same way, a healthy marine ecosystem will be in a better position to withstand the negative effects of climate change than a marine ecosystem affected by pre-conditions, represented in this case by overexploitation and illegal, unreported and unregulated (IUU) fishing, and other stressors like marine pollution and market globalization. Therefore, the prevention and eradication of these pre-conditions is the best strategy to follow to help Galapagos marine ecosystems to cope with the impacts of climate change, together with the global reduction of atmospheric greenhouse gases.

Commercial fisheries in the Galapagos archipelago started as early as the 18th century, but the explosive growth of the SSF began in the 1970s onwards and was incentivized by the profitability, first of groupers and lobsters, and later of sea cucumber fisheries (Reck, 1983; Castrejón & Charles, 2013). The Galapagos National Park Directorate (GNPD), in collaboration with non-environmental organizations (NGO) and other strategic allies, has taken concrete actions to prevent and eradicate the impacts of overexploitation and IUU fishing on HEVAS and to ensure the sustainability of Galapagos SSF. The most relevant has been the creation of the GMR, through the approval of the Galapagos Special Law (GSL) in march 1998 (González et al. 2008; Castrejón 2011). The GMR ensures the conservation of this immense natural wealth and guarantees sustainable economic development for the island's population. Since then, several fisheries management measures have been implemented to shift from an open-access to a common property regime in fishery resources (Heylings and Bravo 2007; Castrejón 2011). Some of the most important included the prohibition of industrial fishing inside the reserve, the allocation of exclusive use rights to local fishers, in the form of licenses and fishing permits, a moratorium on new entrants, and the adoption of an ecosystem-based spatial management (EBSM) approach. The latter was implemented through the adoption of marine zoning (Fig. 1), a spatially explicit management tool that was designed and implemented through a consensus-based participatory process between 1999 and 2006 (Heylings et al. 2002; Castrejón and Charles 2013). As a result, ca. 18% of the Galapagos coastline were declared as no-take zones (Fig. 1), whose individual size ranged from small offshore islets to a 70 km span of coast, with no offshore boundaries legally established (Heylings et al. 2002; Castrejón and Charles 2013).

Unfortunately, the effectiveness of Galapagos marine zoning to improve the governance and sustainability of SSF has been limited by the biased location of no-take zones in areas of low abundance of the most lucrative fishery resources (e.g., sea cucumbers and spiny lobsters), in combination with a lack of effective enforcement and a high rate of non-compliance (Edgar et al. 2004b; Viteri and Chávez 2007; Castrejón and Charles 2020). The sea cucumber fishery collapsed in 2006 (Wolff et al. 2012b; Defeo et al. 2016), while the Galapagos grouper, the white-spotted sand bass, and the olive grouper (*Epinephelus cifuentesi*) show signs of overexploitation (Usseglio et al. 2016; Eddy et al. 2019). Despite these failures, spiny lobster stocks showed an unexpected and remarkable recovery after a period of overexploitation, probably caused by the combined effect of market forces and the ENSO rather than no-take zone implementation (Defeo et al. 2013b; Defeo et al. 2016; Szuwalski et al. 2016; Castrejón and Charles 2020). Nevertheless, overfishing and IUU fishing of sea cucumbers, groupers, and sharks has substantially decreased their ecological role on marine ecosystems, triggering cascading effects with profound effects on the whole food web (Ruiz and Wolff 2011; Eddy et al. 2019).

As ENSO and climate change are likely to exacerbate the effects of overexploitation and IUU fishing, it is fundamental to comprehend how fishery resources, and people that depend on them, will be affected by climate stressors in the coming decades. This is a research and management priority relevant for sea cucumbers, sailfin grouper, and many other Galapagos shellfish and finfish fisheries, whose exploitation status is overfished or unknown (Schiller et al. 2014; Usseglio et al. 2016). Based on this knowledge, policies aimed at building resilience of Galapagos marine ecosystems must be implemented by the GNPD and the Galapagos Governing Council to increase the resilience and adaptive capacity of fishery resources, fishing communities, and institutions to cope with and adapt to climate change. However, even though climate change and variability are currently attracting the most attention, the socioeconomic disruptions caused by overexploitation and IUU fishing, and their ecological impacts on targets species, critical habitats, and ecosystems, should not be neglected (McCay et al. 2011; Defeo et al. 2013b; Castrejón and Charles 2020).

Despite of its paramount importance, no study has predicted how climate change will impact the entire Galapagos fishery system, including fishery resources, fishers, and the social and economic significance of this impact. Answering this question not only requires a prediction of impacts of atmospheric warming on climatic, hydrological, oceanographic and ecological processes, through coupled physical-ecosystem models, but an understanding of the social and economic dynamics of fishing fleets and fishing communities, and their capacity to adapt to change (Allison et al. 2009). This integrated prediction approach is beyond the current frontiers of knowledge in Galapagos.

However, potential future climate change scenarios can be elaborated qualitatively, based on the scientific information available, assuming that future ocean conditions will shift toward an El Niño-like ocean state, meaning that sea surface temperature will increase, while primary productivity will decrease, possibly permanently. In this context, the worst climate change scenario possible would be the collapse of all Galapagos fishery resources due to unfavourable ocean conditions caused by El Niño-like ocean state, while the best scenario would be the recovery of overfished fishery resources due to favorable conditions caused by this global climatic driver.

Nevertheless, based on the scientific information available, the most probable scenario could be one on which different species will show variations in their availability and/or accessibility due to gradual or sudden changes in their abundance or distribution as ocean conditions shift towards El Niño-like ocean state. For example, the accessibility to spiny lobsters and yellowfin tuna stocks could decrease in an El Niño-like ocean state, probably due to changes in their distribution, which will make them inaccessible to Galapagos small-scale fishers. However, the availability of predatory finfish species, such as sailfin groupers, could also be reduced due to higher mortality rates caused by overfishing and ENSO, or increasing SST caused by climate change, as suggested by Wolff et al. (2012a), Eddie et al. (2019) and Monnier et al. (2020). These changes will negatively affect fishers' livelihoods and food security of coastal communities.

4.1 Impact of the ENSO and climate change on Galapagos small-scale fisheries

A growing number of empirical studies have shown that climate variability, represented mainly by the ENSO and coupled with anthropogenic drivers, has affected Galapagos marine ecosystems, fishery resources, and fisher´s behavior. Climate change research related to the Galapagos Islands has mostly focused on evaluating the observed effects of ENSO on landings, fishing effort and CPUE of several fisheries. In contrast, few studies have evaluated the ecological impact of ENSO on fishery resources and the consequences of climate variability on Galapagos' small-scale fishers and coastal communities.

Considering that ca. 68 species are commercially exploited in Galapagos (Castrejón 2011; Schiller et al. 2014), then there is empirical information about the impact of ENSO for less than 6.1% of Galapagos fishery resources. This a matter of great concern, as some species, particularly pelagic and demersal finfish species, are fundamental for the economy and food security of Galapagos human population.

In consequence, the GNPD lacks information to guide and prioritize decisions about investments and initiatives needed for climate change mitigation and adaptation in the small-scale fishing sector.

4.1.1 Spiny lobster and sea cucumber fisheries

The spiny lobsters is the Galapagos SSF on which most information about the impact of ENSO exists. However, even in this case study, there is uncertainty about the observed impact of the ENSO and climate change. According to Defeo et al. (2013b) the production (landings) of the spiny lobster and sea cucumber fisheries could be related to variations in sea surface temperatures (SST) in general, and particularly during El Niño events. Two and five years after the 1997/98 El Niño event, the spiny lobster and sea cucumber registered maximum historic production levels (Fig. 2). Furthermore, Wolff et al. (2012a), based on a trophic mass balance model for the Bolivar Channel ecosystem, suggest that lobsters biomass increased following the 1997/98 El Niño event.

The increased production levels registered for the sea cucumber SSF in 2002 are suggested to be product of the combined result of two main factors (Hearn et al. 2005; Castrejón 2011; Wolff et al. 2012a): (1) a strong recruitment pulse triggered by the 1997/98 El Niño that led to unusually high stock densities during years 2000-2003; and (2) an increase in fishing effort that resulted from the opening of the sea cucumber artisanal fishery in 1999 (Fig. 2) (Hearn et al. 2005; Castrejón 2011; Wolff et al. 2012a). Furthermore, the same factors, combined with a low predator abundance (e.g., demersal fish) and high prey abundance (e.g., sea urchins) after the 1997/98 El Niño, could explain the high production of spiny lobsters in 2000 (Bustamante et al. 2000; Hearn and Murillo 2008; Wolff et al. 2012a). However, Szuwalski et.al (2016) determined that the ENSO did not affect the biomass and recruitment of red spiny lobster stocks between 1997 and 2011.

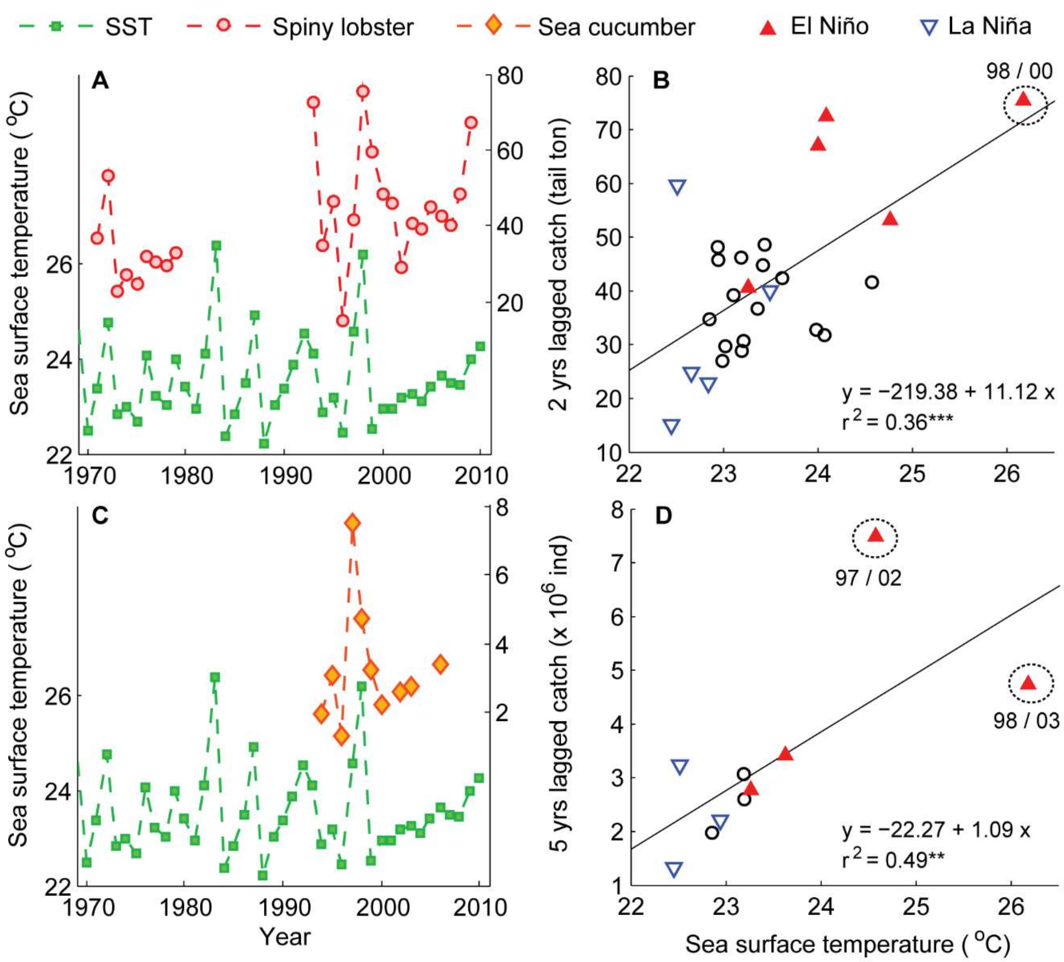

Figure 2. Time series and linear regressions between mean annual sea surface temperature (SST *in situ*, Santa Cruz Island) and lagged annual catch of spiny lobster (*Panulirus penicillatus*

and *P. gracilis*; A, B) and sea cucumber (*Isostichopus fuscus*; C, D) in the Galapagos Islands, Ecuador. Catch series from 1995 to 2011 were linearly detrended and the residuals added to the mean, to account for the effect of fishing. Encircled triangles in B and D indicate the positive effect of 1997/98 El Niño over spiny lobster (2000) and sea cucumber (2002–2003) catches. El Niño and La Niña events were defined based on the Oceanic Niño Index (ONI) estimated by the National Oceanic and Atmospheric Administration (NOAA). **: $P < 0.05$; ***: $P < 0.001$. Catch and SST time series were provided by Galapagos National Park and Charles Darwin Foundation (2012). Source: Defeo et al. (2013).

Although El Niño events caused a positive effect in shellfisheries, the sea cucumber fishery collapsed in 2006 due to overexploitation (Wolff et al. 2012b; Defeo et al. 2016). Apart from their economic importance to Galapagos fishers, sea cucumbers are also important in marine ecosystems due to their key role as nutrient recyclers (Purcell et al. 2016). Sea cucumbers excrete inorganic nitrogen and phosphorus, enhancing the productivity of benthic biota. This form of nutrient recycling is crucial in ecosystems in oligotrophic waters such as coral reefs. Feeding and excretion by sea cucumbers also act in increasing seawater alkalinity which contributes to local buffering of ocean acidification (Purcell et al. 2016). As the ocean is absorbing a large proportion of atmospheric CO_2 derived from anthropogenic activity, the seawater carbonate chemical equilibrium is shifting towards lower pH, i.e., more acidic waters and lower calcium carbonate saturation states (Manzello et al. 2017). These changes impact many calcifying species, e.g., shell-forming marine organisms, but also probably the physiology and respiration of fishes, especially the more vulnerable early life stages. However, the ecological impact generated by the overexploitation and collapse of sea cucumbers stocks on the regulation of seawater carbonate chemical equilibrium in the Galapagos is unknown.

Unlike the spiny lobsters and sea cucumbers, no studies have been conducted to evaluate the impact of ENSO over slipper lobster and other benthic species, such as octopus (Table 1). This is a matter of concern because slipper lobsters and octopus are important for the economy and food security of Galapagos.

Table 1. Social-ecological impacts of ENSO reported for Galapagos small-scale shellfisheries. Type of impact: green (increase), red (decrease), yellow (no impact), blue (uncertain), grey (no information). SC: sea cucumber; SL: spiny lobster; SLL: slipper lobster; YT: yellowfin tuna; SG: sailfin grouper; MSF: mottled scorpionfish; OCT: octopus.

Impacts	SC	SL	SLL	YT	SG	MSF	OCT
Ecological							
Biomass							
Recruitment							
Spawning stock biomass							
Sexually immature individuals							
Social							
Landings							
CPUE							
Catchability							
Socio-economic well-being (temporal or permanent)							
Coping strategies							
Search times							
Fishing hours per trip							

The uncertainty about the observed impact of El Niño over the spiny lobster fishery could be associated with variations on the intensity of this climatic event. According to (Bertrand et al. 2020), no two El Niño events are alike, nor are the resulting ecological responses. In consequence, these authors have identified five ENSO events that occur at a global scale with different warming conditions.

1. Extreme El Niño events: intense warming over most of the equatorial Pacific with the strongest oceanic signature located in the eastern part of the basin.
2. Moderate Eastern Pacific (EP) El Niño events: modest warming over most of the equatorial Pacific with the strongest oceanic signature located in the eastern part of the basin.
3. Moderate Central Pacific (CP) El Niño events: modest equatorial Pacific warming located near the dateline with weak oceanic signature along the west coast of South America.
4. Coastal El Niño events: warm conditions along the west coast of South America, but normal or cool conditions elsewhere in the Pacific.

5. Strong La Niña events: large-scale cooling over most of the equatorial Pacific with the strongest oceanic signature located in the central part of the basin.

Bertrand et al. (2020) suggests that El Niño events differ on their impacts on the southeast Pacific. They found that while CP El Niño events do not significantly impact the Humboldt Current System (HCS) and related fisheries, strong and coastal El Niño events lead to warm ocean temperatures, heavy rain, floods, and heavy river discharges in northern Peru that can impact SSF infrastructure. Therefore, while extreme El Niños have the greatest impact, the response strongly differs from one event to the other, with the extreme El Niño of 1982/83 producing a much larger impact than that of 2015/16. As a result, Bertrand et al. (2020) conclude that the strength of the impact depends on the type of event. Extreme El Niños have by far the most relevant effect, followed by the EP El Niños.

As Galapagos is located in the main influence area of ENSO, it is expected that SSF from this archipelago will be strongly impacted by future ENSO events, particularly during extreme and EP El Niños (Bertrand et al. 2020). As the strength of the impact depends on the type of event, this might explain why different impacts have been observed in the Galapagos spiny lobsters fishery from 1997 to 2018.

Another source of uncertainty that limits the capacity to predict the observed impact of El Niño on the Galapagos spiny lobsters fishery is the influence of overfishing, which is an anthropogenic driver that exacerbates the effects of climate stressors (Defeo et al. 2013a). Studies hve shown that fishing effort varied remarkably between 1997 and 2018, contributing to the overexploitation and subsequent recovery of the spiny lobster stocks (Defeo et al. 2016; Castrejón and Charles 2020).

Overall, it seems the resilience and adaptive capacity of these species has increased, counteracting the impacts of the ENSO. However, it is uncertain how spiny lobster stocks will respond to future extreme El Niño events and climate change, if fishing effort is not regulated. The spiny lobster fishery is a case study that demonstrates how the influence of climatic and human-induced factors over the dynamics of fishery resources and SSF is difficult to disentangle. Therefore, climatic and anthropogenic drivers must be taken into consideration to formulate management strategies that contribute to increasing the resilience and adaptive capacity of SSF to climate variability and change.

4.1.2 Galapagos sailfin grouper and other demersal fish species

The Galapagos artisanal finfish fishery, referred locally as “pesca blanca”, target benthic and demersal fishes, being the most relevant the sailfin grouper (*M. olfax*), the endemic white-spotted sandbass (*P. albomaculatus*), mottled scorpionfish (*P. clemensi*), and the misty grouper (*H. mystacinus*). According to Schiller et al. (2014), 26 500 t of finfish were caught within the economic exclusive zone of the Galápagos Islands between 1950 and 2010. Of these catches, approximately 25.3%, equivalent to 6700 t, was consumed by Galapagos human population, including tourists, while the remainder 74.7%, equivalent to 19 800 t, was exported to mainland Ecuador.

Some studies have recently evaluated the impact of the ENSO and climate change on the sailfin grouper. Research evaluating the effect of El Niño 2015/16 over the landings composition of the Galapagos artisanal finfish fishery showed how catch composition changed during the 2016 El Niño event. Larger size individuals and uncommon demersal and benthic predatory fish species, like the Grape eye seabass (*Hemilutjanus macrophthalmos*) and Pacific dog snapper (*Lutjanus novemfasciatus*) were caught during this event (Marin and Salinas de León 2020). It is believed that the 2015/16 El Niño event probably decreased prey biomass by reducing primary productivity, leading to demersal and benthic predatory fish species into a starvation state. Thus, the catchability of these species probably increased, as they were more likely to be attracted to the bait offered by artisanal fishers. According to Marin and Salinas de León (2020), the increased catchability of larger individuals, caused by El Niño, could exacerbate the overexploitation of the Galapagos sailfin groper. In consequence, these authors proposed the implementation of management actions, including minimum legal size, catch limits, and spatiotemporal closures, to promote the recovery of this endemic and vulnerable species across the archipelago.

Furthermore, studies examining the impact of fishing on the biomass and ecosystem role of Galapagos sailfin grouper, during both normal and El Niño years, suggests that the ecosystem role of groupers, as top predators, has greatly diminished with overexploitation, which has depleted the stock by ca. 85% compared to unfished levels.

Reduction of groupers biomass decreases their ecosystem role as a keystone species[2], hence, their removal produces cascading effects with profound effects on the whole food web, during both normal and El Niño years. Grouper's overexploitation has triggered large changes (increase and decrease) in the biomass of many functional groups, and with covariations during El Niño years. If the Galapagos sailfin grouper stocks were rebuilt to at least half of unfished biomass, their role in the ecosystem would be partially restored and more fish would be caught (Eddy et al. 2019).

On the other hand, Monnier et al. (2020) indicate that under business-as-usual scenario (RCP 8.5) SST in Galapagos would increase 3.9 °C by the end of this century. This means that by the year 2100 the SST in Galapagos would be, on average, 30.9 °C in the worst case scenario. According to Kaschner et al. (2016) the preferred sea temperature of the sailfin grouper ranges between 14.5 °C and 23.7 °C, thus, this species would be outside of its thermal range under an RCP 8.5 scenario in Galapagos. In fact, Monnier et al. (2020) indicate that the sailfin grouper is already outside of its preferred temperature range in Galapagos and predicts that this species will be severely impacted by sea water warming, even in the case of the IPCC strong mitigation scenario (RCP 2.6). These authors also estimate that the sailfin grouper's ecosystem biomass will be reduced 8.3% and 10.8% by 2030 under RCP 2.6 and 8.5 scenario, respectively. Such reduction in biomass will be higher by 2100 (8.0% and 15.6% for RCP 2.6 and 8.5 respectively).

Another potential impact of climate change on groupers are the expected changes in oceanic circulation patterns as a result of rising water temperatures (Kennett & Ingram, 1995). It has been demonstrated that anthropogenic global warming will change oceanic circulation patterns around the Galapagos archipelago in the time span 2025 and 2050, and will affect bioregions differently (Liu *et al.*, 2013). These changes in ocean circulation are expected to have consequences on the larval stage of fish species (Kendall *et al.*, 2016). Although information on the sailfin grouper larvae and its actual transport

[2] Keystone species are those which have an extremely high impact on a particular ecosystem relative to its population.

mechanism is still unknown, changes in the oceanic currents surrounding the archipelago could result in larvae transported away from highly productive habitats, ultimately resulting in poor recruitment.

Furthermore, groupers are known to have ontogenetic habitat use differences in the GMR. Adult sailfin groupers are mainly found in rocky reefs and *bajos* (shallow seamounts), while juveniles are mostly found in mangrove fringes (Aguaiza, 2016; Fierro, 2017). As such, adaptations measures for sailfin groupers should consider all grouper's habitats. Climate change will also impact species through sea level rise, negatively affecting mangrove ecosystems in the Galapagos. While mangroves could keep pace by migrating landward (Alongi, 2002), this will depend on water rising at a sufficiently slow rate to allow mangrove migration to occur (Gilman et al. 2008). The combined effect of rising temperatures and sea level rise, will affect adults and juveniles respectively. can have devastating effects on the already threatened Galapagos grouper.

Since mangroves provide critical habitat for a suite of economically important species, including the sailfin grouper EBA measures must identify and conserve, through no-take areas, those mangrove forest patches with the highest structural complexity and with the possibility to migrate inwards to keep pace with rising waters. These patches will act as climate change refuges for the juvenile stages of the sailfin grouper and other commercially important species that are expected to be fundamental in the recovery of the species.

A recent analysis based on the abundance of this species measured in coastal waters across the archipelago (all bioregions) for a time span of 20 years (1994-2014), shows no statistically significant linear patterns with regard to temperature measured on-site (linear regression, $p=0.18$, $n=520$) nor with average Oceanic Niño Index (ONI) values (Ramírez-González et al. 2020). However, visual inspection suggests that normal conditions (i.e. neutral ONI values) are those with the highest sailfin grouper abundances (Fig. 3). This analysis also shows that the effects of temperature anomalies have different responses according to bioregion (Fig. 4-5). The Western and Central south-eastern bioregions seem to have lower abundancies in the extremes, i.e. with ONI values above and below 0.5, corresponding to El Niño and La Niña respectively. For the Far Northern and Northern bioregions the pattern is less clear.

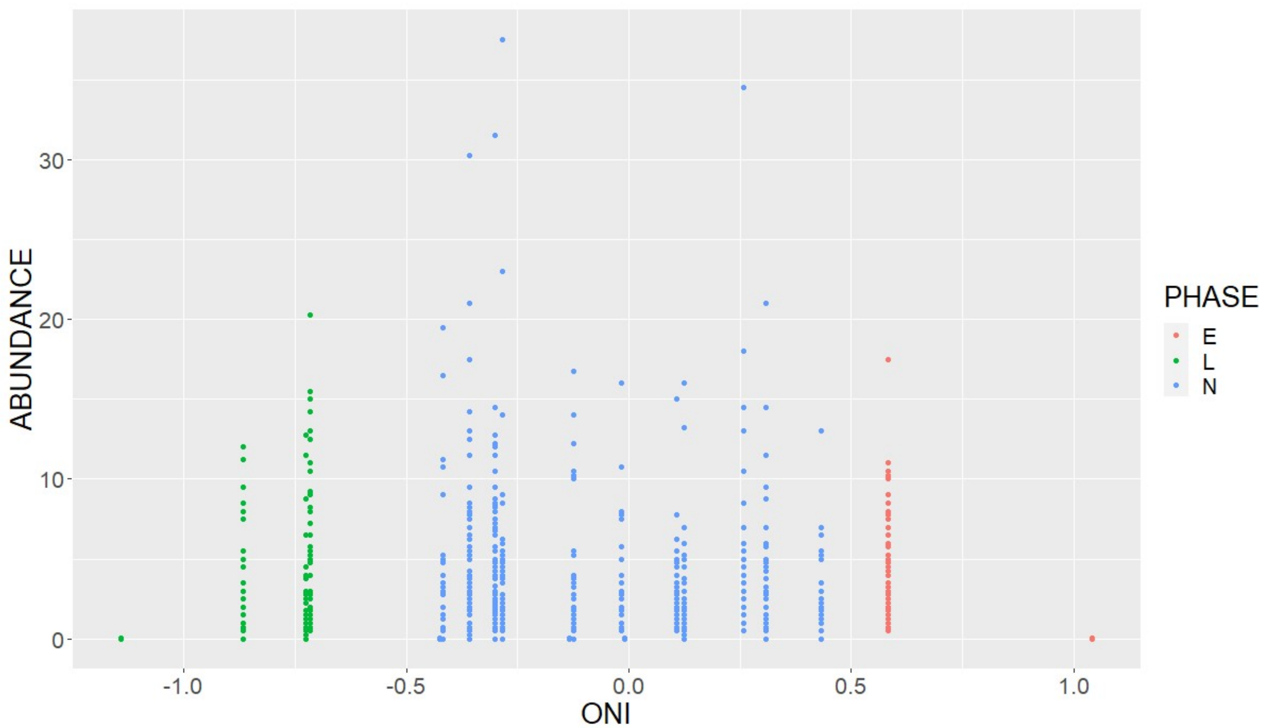

Figure 3. Abundance of bacalao (mean per site along a 250m^2 transect) versus Oceanic El Niño Index (n=972). Colors indicate El Niño phase [3 month running mean of ERSST.v5 SST anomalies in the Niño 3.4 region (5ºN-5ºS, 120º-170ºW)], E= El Niño (red), L=La Niña (green), N=Neutral (blue. (Ramírez-González et al. 2020).

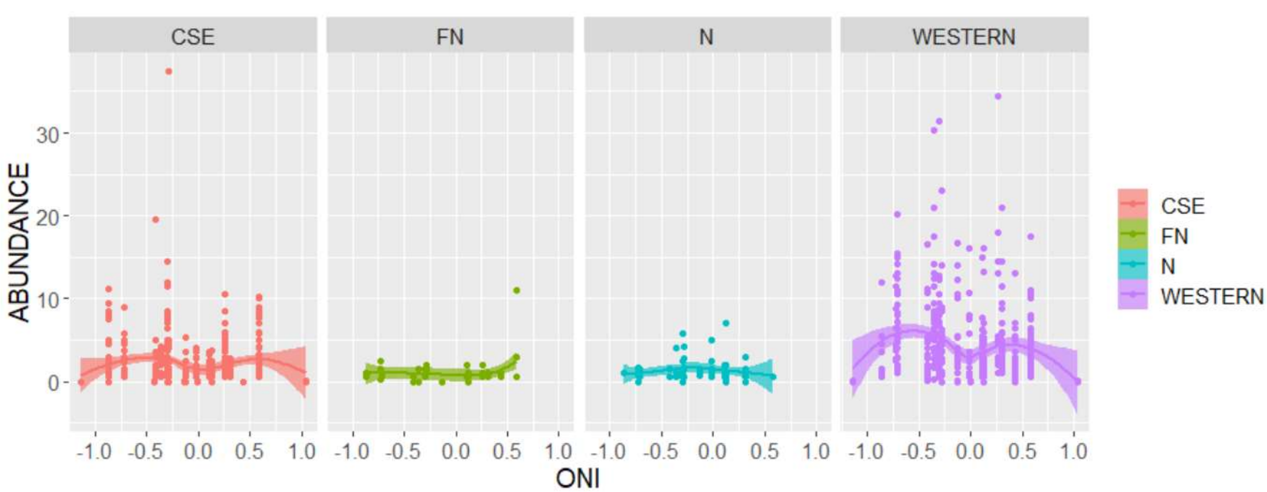

Figure 4. Abundance of bacalao (mean per site along a 250m^2 transect) versus Oceanic El Niño Index (n=972). Colors indicate bioregion, CSE=Central southeaster, FN=Far North, N=North and Western (Ramírez-González et al. 2020).

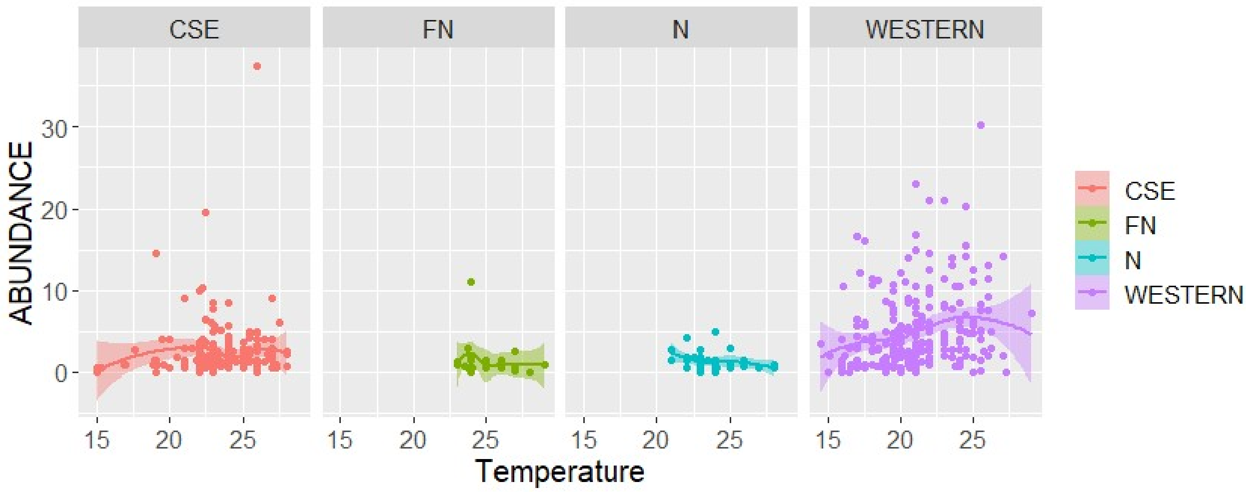

Figure 5. Abundance of bacalao (mean per site along a 250m^2 transect) versus temperature measured on-site in (C) (n=520). Colors indicate bioregion, CSE=Central southeaster, FN=Far North, N=North and Western. (Ramírez-González et al. 2020)

Although recent efforts have studied the sailfin grouper fishery and biology, no information exists for other commercial finfish species in Galapagos, including the mottled scorpionfish (Table 1). This is a matter of great concern because seeveral demersal finfish species are important for the economy of the SSF and tourism sectors of Galapagos.

4.1.3 Yellowfin tuna

In Galapagos, the harvest and consumption of tuna have increased gradually since 2006 due to the increasing number of tourists, residents, restaurants and hotels. Between 1997 and 2017, yellowfin tuna landings increased by a factor of nearly five, from 41.1 to 196.8 t per year (Castrejón and Moreno 2018). According to the DGNP statistics, approximately 70% of the tuna catch (138.5 t) is consumed in Galapagos, while 30% is shipped to mainland Ecuador (58.3 t) (Berman et al. 2018). Thus, the increasing importance of yellowfin tuna highlights the need for adaptation measures against climate change for this specific fishery.

Tuna are characterized by dynamic distribution patterns that respond to climate variability and long-term change (Erauskin-Extramiana et al. 2019). These highly migratory and transboundary species are of particular importance in Eastern Tropical Pacific, as they contribute significantly to the livelihoods, food and economic security of Ecuador, Panama, Costa Rica and Colombia (Castrejón 2020). However, changes in water properties and circulation will impact on tuna larval dispersal, preferred habitat distributions and the trophic systems that support tuna populations throughout the region (Ganachaud et al. 2013).

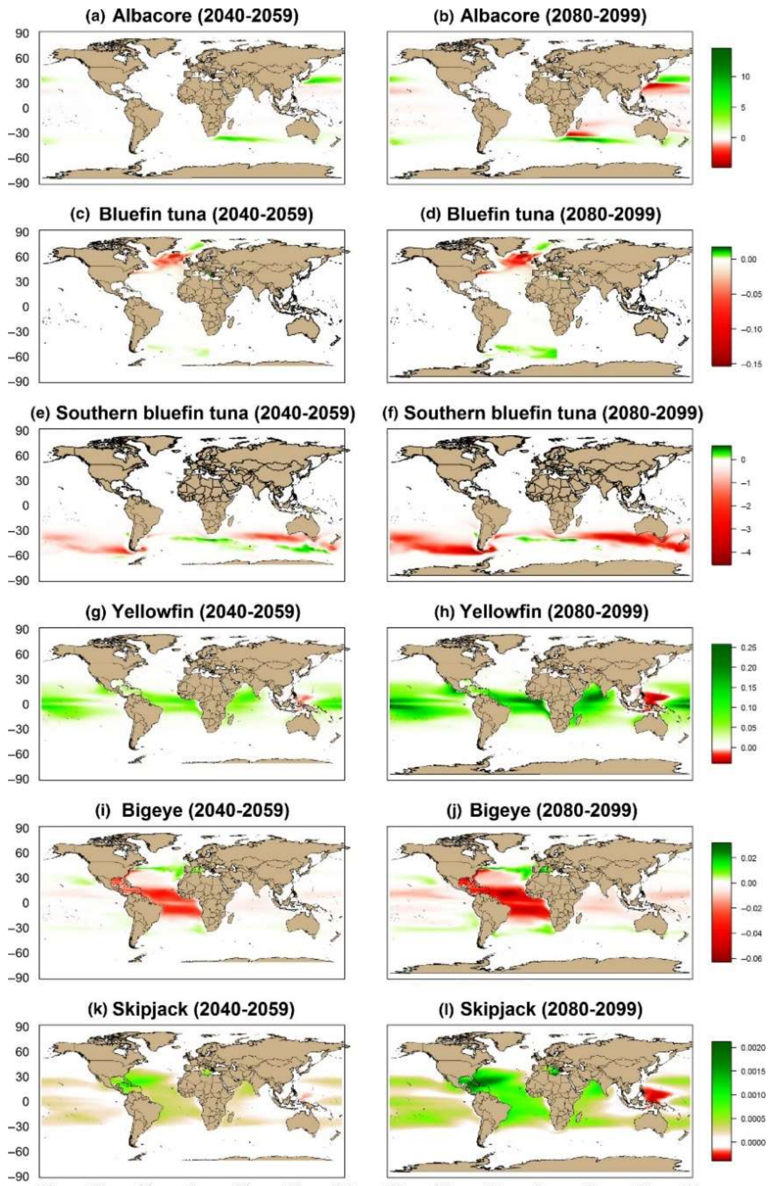

Figure 6. Gains and losses of abundance (in tons per 1,000 hooks, except for southern bluefin tuna, in number of individuals per 1,000 hooks) for mid- (left column, a, c, e, g, i and k) and end-of-the-century (right column, b, d, f, h, j, l). Source: Erauskin-Extramiana et al. (2019).

In the Eastern Tropical Pacific, the yellowfin tuna (*T. albacares*), bonito (*Sarda chilensis*), and dolphin fish (*Coryphaena hippurus*) stocks are expected to move into the coastal waters from northern Chile to northern Peru–south Ecuador due to the ENSO, increasing the availability of these species to fishers in this area (Bertrand et al. 2020). This suggests that yellowfin tuna abundance, within the Galapagos Marine Reserve could decrease, as well as their catchability, due to changes in the migratory movements.

In contrast, Erauskin-Extramiana et al. (2019) projected that skipjack and yellowfin tunas will become more abundant in tropical areas as well as in most coastal countries' exclusive economic zones (EEZ) at the end of the century (Fig. 6 g,k).

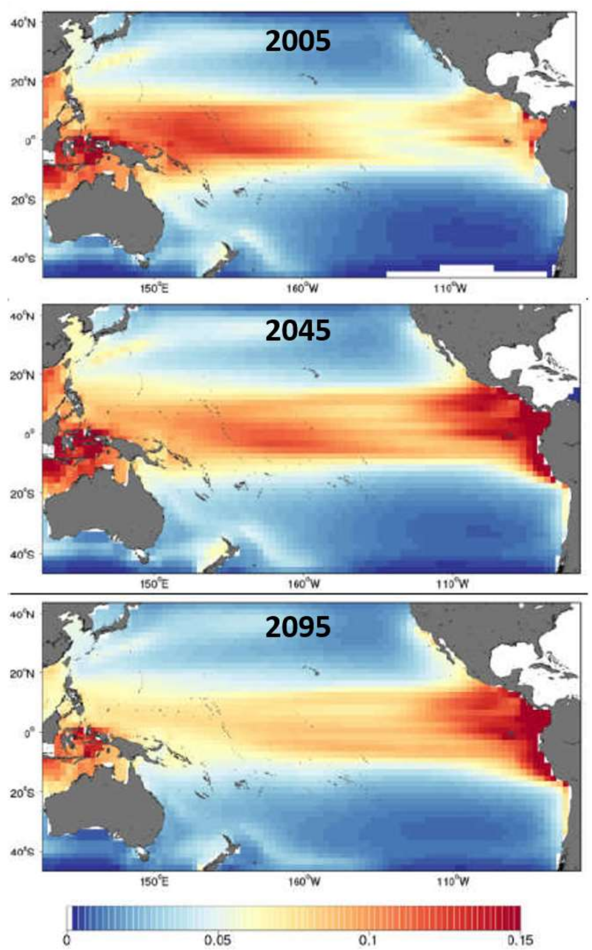

Figure 7. Projected mean distribution of yellowfin tuna biomass across the Tropical Pacific Ocean under IPCC-RCP 8.5 climate change scenario for 2005 and from the decades centered on 2045 and 2095. Modified from Senina *et al*. (2018).

Similarly, Senina et al. (2018) projected a clear shift from the western to the central and eastern Pacific (Fig. 7), with a biomass increase above 50% in the International Water Eastern Pacific Ocean-Central, without considering the fishing impact in the past and future. In addition, when Senina et al. (2018) included the effects of fishing in the climate change models under the RCP 8.5 scenario, they projected an increase in catches (52-107%) of yellowfin tuna in the ETP by the end of this century. However, it is important to consider that larval mortality, due to ocean acidification, shows a strong effect in the ETP yellowfin abundance, leading to a 20% decline in biomass, which could increase 10% to 15% by 2100.

Analyses based on sea temperature and oxygen as the main variables that explain the distribution of yellowfin tuna (Arrizabalaga *et al.*, 2014) partially support the hypothesis of an increase in biomass of yellowfin tuna in Galapagos under the climate change RCP 8.5 scenario. By the end of the century, Galapagos would meet favourable yellowfin tuna conditions for oxygen concentration, general SST, yolk sac and larval growth development (Senina *et al.* 2018), but will not meet ideal conditions for optimal spawning (Wexler et al 2011) (Fig. 8).

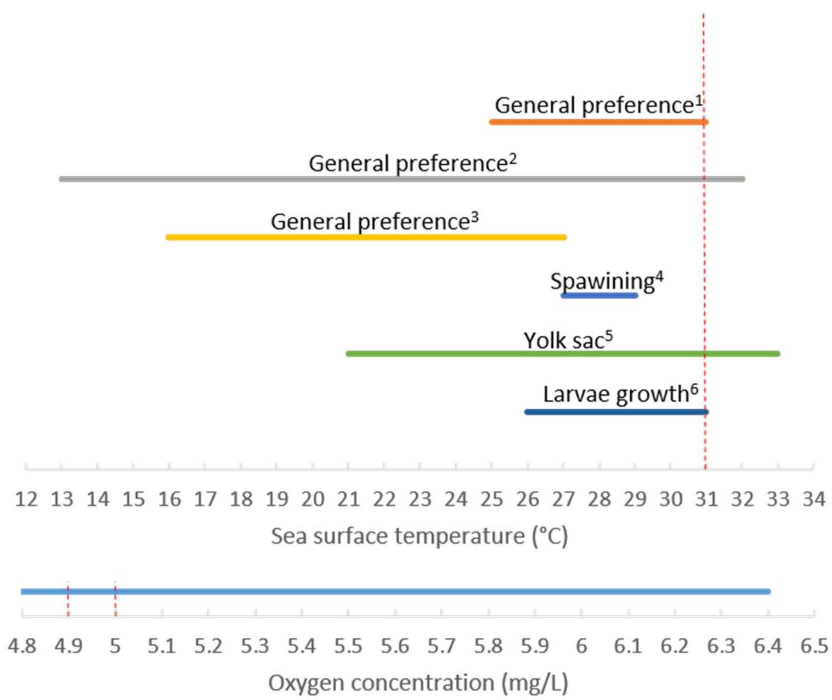

Figure 8. Sea surface temperature and oxygen preferences for yellowfin tuna and projections of these parameters (red dotted vertical lines) under IPCC-RCP 8.5 climate change scenario by the end of this century in Galapagos. Own elaboration from Monnier *et al.* (2020), CPPS (2018), [1]Arrizabalaga *et al.* (2014), [2]Senina *et al.* (2018), [3]Kaschner *et al.* (2016), [4]Wexler *et al.* (2011).

Furthermore, by using empirical data to explore the relationships between the presence of yellowfin tuna and the sea surface temperature and other environmental variables in the GMR, analyses using data from echosounders (Satlink ELB3010) attached to four Fishes Aggregation Devices (FADs) predict a significant and negative relationship between the probability of presence of yellowfin tuna in the FADs and SST and depth.

Figure 9 shows the interpretation of a Bernoulli (presence – absence) model of the echosounders data. The model indicates that the higher the SST, the lower the probability of yellowfin tuna presence in the rod and trolling depth (3m-10m), longlines (vertical and horizontal) depth (10m-80m) and depths were small-scale fishers usualy does not fish (80m-115m).

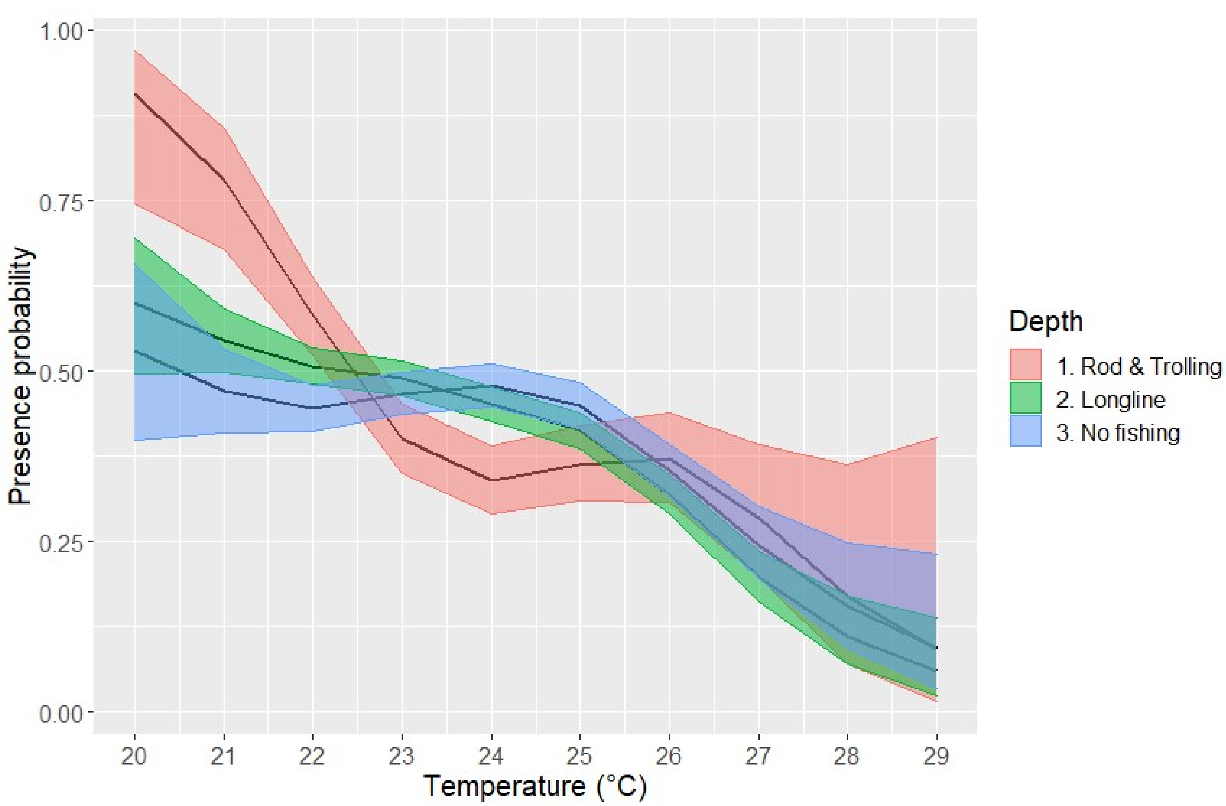

Figure 9. Bernoulli model (with 95% confidence intervals) of the FADs data with relationships of the probability of yellowfin tuna presence and SST at different fishing depths.

This model was used to predict the probability of yellowfin tuna presence around seamounts (including shallow seamounts locally known as 'bajos') of the GMR for the periods 2006-2055 and 2055-2099 under RCP 4.5 climate change scenario. This was done by calculating the average SST around seamounts of the GMR for each period based on changes projected in the oceans by coupled climate models' CMIP5 experiments. The average SST values obtained for these future time-periods were used to predict the probability of yellowfin tuna presence on seamounts using the Bernoulli model mentioned above. The results indicate that the probability of yellowfin tuna presence in the seamounts of the GMR will decrease in both periods at all depths. This decrease is clearer in the longlines and no-fishing depths (Figure 10).

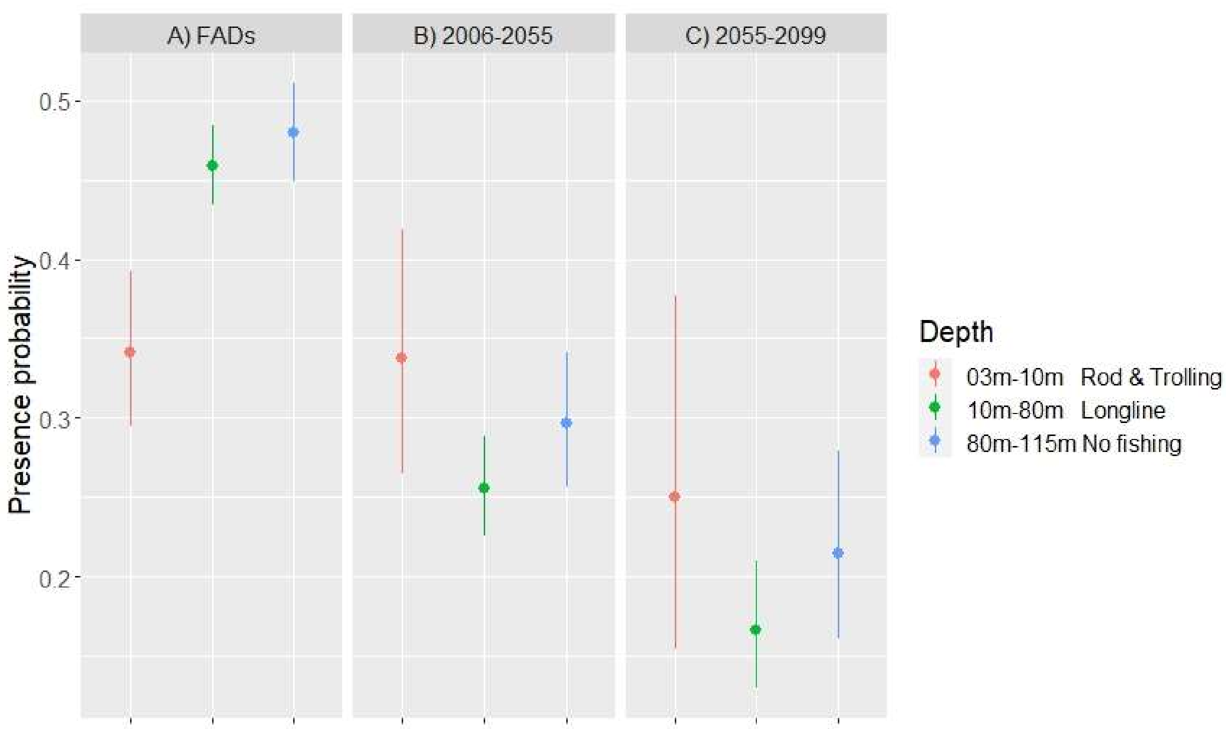

Figure 10. Probability (with 95% confidence intervals) of yellowfin tuna presence by depth in three scenarios: A) average SST of FADs (23.8°C); B) average SST in seamounts (26.5°C) in the period 2006-2055 under climate change scenario RCP 4.5; C) average SST in seamounts (27.3°C) in the period 2055-2099 under climate change scenario RCP 4.5.

Combining these projections with those of Erauskin-Extramiana *et al.* (2019) and Senina *et al.* (2018), it is possible to envisage that with climate change, yellowfin tuna populations will move from west to east in the Pacific Ocean, but its probability of presence in the GMR will decrease along the water column, meaning that its populations will move down vertically.

It is important to mention that, currently, the only fishing gears permitted for catching yellowfin tuna in the GMR is the rod, trolling and the vertical longline with 3 to 5 hooks, the latter of which is not used by the fishers because of the great physical effort and fuel cost that it represents. Another important fact is that, according to Galapagos fishers' knowledge, the largest tuna that have the highest quality and price in the market are found at longlines (vertical and horizontal) fishing depths. This is one of the reasons why the fishers in Galapagos are constantly asking the authorities to allow the use of horizontal longlines, which is currently prohibited in the GMR.

This is important because with the predictions of our model, under climate change scenario 4.5, fishers are expected to be less likely to catch large, good quality, highly priced tuna. This translates into a decrease in the catchability and an increase in the number of hours spent searching for tuna and fishing hours per trip, decreasing the fishers' socio-economic well-being (Table 1).

4.2 Influence of climate and anthropogenic drivers on fisher's behavior

Only two studies have evaluated the consequences of climate variability on Galapagos' small-scale fishers and coastal communities. Bucaram et al. (2013) and Castrejón and Charles (2020) found that climatic variables, in combination with economic and oceanographic conditions, influence fisher's behavior regarding how and where to fish. Travel distance from vessels' home ports to fishing grounds and expected revenues are the most important factors affecting the spatial allocation of fishing effort in Galapagos spiny lobster fishery (Bucaram et al., 2013). Furthermore, fishing effort increased during El Niño events, which could be caused by the redistribution of spiny lobster stocks from inshore to deeper waters, making them inaccessible to hooka divers, who in response increased search times and diving hours per fishing trips (Table 1) (Castrejón and Charles, 2020).

4.3 Climate change impacts on fishers and communities

Based on the potential future climate change scenarios described, the potential socio-economic impact of climate change on Galapagos small-scale fishing sector and coastal communities should be evaluated on five aspects: (1) the multiplicative effect of seafood trading along the value chain; (2) the influence of climate change on food security of Galapagos human population; (3) the economic dependence of fishing; (4) the implications of climate change on the recovery of overfished fisheries, and (5) the adaptive capacity of local fishing communities to cope with and adapt to climate change. These aspects were evaluated considering a climate change scenario in which the availability and accessibility of spiny lobsters and sailfin groupers stocks decrease due to permanent changes on their abundance and distribution caused by El Niño-like ocean state. In the case of yellowfin tuna, according to the model explained above, under climate change scenario the accessibility of this species for fishers will decrease. Based on these scenarios, it is expected that climate change will exacerbate the effect of fishing on fishery resources and marine ecosystems. In these scenarios, it is assumed that the sea cucumber fishery did not recover due to persistent illegal fishing and the negative impact of climate change, remaining closed to fishing in the coming decades. Besides, as sea cucumbers are not traditionally consumed in Galapagos, as in the rest of Ecuador and Latin America, no impact is expected on the food security of Galapagos coastal communities. Therefore, sea cucumbers are not considered relevant in the climate change scenario described and analyzed below. However, an EBA for the recovery of sea cucumbers stocks is proposed as part of an ecosystem-based fisheries management strategy that includes rebuilding sailfin groupers to restore their ecological role and diversify fisher's livelihoods (see section 6.2).

4.3.1 The multiplicative effect of seafood trading along the value chain

As fisheries represent a small percentage of the Galápagos gross domestic product (< 4 %), it is expected that negative or positive climate change impacts on fisheries will have limited implications for Galapagos' economy (Bertrand et al. 2020). However, this hypothesis does not consider the multiplicative effect of seafood trading along the value chain.

The total gross revenue is the main economic indicator used to estimate the contribution of SSF to the Galapagos gross domestic product (GDP). This indicator is estimated multiplying the annual total catch by the annual average ex-vessel price; i.e., the price that fishers receive for their catch, or the price at which fish are sold when they first enter the seafood supply chain.

However, the GDP didn't take into consideration that Galapagos fishers only capture a small proportion of the total value created along the value chain, both in the domestic and export markets. For example, according to Berman et al. (2018), Galapagos small-scale fishers only capture 27% of the total value created by the tuna fishery in the domestic market, while 61% and 12% is captured by restaurants and intermediaries, respectively. In the export market the situation is worse, fishers captured only 21% of the value created, while 15%, 26%, and 38% are captured by intermediaries, restaurants, and exporters, respectively. Another example is provided by the spiny lobster fishery. Fishers capture 18% of the net earnings generated by the value chain, while 82% is capture by intermediaries (Castrejón 2012). These estimates highlight that a high proportion of the contribution to the tourism sector to Galapagos' GDP depends indirectly on SSF.

Based on the two examples above, the negative or positive impacts of climate change will probably have strong implications on Galapagos economy, as it will affect all economic agents involved in SSF's value chains, including fishers, intermediaries, restaurants, exporters and final consumers.

4.3.2 Influence of climate change on food security of Galapagos human population

Because of its importance in Galapagos households, the decrease in catchability of yellowfin tuna could have a severe impact on the food security. For example, tuna has been the main species consumed by local communities, before and during the lockdown established by the Ecuadorian government to avoid the spread of COVID-19 in the archipelago (M. Castrejón – unpublished data). After yellowfin tuna, shrimps, octopus, mottled scorpionfish, wahoo, and sailfin grouper are the most important species consumed by Galapagos coastal communities, thus, the collapse of any fishery targeting these species will also geopardize food security in Galapagos.

4.3.3 Economic dependence of fishers on Galapagos fishery resources

The socioeconomic impact of climate change on the small-scale fishing sector will depend on the level of economic dependence of fishers on Galapagos fishery resources. The greater a fisher's dependence on fishery resources, the greater the economic impact of climate change on their livelihoods. Castrejón (2011) evaluated the level of economic dependence of fishers on the spiny lobster and the finfish ("pesca blanca") fishery. According to this study, more than 64% of Galapagos fishers are highly dependent on the spiny lobster and finfish fisheries to sustain their livelihoods. Highly dependent means that between 70 and 100% of fishers' monthly income comes from these two fisheries. Therefore, the greater the number of commercial species negatively affected by climate change, the greater the economic impact on the Galápagos fishing sector.

Based on this information, the collapse of the spiny lobster fishery is expected to have a significant impact on fishers' livelihoods, particularly during lobster fishing seasons (August/December). Similar impacts could be expected if the finfish fishery collapsed. However, it is unlikely that the finfish fishery entirely collapses because it targets a high diversity of pelagic and demersal fish species. If the abundance and catchability of one or two demersal finfish species decrease or collapse then probably fishing effort will shift to other demersal or pelagic species. Such changes in fishing patterns probably could mitigate the impact of climate change on fisher's livelihoods, but fishing pressure will increase over finfish species whose exploitation status is, in most cases, unknown.

4.3.4 Implications of fisheries collapse due to climate change on the recovery of overfished fisheries

The collapse of certain commercial species due to climate change could lead to the redistribution of fishing effort towards other species, increasing their risk of overexploitation. For example, the reduction in the catchability of yellowfin tuna across the archipelago could result in changes of fishing patterns, in order to continue satisfying seafood consumption in the domestic market. As a result, fishing effort will likely switch to mottled scorpionfish, wahoo, and sailfin grouper leading to their renewed overexploitation and thereby compromising their population recovery. It is therefore our opinion that the sustainable management of the yellowfin tuna is fundamental to promote the recovery of all coastal overexploited fisheries.

Before the creation of the GMR, the large-scale fishing fleet caught 29 710 t of tuna, equivalent to 24.3% of total tuna landings at the national level (Bustamante, 1999). Nowadays, the small-scale fishing fleet catch less than 300 t of tuna annually (Castrejon and Moreno, 2018). Therefore, the impact of the local fishing fleet over yellowfin tuna stock is minimal, eliminating the risk of overexploitation. The annual demand for fish, including the tuna and whitefish fishery before the COVID-19 pandemic was approximately 871.3 t, of which 31% was consumed by the local community, while the remaining 69% was consumed by tourists (Berman et al. 2018). Therefore, even if the Galapagos finfish fishery collapsed and fishing effort turn entirely to the tuna fishery, the risk of overexploitation of yellowfin tuna stocks by the local fishing fleet will continue be minimal.

4.3.5 Adaptive capacity to cope with and adapt to climate change

Coping and adaptive responses to ENSO will vary depending on ENSO types and their positive or negative effect on fishery resources and their fisheries along the supply chain (Bertrand et al. 2020). However, the magnitude of the impact will also depend on the adaptive capacity of fishers to climate change.

According to Cinner et al. (2018), adaptive capacity could be built across five key domains: (1) the assets that people can draw upon in times of need; (2) the flexibility to change strategies; (3) the ability to organize and act collectively; (4) learning to recognize and respond to change; and (5) the agency to determine whether to change or not. Altogether, fishers' adaptive capacity will vary according to diverse factors, including the portfolio of fisheries in which a single fisher depends on to sustain their livelihoods, the level of diversification of their fishery products, markets, and livelihoods, as well as their economic condition, social network, and willingness and entrepreneurial capacity to change and improve their socio-economic condition.

For example, a fisher will be more vulnerable to the negative impacts of climate change if they specialize in a single fishery (e.g., spiny lobster fishery), if their monthly income depends entirely on fishing, if they don't add value to their fishery products (e.g., individual fishers sell tail lobsters instead of whole or live lobster whose market price is higher), and if they rely upon one market or client to sell their products (e.g., export market and intermediaries). Their vulnerability will also be aggravated if they have a huge amount of debts and no savings, if they don’t have family or friends who provide support in times of crisis, and if they don’t have the willingness to face adversity and the entrepreneurial capacity to take advantage of crisis as opportunities to change their livelihoods or create new ones.

According to Quiroga et al. (2010), Galapagos fishers have a moderate adaptive capacity to climate change because they can shift to alternative fisheries and livelihoods, have access to credit, and strong social and institutional networks. However, most fishers also have low levels of education and computational skills, and few speak other languages besides Spanish, which reduces their adaptive capacity to shift to other economic activities, such as tourism or experiential fishing, during times of adversity. Unfortunately, no additional studies about the adaptive capacity of the Galapagos small-scale fishing sector have been conducted since Quiroga et al. (2010). Consequently, policymakers lack updated information to design policies aimed at enhancing the adaptive capacity of fishing communities and institutions to cope with and adapt to climate change.

5. ECOSYSTEM-BASED ADAPTATION (EBA) MEASURES

As the potential impact of climate change on Galapagos SSF is uncertain for 93.9% of the marine species commercially exploited in Galapagos, mitigation and adaptation measures must be taken by the GNPD and Galapagos Governing Council to enhance the resilience and adaptive capacity of fishery resources, fishers, and institutions.

According to Bertrand et al. (2020), successful adaptation in the fisheries and aquaculture sector must be based on three non-mutually exclusive areas: (1) institutional adaptation, (2) livelihood adaptation and (3) risk reduction and management for resilience. Institutional adaptation comprises the actions of public bodies, that address policy, legal and institutional issues including public investments and incentives, that revolve around planning and management of fisheries and aquaculture following the principles of the ecosystem approach to fisheries (EAF) or the ecosystem approach to aquaculture (EAA). Livelihood adaptation includes a mix of public and private activities, within or among sectors, most commonly through diversification strategies within or outside the sector to reduce vulnerability. Finally, risk reduction and management for resilience include a mix of public and private activities that promote early warning and information systems, improve risk reduction strategies, and enhance response to shocks.

Based on the previously mentioned areas and Galapagos SSF data, this program proposes three ecosystem-based adaptation measures (EBA) to increase the resilience and adaptive capacity of Galapagos SSF against climate change, in order to help safeguard one of most the important biodiversity and climate change hotspots in the world. An EBA is a measure designed to simultaneously reduce poverty, protect biodiversity and ecosystem services, and remove atmospheric greenhouse gases. Therefore, an EBA integrates the use of biodiversity and ecosystem services into an overall strategy to help populations and ecosystems adapt to the adverse impacts of climate variability and change (Scareno et al., 2017).

If successfully implemented, the three EBA measures proposed will help local fishing communities to adapt to climate change and will yield direct and ancillary benefits in the short and long-term, resulting in positive returns on investment and ‘‘win-win’’ situations for coastal communities and marine ecosystems. However, their implementation will demand effective and enforceable regulations and economic incentives, all of which will require the political will of the GNPD and Galapagos Governing Council, as well as adequate financial and human capital.

In the following sections, the rationale for each EBA is described, together with their objectives, outcomes and outputs, including a description of their impact on the resilience and adaptive capacity of the Galapagos marine ecosystems and fishers' livelihoods, and other relevant information. Table 2 summarizes outcomes and outputs expected for all proposed EBA measures. Similar tables, including actions and costs are included in the description of each EBA.

Table 2. Integrated activities of all EBA measures.

EBA 1: The combined effect of climate change, overfishing and IUU fishing is prevented and mitigated through an adaptive co-management of the Galapagos marine zoning.	
Activities	**Subactivities**
Improve the design and effectiveness of Galapagos marine zoning, based on conclusive scientific evidence on the impact of climate change on fishery resources, marine biodiversity, and fishers' livelihoods.	Asses the effectiveness of former Galapagos marine zoning to protect HEVAS, key target fishing resources and ecosystem processes
	Identify HEVAs particularly vulnerable to climate risks and select the most suitable areas to ensure commercial stocks recovery, based on climate change risk assessment.
	Estimate the cost and potential benefits associated with the implementation of the new Galapagos marine zoning options.
	Engage stakeholders and facilitate a negotiation process through innovative, extensive and participatory consultation in the CCPM, to promote their formal endorsement of new marine zoning.
Design and implement an advanced data system for the adaptive co-management of the Galapagos marine zoning.	Design and implement an advance data monitoring and information system for the Galapagos subtidal ecological monitoring program, including the development of sensitive adaptation SMART indicators.
	Create a public data repository and a geographic information system on Galapagos marine biodiversity, oceanography, fisheries, transport,

	IUU fishing, and marine traffic to support marine spatial planning.
Structured decision-making framework to inform the adaptive co-management of the Galápagos Marine Reserve	Development of a training program to ensure the effective implementation of the structured decision-making framework for the GMR.
	Investment of $US2.0 million into the "Fondo para la Reserva Marina de Galápagos (FRMG)" to ensure the sustainability of the structured decision-making framework and ecological and fisheries monitoring programs.
EBA 2: The ecological role of shellfish and finfish stocks are restored and livelihoods diversified, through the adoption of climate-smart small-scale fisheries and aquaculture approach.	
Activities	**Subactivities**
Stenghthen management conditions of small-scale tuna fisheries, to reduce ecological impact of the fishery over secondary and endangered, threatened and protected (ETP) species.	Design and implement an electronic monitoring and blockchain traceability system.
	Promote the adoption of a code of good fishing practices and handling techniques, based on the assesed impact of ghost fishing and illegal fishing aggregating devices (FADs) on vulnerable marine ecosystems.
	Carry out research priorities to improve the management and sustainability of the Galapagos tuna fishery
Strengthen management of sailfin groupers fishery to mitigate climate change impacts while restoring the species ecological role.	Evaluate current sailfin groupers population status, including projections under climate change conditions and fishing regulations.
	Elaborate and adopt a climate smart community-based fishery improvement project (C-FIP) for the sailfin grouper.
	Following-up C-FIP implementation of sailfin grouper, yellowfin tuna and spiny lobster fisheries.
	Update annually the Benchmarking and Tracking Tool (BMT) elaborated for each C-FIP and adapt action plan, based on results.
Implement small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing	Update stock assessment of *I. fuscus*, including projections under climate change conditions and fishing regulations.

(TURFs), to rebuild sea cucumber stocks and diversify fishers' livelihoods.	Reproduce in captivity and release a substantial number of sea cucumbers into the remaining wild stock, to significantly accelerate rebuilding.
	Experimental allocation and evaluation of TURF to regulate harvesting and fishing intensity of *I. fuscus*.
EBA 3: Enhanced climate change resilient local value chains to improve Galapagos seafood system access to markets.	
Activities	**Subactivities**
Promotion of a blue circular economy through new sustainable and social responsible seafood enterprises	Design and develop a G-Lab platform to provide analytical services, capacity building, knowledge sharing and facilitation services to fishers and entrepeneurs to make their seafood enterprises investment-ready.
	Conduct a market and behavioral science analysis.
	Provide technical assistance to local fishers and entrepreneurs, to comply with all technical, legal, organizational and administrative requirements for the creation or consolidation of new seafood enterprises
	Train fishers and entrepreneurs on tuna grading and production of seafood value added products.
Long-term financing mechanism in place to improve sustainability and competitiveness of Galapagos small-scale fishing sector.	Design, establishment and administration of a soft credit line for entrepreneurs interested in adopting sustainable fishing practices.
	Allocate soft loans to those entrepreneurs who submit the most attractive, innovative business plans and with the greatest probability of generating a positive social and environmental impact.
Socioeconomic monitoring in place to follow-up performance of seafood enterprises and wellbeing of Galapagos small-scale fishing sector.	Steering Committee in place to follow-up implementation of the Blue Incentives Program and G-Lab
	Determine the performance of those seafood enterprises supported by the Blue Action Program and G-Lab, and the wellbeing of Galapagos small-scale fishing sector.

5.1 <u>EBA measure 1.</u> The combined effect of climate change, overfishing and IUU fishing is prevented and mitigated through an adaptive co-management of the Galapagos marine zoning.

5.1.1 Justification, current situation and baseline

There is a growing recognition that MPAs in combination with co-management regimes can be an effective solution for rebuilding depleted marine populations, conserving HEVAS, and increase resilience to climate change (Gutiérrez et al. 2011; Micheli et al. 2012; Edgar et al. 2014; McCay et al. 2014). However, this spatially explicit management approach is not a one-size-fits-all solution effective in all contexts (Castrejón and Charles 2013). This can be observed in cases where MPAs were created using a top-down approach and designed without considering a broad-based and integrated social-ecological approach, which takes into consideration not only the spatial-temporal dynamics of fishery resources and the spatial distribution of HEVAS, but also the dynamics of fishing fleets and fishers' adaptive responses to regulations (Castrejón and Charles 2020).

The resilience of MPAs can be degraded by the impacts produced by diverse climatic and human perturbations, such as climate variability and climate change, overfishing, IUU fishing, marine pollution, market globalization, the establishment of new institutions, regulations or policies, and the boom-and-bust exploitation of new fisheries (Badjeck et al. 2010; Perry et al. 2011; Castrejón and Defeo 2015; Bertrand et al. 2020). Therefore, a comprehensive understanding about how the interaction of these external drivers of change affects the dynamics of resources, their marine environment, and the people whose livelihoods depend on them, is fundamental to develop policies and management strategies to enhance the adaptive capacity and resilience of marine ecosystems, local fishing communities, and institutions to cope with and adapt to change (Castrejón and Charles 2020).

In 2014, the GNPD with the support of international NGO, officially initiated a participatory marine and terrestrial spatial planning process to improve the management effectiveness of Galapagos protected areas. After six years, this participatory process is close to an updated reconfiguration of management areas, including the creation, expansion, or redistribution of no-take zones to improve the protection of HEVAS and to ensure the conservation of at least 30% of all marine macro-habitats (e.g., corals, mangroves, etc.) at each of the five marine bioregions of the GMR (Fig. 11).

However, the top-down implementation of a “Marine Sanctuary” in the Far Northern bioregion of the archipelago, in combination with inconclusive scientific evidence about the impact of previous no-take zones on fishery resources and fishers’ livelihoods, affected fishers trust and buy-in on the new marine zoning. The resulting socio-political pressure forced the Minister of Environment to postpone the effective implementation of the new marine zoning, approved in March 2016, until GNPD provides scientific evidence about the potential impact of the new network of no-take zones on local small-scale fishers’ livelihoods.

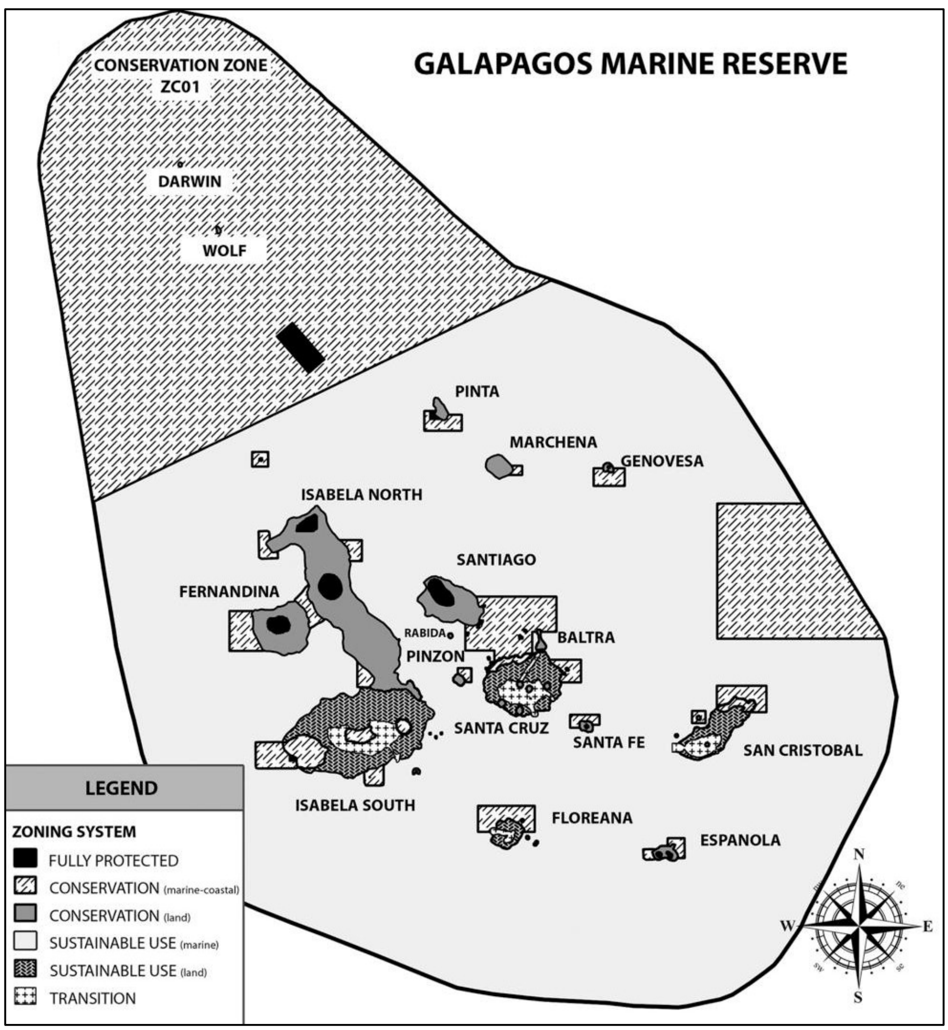

Figure 11. The new Galapagos marine zoning approved in March 2016 by the Minister of Environment of Ecuador, but not implemented yet. No-take zones are represented by fully protected and conservation subzones. Source: Burbano et al. (2020).

A comprehensive understanding about how Galapagos fishery resources and marine biodiversity have been impacted by the interactions of the ENSO, overfishing and IUU fishing, and other drivers of change, is fundamental to determine the effectiveness of the former network of no-take zones over the sustainability of commercial stocks and conservation of marine biodiversity. Based on this knowledge, the GNPD and Galapagos Governing Council will receive a set of recommendations to improve the design and management effectiveness of the new Galapagos marine zoning. To reconcile conservation and fishery management objectives, no-take zones should be strategically re-distributed across the archipelago to ensure the recovery of overexploited fishery stocks and degraded habitats. The new network of no-take zones of the new Galapagos marine zoning will maximize not only the protection of HEVAS, but also the protection of a relevant proportion of fishery resources spawning stocks and critical recruitment and nursery habitats while minimizing its negative impact on fisher's livelihoods. The effective implementation of the new marine zoning, in combination with co-management regime, long-term ecological and fisheries monitoring programs, advance information system, and a structured decision-making framework, will promote the adaptive co-management of the GMR. The successful implementation of this ecosystem-based management approach is expected to be an effective solution for rebuilding depleted marine populations, conserving HEVAS, and increase resilience of marine ecosystems, fishery resources and fishers to climate change.

5.1.2 Target indicators and beneficiaries

The target indicators for EBA 1 are described in Table 3, together with the direct and indirect expected beneficiaries.

Table 3. Target indicators and beneficiaries associated to EBA 1.

Target indicators

At the end of the project: • Conclusive scientific evidence about the impact of the former marine zoning, in combination with other human and climatic drivers of change, on marine biodiversity, fishery resources and fishers' livelihoods has been published in at least two peer-review papers. • The GNPD and Galapagos Governing Council received a set of recommendations to improve the design and management effectiveness of Galapagos marine zoning, contributing to the effective implementation and adaptive co-management of the new marine zoning. • The new marine zoning has been effectively implemented and protect at least 80% of HEVAS and 30% of all marine macro-habitats (e.g., corals, mangroves, etc.) at each of the five marine bioregions of the GMR, including critical habitats • No take zones have been strategically distributed to protect at least 30% of the breeding stock and critical recruitment and nursery habitats for sea cucumbers, spiny lobsters and sailfin groupers. • The location of traditional fishing grounds and opportunity costs for the small-scale fishing sector were socioeconomic selection criteria used as inputs to adapt the 2000 Galapagos marine zoning. • At least 60% of Galapagos small-scale fishers and 80% of the local community endorse the new marine zoning.	
Beneficiaries	
Direct	• The effective implementation of the new Galapagos zoning will promote the recovery of sea cucumbers, spiny lobsters and sailfin groupers stocks. • At least 400 fishers and their families will benefit from the recovery of sea cucumbers, spiny lobsters and sailfin groupers stocks.
Indirect	• At least 25,000 residents will benefit from availability and accessibility to seafood, ensuring the food security of the entire province of Galapagos.

5.1.3 Activities description

The prevention and mitigation of the impact of ENSO and climate change on marine ecosystems is fundamental to increase the effectiveness and adaptive co-management of the new Galapagos marine zoning as a fishery management and marine biodiversity conservation tool. To accomplish this objective, the following four sequential activities are proposed.

Activity 1.1: Improve the design and management effectiveness of Galapagos marine zoning, based on conclusive scientific evidence on the impact of climate change on fishery resources, marine biodiversity, and fishers' livelihoods.

To date, there is no conclusive scientific evidence about the impact of the former Galapagos marine zoning on fishery resources, marine biodiversity, and fishers' livelihoods, leading to a lack of trust and buy-in of the local fishing sector on the new marine zoning (Castrejón and Charles 2013). Therefore, a comprehensive understanding about how fishery resources and marine biodiversity have been impacted by the interactions of the ENSO, overfishing and IUU fishing, and other drivers of change, is fundamental to determine the effectiveness of the former network of no-take zones over the sustainability of commercial stocks and conservation of marine biodiversity.

This type of study, usually unfeasible in Latin America due to the dominance of data-poor fisheries, will be conducted thanks to the availability of spatially explicit fisheries-related data (1997-present) and subtidal ecological monitoring data (2002-present) collected by the GNPD and the Charles Darwin Foundation. For the first time, these two unique long-term datasets will be integrated, by this program, to evaluate how the establishment of the former marine zoning affected commercial species stocks and marine biodiversity. Other relevant climatic and human events that occurred before and after marine zoning implementation will be evaluated, including the ENSO, the boom and bust exploitation of the sea cucumber fishery (1999-2006), the global financial crisis (2007-2009), and the most recent economic crisis caused by COVID-19.

Long-term fishery-dependent data (e.g., catch composition, fishing effort, unit prices, individual size, and weight) will be integrated with subtidal ecological (e.g., species richness, functional diversity, relative abundance, size distributions, and estimated biomass per species) and oceanographic (sea-surface temperature, and anomalies) data to evaluate the impact of no-take zones, and a relevant set of human and climatic drivers, on fishery stocks and marine biodiversity across the Galapagos Islands.

The hypothesis to be tested is whether the long-term variability of fishery stocks (e.g., catch rates and population structure) and marine biodiversity (species richness, functional diversity and relative abundance) since the creation of the GMR in 1998, is product of ENSO, the boom-and-bust exploitation of the sea cucumber fishery, the global financial crisis and the COVID-19 pandemic, rather than the no-take zones implementation in 2000.

Spatial GIS based modeling techniques will be used in combination with boosted regression models and other statistical methods to identify the factors that explain spatiotemporal patterns in catch rates and community indicators, as a function of geographic, oceanographic and socioeconomic variables. This analysis will be complemented with participatory research methods. Semi-structured interviews and social-ecological network analysis techniques will be used to identify the main drivers that have affected fishery stocks in the long-term, and to determine socially salient options for adapting or transforming the Galapagos fishery system considering the social-ecological impacts identified.

The results derived from local and scientific knowledge will provide a comprehensive perspective of the effects of human and climate drivers on fishery stocks and marine biodiversity. These results will be used to recommend, to the GNPD and Galapagos Governing Council, a set of adaptation and transformation pathways to sustain SSF, conserve marine biodiversity, and support human wellbeing into the future.

The primary objective of the new Galapagos marine zoning is to increase the protection of HEVAS and improve ecological representativeness and connectivity through an improved network of no-take zones. However, to reconcile conservation and fishery management objectives, no-take zones should be strategically re-distributed across the archipelago (Edgar et al. 2004b; Castrejón and Charles 2013). The population dynamics of fishery resources, including as priority spiny lobster, sea cucumbers, Galapagos groupers, and yellowfin tuna, will be evaluated in an integrated way to improve the design and management effectiveness of the new marine zoning scheme.

The location of traditional fishing grounds and opportunity costs for the small-scale fishing sector should be additional selection criteria to take into consideration (Castrejón and Charles 2020). However, most of these socioeconomic criteria were not used as inputs to create and adapt the 2000 Galapagos marine zoning. For example, preliminary analysis show that no-take zones were located in areas of low catch per unit effort (CPUE) of spiny lobsters (Fig. 12), which explains why fishers have shown historically a lack of interest in these areas, as reflected in a lack of 'fishing the line' effect around no-take zone boundaries (Castrejón and Charles 2020).

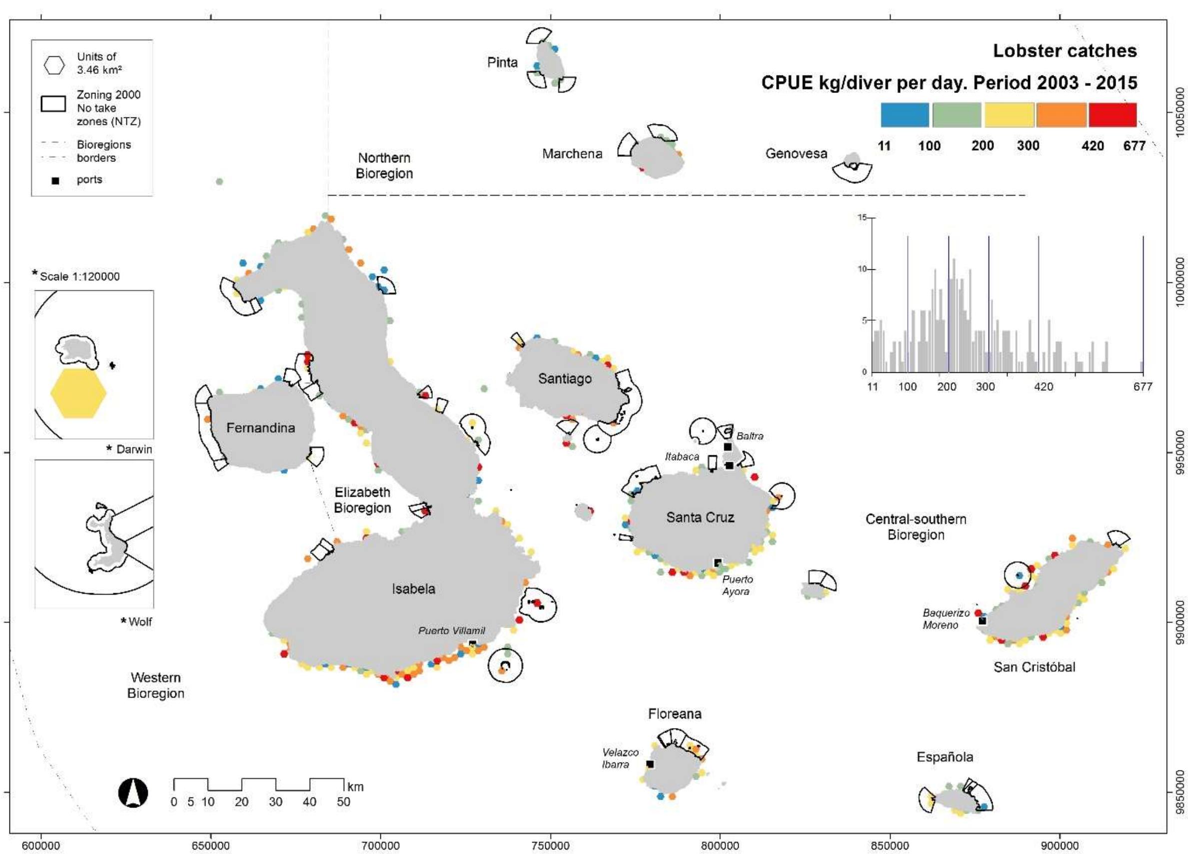

Figure 12. Spatial distribution of catch per unit effort for the spiny lobster fishery between 2003 and 2015, based on catch and effort data collected by the Directorate of Galapagos National Park (DPNG) in the three main ports of the Galapagos Marine Reserve. Black lines: network of no-take zones of the 2000 marine zoning.

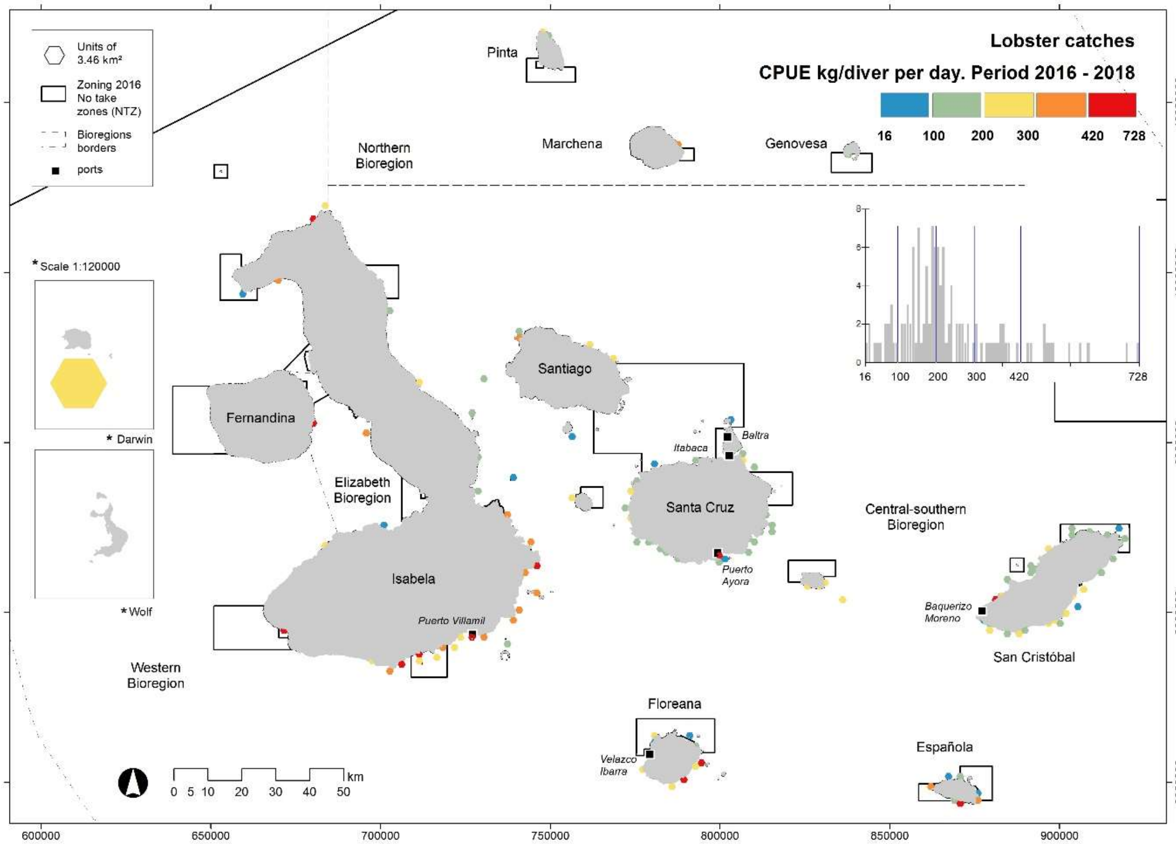

Figure 13. Spatial distribution of catch per unit effort for the spiny lobster fishery between 2016 and 2018, based on catch and effort data collected by the DPNG in the three main ports of the Galapagos Marine Reserve. Black lines: network of no-take zones of the 2016 marine zoning.

Thus, the non-overlapping location of CPUE hotspots and no-take zones suggest that fishers were not displaced from their traditional fishing grounds. In addition, it suggests that no take zones have not contributed to the recovery of the spiny lobster fishery, as suggested by several studies (Hearn 2008; Defeo et al. 2013a; Defeo et al. 2016; Buglass et al. 2018).

In contrast, the new Galapagos zoning declared a certain number of traditional spiny lobster fishing grounds as no-takes zones (Fig. 13). Even though the protection of a proportion of the breeding stock and critical recruitment and nursery habitats will ensure the sustainability of the spiny lobsters fishery, the impact of the new network of no-take zones on fisher’s livelihoods is uncertain. Therefore, declaring traditional fishing grounds as no-take zones will represent a huge challenge, considering the lack of evidence of the ecological and economic benefits provided by the former network of no-take zones, and the high opportunity and transaction costs associated with the implementation and enforcement of the new Galapagos zoning. That reality has contributed to reduce the acceptability and legitimacy of what could be potentially a valuable tool to co-manage Galapagos shellfisheries (Castrejón and Charles 2013).

To increase the usefulness of marine zoning as fishery management and marine biodiversity conservation tool, scientific and local knowledge about marine biodiversity and shellfish and finfish fisheries will be integrated with fishery-related socioeconomic information, to suggest improvements to the new network of no-take zones. To this end, complementary fishery-related objectives, criteria and indicators will be set up, based on the scientific literature and international experts' advice, to re-evaluate the distribution of no-take zones across the GMR. The efficacy and opportunity cost of the new network of no-take zones in meeting both conservation and fishery goals will be evaluated by software-based simulative and marine spatial planning tools (Klein et al. 2010; Davidson and Dulvy 2017). Fishery monitoring data (1997-2018) and participatory research methods (semi-structured interviews, participatory mapping, and focal groups) will be used to estimate opportunity costs and to identify critical recruitment and nursery habitats for spiny lobsters, sea cucumbers and Galapagos groupers. The location of fishing effort hotspots for commercial species will be determined by long-term spatio-temporal analysis of fishing effort from 1997 to 2021. Furthermore, data collected by SCUBA visual census using 50 x 5 m line transects at 70 sites between 2004-2018, collected by the Charles Darwin Foundation, will be used to assess species richness, relative abundance, and habitat composition across the coastal area of the GMR. Marxan and SeaSketch will be used to design and analyze trade-offs associated with different marine zoning scenarios (Ball et al. 2009; Janßen et al. 2019).

The results of this studies will provide a set of recommendations to improve the design and management effectiveness of Galapagos marine zoning, to reconcile conservation and fishery management objectives. These recommendations will be the basis for the participatory process that will need to take place for the endorsement of the new marine zoning by the small-scale fishing sector and other relevant stakeholders.

One of the most important challenges for the effective implementation of the new marine zoning is to re-establish the credibility and legitimacy of the small-scale fishing sector on the re-zoning process, through extensive and participatory consultation (Castrejón and Charles 2013). To this end, it is fundamental the effective implementation of the Consultative Board of Participatory Management (CBPM).

Between 1998 and 2009, management decisions on the GMR were the sole responsibility of the Participatory Management Board (PMB) and the Institutional Management Authority (IMA), while decisions related to the management of the province of Galapagos (i.e., inhabited areas) were the responsibility of the National Galapagos Institute (INGALA). In other words, the protected and inhabited areas were managed individually by two different institutions.

The PMB and IMA represented a collaborative co-management system (Defeo et al. 2009), where local stakeholders (i.e., fishers, tourism operators, naturalist guides, scientists, and conservationists) participated in the decision-making process along with the DPNG and the Minister of Environment, the institutions that manage the GMR. Decisions were taken by consensus in the PMB and by the majority of votes in the IMA.

This governance structure changed through the reform made to the Organic Law for Galapagos Special Regime (LOREG) on June 11, 2015. According to article 4 of the new LOREG, the province of Galapagos must be administered by the Governing Council of the Special Regime of the province of Galapagos (CGREG). This instance of management is responsible for "*planning, managing resources, organizing activities carried out in the territory of the province of Galapagos and inter-institutional coordination with State institutions, within the scope of its powers*". The CGREG is made up of representatives of the Ecuadorian presidency, the ministers of the Environment, Tourism, and Coordinator of Strategic Sectors, the Secretary of National Planning (SENPLADES), and the municipal governments and parish boards of Santa Cruz, San Cristóbal, and Isabela.

The new LOREG also established an institutional change of the co-management system from a cooperative to a consultative one. This implied the repeal of the PMB and the creation in its place of the CBPM, which is an instance of citizen participation and non-binding advice for the administration and management of GMR. However, at the time of writing this report, the CBPM has not yet been constituted and put into operation. This has generated confusion regarding the role that local stakeholders will play in generating high-level policies for co-management of the GMR fisheries.

The repeal of the PMB discouraged and delegitimized the participation of stakeholders in the re-zoning process, making unclear the decision-making process associated with the management of the GMR. Therefore, to improve the trust and buy-in of the local fishing sector on the marine zoning and ensure its effective implementation, the implementation of the CBPM is fundamental (Castrejón and Charles 2013).

The first step to re-establish the credibility and legitimacy of the GMR´s marine zoning is to provide technical advice and funding to the CGREG and DPNG to create the basic enabling conditions to install the CBPM. This process should be built on the experience and lesson learned associated with the former collaborative co-managememt system implemented between 1998 and 2015.

Further, it is fundamental to engage stakeholders in the re-zoning process, through extensive and participatory consultation in the CBPM. At this point, the GNPD, CGREG, small-scale fishimg sector and other relevant stakeholders must agree upon and support the process that will be implemented by this program to evaluate the past and potential social-ecological impact of the Galapagos marine zoning on fishery resources, marine biodiversity, and fishers' livelihoods. To be successful, the GNPD and the CGREG should define the decision-making process that will be followed to conclude the fine-tune of the former GMR´s zoning design.

An even more important step will be to engage GMR´s grassroots fishers on the rezoning process, a difficult task due to a lack of social cohesion, leadership, and representativeness of fishers' organizations (Castrejón and Charles 2013). To overcome this problem, extensive and participatory consultation is needed beyond the boundaries of the CBPM through innovative participatory methods that involve not only small-scale fishers but also tour operators, naturalist guides, conservationists, scientists, representatives of local governments, and the general public. At the end of this process, it is expected that the new marine zoning will be endorsed by the small-scale fishing sector and other relevant stakeholders. Such co-management approach will improve the credibility and legitimacy of the new Galapagos marine zoning because it will provide a voice to several members of local coastal communities who have influence or are influenced by the decisions taken concerning the management of the GMR (Castrejón and Charles 2013).

Activity 1.2: Design and implement an advanced data system for the adaptive co-management of the Galapagos marine zoning.

The Galapagos subtidal ecological monitoring program was created in 2004 to evaluate the impact of anthropogenic and climatic drivers, including the implementation of no-take zones, upon marine biodiversity. Based on this information the effectiveness of marine zoning can be determined and adaptations to its design can be developed, following a consensus-based participatory process.

Since 2004, quantitative surveys of fishes, mobile macroinvertebrates, and sessile invertebrates have been conducted at 6 and 15 m at ca. 70 sites by the Charles Darwin Foundation. After ecological monitoring data are physically collected in paper-based logs, they are manually recorded in Access datasets. Manual data recording on paper logbooks has led to issues with data accuracy and reliability due to standardization, transcription, and misreporting problems. Processing and analyzing data are quite slow due to insufficient resources and limited institutional capacity, resulting in a paucity of basic ecological indicators for decision-making. In consequence, subtidal ecological data is subtilized given the prolonged lag between data processing and management interventions.

The adaptive co-management of the Galapagos marine zoning requires better data collection, dimensioned to inform appropriate indicators in a faster and more accessible format for reporting, processing and analysis, that will translate into more effective mechanisms to disseminate results and enable near real-time adaptive responses.

However, despite the availability of technological innovations to improve the subtidal ecological monitoring program, the utilization of high-tech advanced data systems has been precluded by limitations of funding and institutional shortcomings. Therefore, this program will develop an advanced data system to improve the accuracy, reporting, analysis, and dissemination of subtidal ecological data. Such a system will reduce costs, facilitate adaptive and responsive decision-making procedures, to improve marine zoning management efficiency. An app, a data repository, and a dashboard will be created to collect, store, and analyse annually updated subtidal ecological data. This advanced data system, called the “Subtidal Ecological Monitoring” module, will be created following the transdisciplinary methodology recommended by Bradley et al. (2019). Such a module will be developed in collaboration with the GNP and NGOs, and be integrated into the “Sistema Único de Información Ambiental (SUIA)”, which is the national data repository system for environmental data in Ecuador.

Activity 1.3. Structured decision-making framework to inform the adaptive co-management of the Galápagos Marine Reserve.

The effective adaptive co-management of the GMR requires a structured decision-making framework linked to the subtidal ecological and fisheries monitoring program and other monitoring and evaluation systems conducted by the GNPD and Charles Darwin Foundation, which are fundamental to improve the management effectiveness of the marine zoning. Since July 2019, the Lenfest Ocean Program has supported a team of researchers led by Dr. Leah Gerber, Arizona State University, to leverage multiple data sources and modelling approaches to improve the adaptive co-management of the GMR, based on scientific criteria. Since then, this research team has worked in collaboration with the GNPD to develop a framework for structured decision-making that involves: (1) refining management objectives and modelling ecosystem behaviour; (2) monitoring ecosystem change and response to management actions; and (3) evaluating spatial management options.

The structured decision-making framework will provide a rigorous framework to GNPD’s managers to assess management zones and actions against specified management objectives. Through this approach, the current monitoring programs in place are being evaluated and enhanced, based on ecosystem indicators, thresholds and scientific modelling to ensure the adaptive co-management of the GMR, based on ecological and socioeconomic information.

At the moment, the research team is working with the GPND to develop management objectives that are measurable. The researchers will then evaluate existing ecosystem indicators to establish thresholds for management decisions. To do this, the researchers will integrate multiple existing data sources into metapopulation models to assess ecosystem change against specified management objectives as well as make projections for key species. The team is employing this approach for three fishery species (yellow fin tuna, wahoo, and sailfin grouper) and three threatened or iconic species (waved albatross, green turtles, and Galápagos sharks), and under three climate scenarios. Species and scenarios has been chosen in conjunction with GNPD technical staff.

The research team is also applying metapopulation models to the revised zoning in three distinct regions: southeast Isabela; between Santiago and Santa Cruz; and southern San Cristóbal and Española. The aim is to explore the utility of a structured decision-making approach in areas with contrasting zoning rules. New zoning rules for the GMR considers offshore areas for the first time. Thus, the research team is developing a new monitoring protocol for these areas. To align this protocol with existing monitoring programs, the researchers have leveraged existing information on abundance, capture and movement of species (e.g., pelagic fishes and seabirds); have identified information gaps for all study areas; and have integrated existing data streams, and the input of local tour operators as well as other stakeholders.

Finally, through the structured decision-making framework, the research team is evaluating how likely different spatial configurations of zones in the GMR are to deliver on management objectives. The research team is co-developing all previously described modelling and monitoring efforts with the GNPD to facilitate their application across the GMR. By working directly with technical staff and managers, the research team hopes to ensure their efforts are not only robust but useable in a management context and tangible for stakeholders. This project will end on July 2022.

To ensure the effective implementation of the structured decision-making framework developed by the Arizona State University, this program proposes to the GCF to invest in the development of a training program for local management authorities, scientists, NGO and relevant stakeholders. The objective is to facilitate the integration of the structured decision-making framework into GNPD decision-making process and existing monitoring programs.

To ensure the sustainability of the structured decision-making framework and the ecological and fisheries monitoring programs required to feed this system in the long-term, we propose the investment of $US2.0 million into an environmental trust fund called "Fondo para la Reserva Marina de Galápagos (FRMG)". The condition will be that the FRMG allocate an annual fund to ensure the effective implementation and sustainability of the structured decision-making framework and the ecological and fisheries monitoring programs.

At the moment of writing this proposal, the FMRG is being legally created by the GNPD in collaboration with WildAid and Conservation International. The objective of the FRMG is to provide financial sustainability to the monitoring, control and surveillance system of the GMR and its surrounding waters. The FRMG would operate as an integral part of the Sustainable Environmental Investment Fund (FIAS). The FIAS is a private entity created on September 6th, 2017 through an executive order. FIAS is a non-profit organization, with legal identity, governed by the Ecuadorian Civil Code. The mission of FIAS is to support the financing of environmental management, protection, conservation and sustainable use of natural resources and biodiversity, as well as actions to mitigate and adapt to climate change and to manage environmental quality in Ecuador. This mission is achieved thanks to an organization specialized in the design and implementation of financial strategies and mechanisms, which constitutes a meeting point, coordination of wills and actions to support the financing of environmental management in Ecuador, within the framework of sustainable development.

The activities that will be put in place to accomplish the three outcomes associated to EBA 1 are described in Table 4.

Table 4. Activities and sub-activities of the EBA 1.

EBA 1: The combined effect of climate change, overfishing and IUU fishing is prevented and mitigated through an adaptive co-management of the Galapagos marine zoning.	
Activities	**Subactivities**
1.1 Improve the design and effectiveness of Galapagos marine zoning, based on conclusive scientific evidence on the impact of climate change on fishery resources, marine biodiversity, and fishers' livelihoods.	1.1.1 Asses the effectiveness of former Galapagos marine zoning to protect HEVAS, key target fishing resources and ecosystem processes
	1.1.2 Identify HEVAs particularly vulnerable to climate risks and select the most suitable areas to ensure commercial stocks recovery, based on climate change risk assessment.
	1.1.3 Estimate the cost and potential benefits associated with the implementation of the new Galapagos marine zoning options.
	1.1.4 Engage stakeholders and facilitate a negociation process through innovative, extensive and participatory consultation in the CCPM, to promote their formal endorsement of a new marine zoning.
1.2 Design and implement an advanced data system for the adaptive co-management of the Galapagos marine zoning.	1.2.1 Design and implement an advance data monitoring and information system for the Galapagos subtidal ecological monitoring program, including the development of sensitive adaptation SMART indicators.
	1.2.2 Create a public data repository and a geographic information system on Galapagos marine biodiversity, oceanography, fisheries, transport, IUU fishing, and marine traffic to support marine spatial planning.
1.3 Structured decision-making framework to inform the adaptive co-management of the Galápagos Marine Reserve	1.3.1 Development of a training program to ensure the effective implementation of the structured decision-making framework for the GMR. 1.3.2 Investment of $US2.0 million into the "Fondo para la Reserva Marina de Galápagos (FRMG)" to ensure the sustainability of the structured decision-making framework and ecological and fisheries monitoring programs.

5.1.4 Impact on the resilience of the Galapagos marine ecosystems

The new network of no-take zones of the new Galapagos marine zoning will be useful to maximize not only the protection of HEVAS, but also the protection of a relevant proportion of fishery resources spawning stocks and critical recruitment and nursery habitats while minimizing its negative impact on fisher's livelihoods.

5.1.5 Technologies to be promoted by the EBA 1

A technologically advanced data system for the Galapagos subtidal ecological monitoring program will be designed and implemented to increase data accuracy and analysis, while reducing costs and allowing adaptive, responsive decision-making to improve the co-management of the GMR.

A smartphone/tablet application (apps) will be designed and used, in combination with a data repository and dashboard to collect, store, process and analyze large quantities of real-time, georeferenced data to enable management at more relevant spatial and temporal scales. Such high tech information system will facilitate the distribution of data to scientist, decision-makers and stakeholders, allowing them to get access to the best available information, transforming one-way flows of information (from scientists to managers) into a cooperative, mutually beneficial cycle of data collection, synthesis and sharing. As a result, the time lag between data collection and management interventions will be shortened and embedded in an adaptive co-management framework.

5.2 <u>EBA measure 2.</u> Ecological role of shellfish and finfish stocks are restored and livelihoods are diversified through the adoption of climate-smart small-scale fisheries and aquaculture approach.

5.2.1 Justification, current situation and baseline

The importance of SSF for the economy and food security of Galapagos coastal communities has been highlighted during the COVID-19 pandemic. Seafood is the third most consumed product by the population, after fruits, vegetables, grains and meat (pork and beef). The seafood product most consumed by the local population, before and during the COVID-19, is fresh yellowfin tuna, followed by shrimps, brujo, octopus, wahoo, Galapagos sailfin grouper and slipper lobster (Table 1) (Castrejón et al., in preparation).

The annual demand for fish, derived from the artisanal finfish fishery, is approximately 871.3 t, of which 31% is consumed by the local community (271.8 t), while the remaining 69% is consumed by tourists (599.5 t) (Berman et al. 2018). It is estimated that 14% of the fish consumed is yellowfin tuna (122 t), while the remaining 86% (749.3 t) corresponds to the fish that make up the artisanal finfish fishery, being the Galapagos sailfin grouper, the species in greatest demand, particularly during the Easter season. Yellowfin tuna has been increasingly important in Galapagos' livelihoods. For example, in 2013 the total number of fishers and vessels that actively participated in the tuna fishery is ca. 308 and 94, respectively, representing 27.4% and 22.6% of the total number of fishers and vessels registered by the DGNP (Ramírez and Reyes, 2015). The tuna fishery generated an estimated gross income of US$ 1 180 319 in 2013, where yellowfin tuna contributed 81.7% (US$ 964 483) of this value (Castrejón and Moreno 2018).

Given the growing relevance of the tuna fishery for the food security and economy of the Galapagos, there is a consensus between management authorities, fishers and NGOs to promote the development of a sustainable tuna fishery to accomplish three main objectives (Castrejón et al. 2019): (1) reduce fishing effort on coastal fisheries that are depleted, overexploited or whose conservation status is unknown; (2) improve the socio-economic condition of the small-scale fishing sector by diversifying their livelihoods; and (3) restore the structure and functionality of the marine ecosystems of the GMR. The accomplishment of these three objectives will contribute to the increased resilience and adaptive capacity of Galapagos marine ecosystems and small-scale fishing sector against future crises, including climate change, by adapting livelihoods and reducing risk and doing management for resilience, as recommended by FAO (Bertrand et al. 2020).

Before the COVID-19 pandemic, the adaptive capacity of the small-scale fishing sector was tested by other drivers of change, the most relevant being the boom-and-bust exploitation of the sea cucumber fishery and the global financial crisis (Castrejón and Charles 2020). The collapse of the sea cucumber fishery in 2006 caused a severe perturbation on the economy of the Galapagos small-scale fishing sector, which was intensified by the global financial crisis 2007–09. In response, a significant number of fishers abandoned not only the sea cucumber fishery but also the spiny lobster fishery. The number of active fishers and vessels decreased by 80.3% and 55.3% between 2000 and 2010. The most remarkable decrease was the number of mother boats, which decreased by 88.0% during the same period (Castrejón and Charles 2020).

While the global financial crisis 2007–09 was detrimental for Galapagos fishers, it was beneficial for spiny lobster stocks. Two years after the official end of the recession, lobster CPUE and catch increased 91% and 102%, respectively, whereas fishing effort only increased 6% between 2009 and 2011 (Defeo et al. 2016). Such unexpected recovery, after a period of overexploitation, is attributed to the substantial reduction in fishing effort, together with the combined effect of market forces and the ENSO, rather than no-take zones implementation through marine zoning (Defeo et al. 2013a; Castrejón and Charles 2020). In contrast to spiny lobsters, the sea cucumber fishery has not shown any sign of recovery, despite the implementation of a total closure since 2015. The high economic value of sea cucumbers (*I. fuscus*) in the Asian markets represented for many years a valuable source of revenues for the Galapagos small-scale fishing sector (Toral-Granda 2008). Although sea cucumbers are not currently relevant for the food security of Galapagos, recent scientific evidence points out that sea cucumbers contain a wide range of bioactive compounds, mainly collagen, cerebrosides, glycosaminoglycan, chondroitin sulfate, saponins, phenols, and mucopolysaccharides, which demonstrate unique biological and pharmacological properties, including anticancer, anti-hypertensive, anti-angiogenic, anti-inflammatory, antidiabetic, anti-coagulation, antimicrobial, antioxidation, and anti- osteoclastogenic properties (Abedin et al. 2014; Khotimchenko 2018; Xu et al. 2018). These compounds are potential prototypes for the development of new and high value pharmaceutical and nutraceutical products and medicines, representing a potential new source of food and income for Galapagos communities and the rest of Ecuador.

Furthermore, as previously mentioned (see section 4.1), the Galapagos sailfin grouper also show signs of overexploitation. The sailfin grouper is one of the six most important species consumed by Galapagos coastal communities (Castrejón et al., unpublished data). Thus, this fishery has played traditionally a fundamental role in the food security and economy of the province. The effective implementation of the new marine zoning will contribute to rebuild sailfin groupers and sea cucumber stocks and to restore their ecological role. However, alternative fisheries management measures are required to ensure the restoration of the ecological role of sailfin groupers and sea cucumber, as well as to diversify fishers' livelihoods, contributing to mitigate the impact of the ENSO and climate change.

The former and new Galapagos zoning system has been built on the misconception that no-take zones are the only effective spatially-explicit management tool to conserve marine biodiversity and rebuild overexploited stocks. This wrong idea about the ecosystem-based spatial management (EBSM) approach and its implementation on the marine environment has precluded the Galapagos zoning to reconcile conservation and fisheries management objectives (Castrejón and Charles 2013).

There is growing evidence that no take-zones are useful tools to increase the biomass and size of overexploited species and biodiversity of marine ecosystems around the world (Halpern et al. 2010; Edgar et al. 2014). However, no-take zones represent only one of many management tools available for the successful implementation of EBSM, including territorial user rights for fisheries (TURFs), spatiotemporal closures, rotation of fishing grounds, spatial gear restrictions, small-scale aquaculture, among others. None of these alternative fisheries management tools have been explored to promote the conservation of marine biodiversity and rebuild overexploited fisheries in the GMR.

In summary, the overexploitations of sailfin groupers and sea cucumber stocks, in combination with IUU fishing and other human drivers of change, has degraded the resilience and adaptive capacity of Galapagos marine ecosystems, making them vulnerable to climate variability and change. Therefore, the project will contribute to restore the abundance and ecological of sea cucumber and sailfin grouper stocks and diversify fishers' livelihoods by supporting the implementation of community-based fishery improvement projects, together with the implementation of small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing (TURFs). The objective is to restore Galapagos marine ecosystems and improve the socioeconomic condition of the small-scale fishing sector and the food security of the Galapagos coastal communities. It is expected that the effective involvement of local communities in the co-management of strategically placed TURF will contribute to generate a sense of exclusive use and ownership among fishers, promoting the implementation of effective monitoring, control and surveillance procedures, and the accomplishment of objectives for management and conservation.

5.2.2 Target indicators and beneficiaries

The target indicators for EBA 2 are described in Table 5, together with the direct and indirect expected beneficiaries.

Table 5. Target indicators and beneficiaries associated to EBA 2.

Target indicators
At the end of the project: • At least 70% of the activities contained in the C-FIP action plan for the tuna and sailfin grouper fisheries have been effectively implemented. • The MSC's Benchmarking and Tracking Tool (BMT) reports show that the level of sustainability of the tuna and sailfin grouper fisheries have increased since the inception of the project. • There is conclusive evidence that the quality of tuna landings have improved thanks to improved post-harvest handling and cold-chain infrastructure. • At least 100 ship-owners have implemented in their fishing vessels an electronic monitoring system and they are part of a blockchain traceability system.

• At least one fishing organization has designed and implemented a code of good fishing practices and a manual of best practice handling techniques for target and bycatch species. • Management measures, responsible fishing practices and monitoring activities have been implemented in the sailfin grouper to promote its recovery. • At least 1 million larva have been reared locally, and at least 100,000 sea cucumbers have been released in specific TURF to accelerate stock rebuilding across the GMR. • At least one fishing organization will benefit from the successful allocation of TURF.	
Beneficiaries	
Direct	• At least 400 fishers and their families will benefit from the recovery of sea cucumbers and sailfin groupers stocks. • At least 308 fisher and their families will benefit from the improvement of the Galapagos tuna fishery. • The GNPD and Ecuadorian Army will improve their control and surveillance capacity. • The entire small-scale fishing sector will benefit form reduction of IUU and ghost fishing.
Indirect	• At least 25,000 residents will benefit from availability and accessibility to seafood, ensuring the food security of the entire province of Galapagos.

5.2.3 Activities description

The Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (FAO 2014) provide complementary guidance to the Code of Conduct with respect to small-scale fisheries. The Voluntary Guidelines call on all parties to recognize and take into account the impact of natural disasters and climate change on SSF and recommend that appropriate adaptation, mitigation and aid plans should be put in place, in line with human rights principles.

Therefore, to build the resilience of the Galapagos small-scale fisheries sector to the effects of climate change and to ensure the sector delivers sustainable benefits, it is essential to adopt and adhere to best practices such as those requested by the FAO Code of Conduct for Responsible Fisheries and the Guidelines for Securing Sustainable Small-Scale Fisheries, whose implementation is facilitated by the EAF/EAA.

Considering that healthy ecosystems are the foundation of climate change adaptation and mitigation (FAO 2017; Bertrand et al. 2020), two outcomes are proposed aiming at promoting the development of productive, climate-resilient, and low-carbon capture tuna and sailfin grouper fisheries and small-scale sea cucumber aquaculture.

Activity 2.1: Strengthen management conditions of small-scale tuna fisheries, to reduce ecological impact of the fishery over secondary and endangered, threatened and protected (ETP) species.

Considering the key role that the tuna fishery plays in the economy and food security of Galapagos coastal communities, there is a consensus between management authorities, fishers and NGOs to promote the development of the tuna fishery to increase the resilience and adaptive capacity of Galapagos coastal fishery resources and small-scale fishing sector against future crises, including climate change. However, the key question is how to maximize the socioeconomic benefits generated by the Galapagos tuna fishery, while minimizing its ecological impact on endangered, threatened, or protected species, such as sharks, mantas, and marine turtles. To answer this question, various institutions and NGOs have developed a holistic, community-based management strategy for the yellowfin tuna fishery, based on principles of sustainability and social responsibility (Castrejón et al. 2019).

Since the mid-2000s, most research and management efforts have focused on increasing tuna catch levels through the experimental use of longline, a fishing gear currently prohibited in the Galapagos Marine Reserve (GMR). This approach has generated considerable controversy due to its potential negative impacts on protected species. An alternative research and management approach, whose relevance has gained momentum in recent years, is to enhance the value of the tuna fishery through capture and marketing strategies. Due to its perceived resilience benefits, we intend to focus on capture strategies that focus on increasing the quality of the caught tuna, rather than their quantity, and implementing adequate harvest and post-harvest techniques to improve and maintain tuna quality. Complementary market strategies are addressed in EBA measure 3, including the development of products with added value (e.g., smoked tuna, tuna burgers and sausages, etc.).

The Program will build from the alliance created by 12 governmental and non-governmental organizations in 2019, including the Santa Cruz small-scale fishing sector and WWF, to maximize the economic value of the Galapagos tuna fishery and minimize its ecological impact by improving its management and marketing system. To this end, they joined forces to put in place a holistic, community-based approach to improve the Galapagos tuna fishery through the development of a Community-Based Fishery Improvement Project, or C-FIP[3] (Castrejón et al. 2019). Due to lack of funding for the C-FIP action plan for the Galapagos tuna fishery has not been implemented. Therefore, the C-FIP action plan for the Galapagos tuna fishery was integrated into the GCF proposal to obtain the funding required to continue C-FIP implementation in the context of climate change. Therefore, both EBA 2 and 3, are directly supporting the implementation of the C-FIP.

This EBA measure will build from this initiative to improve the sustainability and governance of the Galapagos tuna fishery through a set of activities whose objectives are: (1) reduce IUU fishing and promote fair trade by implementing an electronic monitoring system that allows the cost efficient collection of catch data *in situ*, both target and bycatch species, in combination with a blockchain traceability system; (2) increase the quality rather than the quantity of tuna landings by improving post-harvest handling and cold-chain infrastructure, and by designing and implementing a code of good fishing

[3] A C-FIP is defined as an alliance of diverse actors and institutions, including fishers, managers, traders, scientists, private sector, and NGOs, who join efforts to define and agree on an action plan, which specifies the activities that are required to create ecologically sustainable, economically profitable, and socially fair fisheries. This people-centered approach for the improvement of community-based coastal fisheries combines globally recognized ecosystem-based and human rights-based approaches, including the UN FAO's Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries, and the Marine Stewardship Council Standard (MSC), in combination with blue finance principles, to promote sustainability of coastal community-based fisheries and benefits they provide to humankind

practices and a manual of best practice handling techniques for target and bycatch species.

Finally, GCF funding will be allocated to carry out the following research priorities identified by the DGNP and stakeholders to improve the management and sustainability of the Galapagos tuna fishery: (1) determining the impact generated by illegal and incidental fishing of sharks, and other ETP species, generated by the industrial and artisanal fishing fleet, both domestic and foreign, that takes place inside and outside the boundaries of the GMR, taking into consideration the impact of the climatic variability on catch composition; 2) determine the level of impact of ghost fishing and illegal fishing aggregating devices (FADs) on the GMR; and (3) determine the migratory patterns and the genetic and population structure of yellowfin tuna from the GMR. The results of these studies will be used by the GNPD to promoting the development of productive, climate-resilient, and low-carbon capture tuna fishery, as well as inputs to develop a strategy to prevent, deter and eliminate IUU and ghost fishing in the GMR. Such action will contribute to increase the resilience and adaptive capacity of Galapagos marine ecosystems by reducing the ecological impact of IUU and ghost fishing over a wide range of commercial and ETP species, including sharks and marine turtles.

Finally, based on the analysis of the migratory patterns and genetic and population structure of yellowfin tuna from the GMR, the GNPD will be able to quantify the “spillover effect” that occur in the boundaries of the reserve (Bucaram et al. 2018). The spillover effect occurs when species located in a marine protected area, where they are protected for a portion of their life cycle and that has allowed them to grow and/or breed, move to adjacent fishing grounds where they are caught, in larger numbers or larger sizes. There is evidence that the catch of commercially important tuna species per fishing set has nearly doubled in the areas adjacent to the GMR (Bucaram et al. 2018). However, the knowledge about the migratory pattern of tuna within and around the GMR is still limited. Therefore, the GNPD has limited information to determine the impact of the GMR over yellowfin tuna stocks and the benefits that large-scale and small-scale fishing obtain from the GMR.

Activity 2.2: Strengthen management of sailfin groupers fishery to mitigate climate change impacts while restoring the species ecological role.

Concerns of overfishing, coupled with a lack of fishing regulations and a warmer ocean, have raised concerns regarding the sustainability of the Galapagos sailfin grouper fishery (Usseglio et al. 2016; Marin and Salinas-de-León 2018; Cavole et al. 2020). Based on the relative impact of grouper fishing and environmental factors to changes in simulated ecosystem effects, Eddie et al. (2019) concluded that overexploitation of groupers has produced greater effects over Galapagos marine ecosystems than El Niño events. In consequence, these authors suggest the participatory development of an evidence-based management plan to allow Galapagos sailfin grouper to recover to approximately half of their unfished biomass. This management approach will contribute to increasing groupers' biomass to the maximum sustainable yield (MSY), increasing fishery productivity, and partially restoring the groupers ecosystem role as keystone species.

Usseglio et al. (2016) suggest the need for specific management regulations to rebuild the Galapagos sailfin grouper fishery, including minimum (65 cm total lenght) and maximum (78 cm total lenght) landing sizes, slot limits (64±78 cm total lenght), as well as a closed season during spawning from October to January. It is recognized that these regulations are harsh and will certainly have negative impacts on the livelihoods of fishers in the short term. However, Usseglio et al. (2016) cautions that inaction will likely result in the collapse of this economically and culturally valuable fishery.

Therefore, to rebuild sailfin groupers stocks and restore their ecological role into Galapagos marine ecosystems, and based on the successful application of the CFIP for the spiny lobster and tuna fisheries, this EBA propose the design and implementation of a C-FIP for the sailfin grouper. So far, the C-FIP model has contributed to mobilize financial resources from the public and philanthropic sector to improve the management and marketing system of the spiny lobster and tuna fisheries, and the same is expected to occur for the Galapagos sailfin fishery. These public and philanthropic investments have the potential to leverage a cascade of private financial resources to fund innovative projects that increase the efficiency of the fishery sector on all the links of the value chain and reduce the impact of the fishing activity on marine ecosystems, increasing their resilience and adaptive capacity to ENSO and climate change impacts.

Therefore, the program will work with the GNPD, Galapagos Governing Council, small-scale fishing sector, private sector and other relevant actor to define a C-FIP action plan and a bankable business plan that helps to attract the investment required for the holistic and community-based improvement of the Galapagos sailfin grouper. As a fundamental part of this framework, with this outcome the program will elaborate and adopt a participatory management plan for the sailfin grouper, considering the effects of climate change; this plan will include landing regulations, improve fishing practices and monitoring activities.

To ensure the effective implementation of the C-FIP action plan for the sailfin grouper, tuna and spiny lobster fishery, the program will hire a C-FIP coordinator, who will responsible to follow-up the implementation of C-FIP, in collaboration with a C-FIP Steering Committee, and to update annually the fisheries diagnostics for each fishery intervened. The C-FIP Steering Committee will be made up by representatives of the GNPD, CGREG, NGO and small-scale fishing sector. Such committee will meet every six months to follow-up the implementation of the C-FIP for the sailfin grouper, yellowfin tuna and spiny lobster fishery.

The adapted version of the MSC's Benchmarking and Tracking Tool (BMT) developed by Castrejon et al. (2015) will be used to update each fishery diagnostic. The BMT is a key component of the C-FIP model. This fishery diagnostic tool represents a comprehensive and standardized analytical framework to measure periodically the progress and impact of C-FIP implementation over fishery improvement. Its main function is to help C-FIP implementers to conduct a comprehensive "Needs Assessment". A needs assessment is an evaluation of a fishery to determine environmental and socioeconomic challenges and improvements needed in the fishery. The results inform the definition of cost-effective intervention strategies to improve the fishery under assessment by designing and implementing a C-FIP action plan and a business plan, or any other type of blue finance mechanism, that helps to attract the investment required for fishery improvement. Based on the BMT results, the C-FIP action plan will be updated by the C-FIP coordinator, in collaboration with the C-FIP Steering Committee.

The MSC+ standard encompasses a set of Principles, Components, Performance Indicators (PIs) and Scoring Guideposts (SG). The scoring guideposts incorporate all the scoring elements or scoring issues required at each guidepost. The hierarchy of Principles, Components, Performance Indicators and Scoring Guideposts is known as "Default Assessment Tree", which is used as the basis for assessment of the fishery for compliance with the MSC+ standard (Castrejon et al. 2015).

Each of the 43 performance indicators of the MSC+ will be scored annually using the BMT and following the procedures established by the MSC+ standard to determine changes in the sustainability status of the fishery. Each of the performance indicator will be scored on a graded scale, with levels 60, 80 and 100 defining key sustainability thresholds. A BMT index of 1 means that all performance indicators in the fishery are at least in the 80 level, whereas a BMT score of 0 means that all of the performance indicators are at less than the 60 level. These thresholds correspond to levels of quality and certainty of fishing management practices and their probability of generating sustainability. The final overall score resulted in a "pass" in those cases in which the average score for each principle was greater than or equal to 80, and that each PI was greater than 60; anything below this level resulted in a fail. A fishery can pass with some indicators less than 80, in which case the fishery receives a 'condition' requiring improvements so that the score can be raised to an 80 level, normally within a five-year period.

Activity 2.3: Implement small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing (TURFs), to rebuild sea cucumber stocks and diversify fishers' livelihoods.

The establishment of fishery management measures to ensure the recovery of the Galapagos sailfin grouper will disrupt the socioeconomic condition of the small-scale fishing sector in the short-term. Therefore, Usseglio et al. (2016) suggest that alternative sources of income should be developed in parallel with the establishment of fishing regulations to limit the impact on fishers' livelihoods during the transition to a more sustainable management regime. In response to this call, this module proposes the development of small-scale aquaculture in Galapagos, in combination with the experimental allocation of Territorial Use Rights for Fishing (TURFs), to rebuild sea cucumber stocks. This will provide an alternative source of income to the small-scale fishing sector, and promote the adoption of a rights-based co-management approach. Such a CSA approach will set up the enabling conditions to address the roots of fisheries management failures that led to the overexploitation of the main shellfish and finfish fisheries of the GMR.

The sea cucumber fishery has not shown any sign of recovery, despite the implementation of a total closure since 2015. Empirical evidence of variable natural recovery following fish stock collapses suggests that populations can become “trapped” in a degraded state, possibly owing to multiple factors such as ecosystem effects, genetic deterioration, and modified intraspecific interactions (Lorenzen et al. 2012). Restocking programmes could address some of these issues, helping depleted populations to “break out of the trap” and regain critical mass capacity to increase population size.

Therefore, as the population abundance of sea cucumbers is substantially below carrying capacity because of overfishing, restocking may be the only active management intervention that can boost population recovery. Restocking or stock rebuilding involve temporary releases of hatchery fish aimed at rebuilding depleted populations more quickly than would be achieved by natural recovery (Lorenzen et al. 2012). To this end, a substantial number of sea cucumbers relative to the abundance of the remaining wild stock will be released to significantly accelerate rebuilding. As restocking calls for close ecological and genetic integration of wild and cultured stocks, combined with very restricted harvesting, fishing intensity will be regulated through the experimental allocation of Territorial Use Rights for Fishing (TURF). This management approach will maximize the contribution of wild and released cultured sea cucumbers for population growth. Furthermore, genetic management will be used to maintain the characteristics of the wild population, and developmental manipulations likewise may be carried out to produce “wildlike” sea cucumbers. Therefore, local sea cucumber population will be used as seed stock and larva will be reared locally.

Cultured filter feeders, such as sea cucumbers, do not need external feeds. They can live on carbon and other nutrients in the environment. Therefore, sea cucumber aquaculture can be done with no or minimal GHG emissions and low or minimum environmental impacts.

Since 2013, aquaculture of *I. fuscus* species has been advancing through larval rearing, juvenile production and asexual reproduction by transverse fission in captivity with a new validated technology at the Centro Nacional de Acuicultura e Investigaciones Marinas of the Escuela Superior Politécnica del Litoral of Ecuador, which is helping to restore wild population at the El Pelado, a marine protected area located in mainland Ecuador (Sonnenholzner et al. 2017).

The outputs and activities that will be put in place to accomplish the three outcomes associated to EBA 2 are described in Table 6.

Table 6. Activities and subactivities of the EBA 2.

EBA 2: Shellfish and finfish stocks have restored their ecological role and diversified livelihoods, through the adoption of climate-smart small-scale fisheries and aquaculture approach.	
Activities	**Subactivities**
2.1 Strengthen management conditions of small-scale tuna fisheries, to reduce ecological impact of the fishery over secondary and endangered, threatened and protected (ETP) species.	2.1.1 Design and implement an electronic monitoring and blockchain traceability system.
	2.1.2 Promote the adoption of a code of good fishing practices and handling techniques, based on the assessed impact of ghost fishing and illegal fishing aggregating devices (FADs) on vulnerable marine ecosystems.
	2.1.3 Carry out research priorities to improve the management and sustainability of the Galapagos tuna fishery
2.2 Strengthen management of sailfin groupers fishery to mitigate climate change impacts while restoring the species ecological role.	2.2.1 Asses current sailfin groupers population status, including projections under climate change conditions and fishing regulations.
	2.2.2 Elaborate and adopt a climate smart community-based fishery improvement project (C-FIP) for the sailfin grouper.
	2.2.3 Following-up C-FIP implementation of sailfin grouper, yellowfin tuna and spiny lobster fisheries.

	2.2.4 Update annually the Benchmarking and Tracking Tool (BMT) elaborated for each C-FIP and adapt action plan, based on results.
2.3 Implement small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing (TURFs), to rebuild sea cucumber stocks and diversify fishers' livelihoods.	2.3.1 Update stock assessment of *I. fuscus*, including projections under climate change conditions and fishing regulations.
	2.3.2 Reproduce in captivity and release a substantial number of sea cucumbers into the remaining wild stock, to significantly accelerate rebuilding.
	2.3.3 Experimental allocation and evaluation of TURF to regulate harvesting and fishing intensity of *I. fuscus*.

5.2.4 Impact on the resilience of the Galapagos marine ecosystems

Systems rich in biodiversity are less sensitive to change than overfished systems with little diversity (FAO 2017). Therefore, the Community-supported Fisheries (CSF) and Community-supported Agriculture (CSA) management approach will contribute to maintaining Galapagos biodiversity, preserve the resilience of human and aquatic systems to change, and improve the capacity to anticipate and adapt to climate-induced changes in marine ecosystems and fisheries production systems. Furthermore, improving the general resilience of fisheries and aquaculture systems will reduce their vulnerability to the impacts of climate change and climate variability on resources and to severe weather episodes that trigger natural disasters, such as the ENSO.

5.2.5 Description of the species that make up the module

The main target species caught by the Galapagos tuna fishery are yellowfin tuna (*Thunnus albacares*) and swordfish (*Xiphias gladius*). Tuna landings and consumption have been increasing in the last 20 years in Galapagos (Castrejón and Moreno 2018; Berman et al. 2018), thus, adaptation measures against climate change need to be implemented for this fishery.

Tuna are highly migratory species wthin the ETP, where its distribution and catchability respond to climate variability. Changing water properties and circulation will impact larval dispersal, preferred habitat distributions, spawning events and tuna trophic systems (Ganachaud et al. 2013).

Furthermore, there is a set of species that are susceptible to being caught incidentally in the tuna fishery, some of them are retained for having an economic value (e.g., wahoo), while others are discarded since their capture it is prohibited (e.g., sharks) or because they have no economic value at the local level. No information exists about the ecological impact produced by the Galapagos tuna fishery due to the lack of a fisheries observer program or an electronic monitoring system, which collect information on target, incidental and discard catch rates generated on a daily basis. A recent study evaluating the ecological impact of the tuna fishery focused on evaluating the impact of longline, which is a prohibited fishing method in the GMR according to the current legal framework (Castrejón and Moreno 2018). Based on an experimental longline fishery project conducted in the GMR, Cerutti et al. (2020) determined that the percentage of incidental catch and discards of protected species is 9%, while the percentage of the catch of the retained catch (target and bycatch with economic value) is 91% (Table 7).

Eleven species of bony fish were incidentally caught and retained because they have economic value. Additionally, sixteen species caught were protected megafauna, most of which were blacktip shark (*Carcharhinus limbatus*), unidentified sharks, and oceanic manta (*Mobula birostris*), but also, Galapagos shark (*Carcharhinus galapagensis*), scalloped hammerhead (*Sphyrna lewini*), thresher sharks (*Alopias vulpinus* and *A. supercilious*), silky shark (*Carcharhinus falciformis*), and six other shark species, as well as green sea turtles (*Chelonia mydas*), Galapagos sea lions (*Zalophus wollebaeki*), and a Galapagos fur seals (*Arctocephalus galapagensis*) (Cerutti-Pereyra et al., 2020). Approximately, 24% of these protected species are listed as Endangered, 42% as Vulnerable, 29% as Near Threatened and 6% as Least Concern by the International Union for the Conservation of Nature (IUCN) Red List, while 6% are included in Appendix I and 41% in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Table 7. Total catch documented in the experimental longline fishery project of 2012–2013. Source: Cerutti-Pereyra et. al. (2020).

Common name	Scientific Name	Total Caught	% from Total Catch	Classification
Yellowfin tuna	*Thunnus albacares*	3513	78.80	Target
Escolar	*Lepidocybium flavobrunneum*	655	14.69	Bycatch- changed status
Swordfish	*Xiphias gladius*	182	4.08	Target
Blacktip shark	*Carcharhinus limbatus*	88	1.81	Bycatch- protected species
Unidentified shark	NA	88	1.81	Bycatch- protected species
Oceanic manta	*Mobula birostris*	80	1.65	Bycatch- protected species
Galapagos shark	*Carcharhinus galapagensis*	63	1.30	Bycatch- protected species
Scalloped hammerhead	*Sphyrna lewini*	36	0.74	Bycatch- protected species
Dolphin fish	*Coryphaena hippurus*	35	0.79	Commercialized bycatch
Skipjack tuna	*Katsuwonus pelamis*	32	0.72	Commercialized bycatch
Oil fish	*Ruvettus pretiosus*	21	0.47	Commercialized bycatch
Bigeye thresher shark	*Alopias superciliosus*	20	0.41	Bycatch- protected species
Black skipjack	*Euthynnus lineatus*	19	0.39	Commercialized bycatch
Green sea turtle	*Chelonia mydas*	16	0.33	Bycatch- protected species
Silky shark	*Carcharhinus falciformis*	13	0.27	Bycatch- protected species
Galapagos sea lion	*Zalophus wollebaeki*	10	0.21	Bycatch- protected species
Blue shark	*Prionace glauca*	8	0.16	Bycatch- protected species
Wahoo	*Acanthocybium solandri*	6	0.13	Commercialized bycatch
Thresher shark	*Alopias vulpinus*	5	0.10	Bycatch- protected species
Oceanic whitetip shark	*Carcharhinus longimanus*	4	0.08	Bycatch- protected species
Rainbow runner	*Elegantis bippinulata*	3	0.06	Commercialized bycatch
Silvertip shark	*Carcharhinus albimarginatus*	3	0.06	Bycatch- protected species
Barracuda	*Sphyraena spp.*	2	0.04	Commercialized bycatch
Indo-Pacific blue marlin	*Makaira mazara*	2	0.04	Commercialized bycatch
Pacific crevalle jack	*Caranx caninus*	2	0.04	Commercialized bycatch
Tiger shark	*Galeocerdo cuvier*	2	0.04	Bycatch- protected species
Bonito	*Sarda spp.*	1	0.02	Commercialized bycatch
Striped bonito	*Sarda orientalis*	1	0.02	Commercialized bycatch
Galapagos fur seal	*Arctocephalus galapagoensis*	1	0.02	Bycatch- protected species
Great frigatebird	*Fregata minor*	1	0.02	Bycatch- protected species
Frigatebird	*Fregata sp.*	1	0.02	Bycatch- protected species
Shortfin mako shark	*Isurus oxyrhinchus*	1	0.02	Bycatch- protected species
Whitetip reef shark	*Triaenodon obesus*	1	0.02	Bycatch- protected species
Total Target		4458		
Total Bycatch		437		
Total Catch		4895		

Another important species of the Galapagos finfish fishery is the Galapagos sailfin grouper (*Mycteroperca olfax*, locally called "bacalao"). The distribution of this species is limited to the offshore islands of Cocos, Costa Rica; Malpelo, Colombia; and Galápagos, Ecuador in the Tropical Eastern Pacific. However, it is rare at both Cocos and Malpelo (Eddy et al. 2019). Bacalao is a top predator in the coastal ecosystems of the Galápagos and is a sequential hermaphrodite, as all individuals are born as females, and transition to males at approximately 12 years of age and 80 cm total length (Usseglio et al. 2016). The life history characteristics that make bacalao susceptible to overfishing, its ecological role within the Galápagos ecosystem, and its current threatened conservation status have prompted recent efforts to inform sustainable management of bacalao (Salinas-de-León, Rastoin & Acuña-Marrero, 2015; Usseglio et al., 2015, 2016).

In Galapagos, the sailfin grouper is distributed in all areas of the archipelago, albeit with higher abundances in the colder central regions than the northern zone (Usseglio et al.

2016). Due to its restricted range and evidence of fisheries declines, the Galapagos sailfin grouper has been listed as Vulnerable (VU) by the International Union for Conservation of Nature (IUCN).

Finally, the brown sea cucumber *I. fuscus* (Holothuroidea: Aspidochirotida) is an epibenthic large-size (19–25 cm and 100–410 g) deposit-feeder that inhabits sheltered (low-medium energy) rocky shores associated with foliate and crustose algae from the shallow subtidal to rocky coasts from Baja California, México to northern Perú, including Galápagos, Socorro, Cocos, Malpelo and Revillagigedos islands (Sonnenholzner et al. 2017). The characteristics of the life history of *I. fuscus*, together with its high commercial value in the Asian market and the ease of its capture, contribute to the economic collapse this fishery in 2006 (Defeo et al. 2016). Since then, sea cucumbers stocks have not shown signs of recovery, despite the implementation of a total closure since 2015. This species is currently listed as endangered in the IUCN Red List of Threatened Species.

5.2.6 Technologies to be promoted by the EBA 2

Three state-of-the-art technologies will be promoted through this EBA:

1) The Centro Nacional de Acuicultura e Investigaciones Marinas of the Escuela Superior Politécnica del Litoral of Ecuador have developed innovative technology to rebuild *I. fuscus* stocks by asexual reproduction by transverse fission. This technology has been tested and validated at the El Pelado in mainland Ecuador (Sonnenholzner et al. 2017) and now can be applied in Galapagos to rebuild sea cucumbers stocks.

2) Vessel monitoring using VMS (vessel monitoring systems) and AIS (Automatic Identification Systems) technology has been implemented by the DGNP to monitor the movement of fishing and tourism vessels across the GMR. However, a weakness of the VMS and AIS systems is that they do not provide information about catch composition. Consequently, the DGNP lack information on the rate of incidental and illegal catch of protected, threatened and endangered species. The electronic monitoring system through video cameras represents a solution to collect information on the composition of the catch obtained by small-scale

vessels. In Ecuador, WWF has launched a pilot project in the small-scale mahi-mahi fishery as part of the “Coastal Fisheries Initiative” project, funded by the Global Environment Facility (GEF), whose objective is to evaluate the experimental use of a traceability system integrating an electronic video monitoring system. The electronic monitoring system was designed by the Shellcatch company, whose technology is also being applied in the hake fishery in the Upper Gulf of California, Mexico.

3) The electronic monitoring system designed by Shellcatch is called "Virtual observer" is waterproof, powered by solar energy, and has video and GPS sensors, through which it is possible to record fishing operations. The data is captured by a WiFi data link unit, which processes the video and GPS data and uploads it to a cloud platform designed by Shellcatch (https://www.shellcatch.com/welcome/). In Puerto Ayora, Galapagos, the Pelikan Bay Dock Fishing Shipowners Association (Asociación de Armadores Pesqueros del Muelle Pelikan Bay), hereafter the P-Bay Association, has implemented a Shellcatch video camera in one of their vessels. Their goal is to market high quality and certified tuna that allows them to add value to their products. To this end, the P-Bay association plans to implement Shellcatch video cameras permanently in all vessels that are part of the seafood company. To this end, the P-Bay has invested in one Shellcatch video camera. The cost was US$ 2 858 with 12 months of subscription. This Shellcatch video camera is the first one to be tested in the GMR, representing a milestone for the improvement of the Galapagos tuna fishery. The main intention of the P-Bay association is to be able to export tuna, possibly to Europe. Therefore, the P-Bay association plan to participate in a local seafood certification system, created by the DPNG, WWF, and Conservation International, called “Sello Galápagos” (Galapagos seal). The program will provide technical and financial support to link the Galapagos seal with a blockchain traceability system. One of the objectives of this technology is to prevent that illegal fishery products be exported to Europe. In addition, a fishery traceability system will provide consumers with confidence that the tuna they have purchased comes from a sustainable tuna fishery, located in Galapagos.

5.3 EBA measure 3. Upgraded and more efficient value chains for climate-smart seafood products, potentiated with links to new markets.

5.3.1 Justification, current situation, and baseline

The GMR is facing a growing number of climatic drivers of change that affect its biodiversity and ecological integrity. Fishers and institutions cope and adapt to these drivers depending on the nature and magnitude of the perturbation caused for each driver and the type of effect, positive or negative, caused on fishery resources or supply chains. For example, the COVID-19 pandemic caused drastic shifts in the demand for seafood worldwide, directly affecting seafood supply chains and the socioeconomic condition of coastal communities, including Galápagos. In contrast, the El Niño-Southern Oscillation (ENSO) directly affects the abundance and distribution of fishery resources, affecting the availability and accessibility of marine resources for fishers. Therefore, the magnitude of impact caused by each driver will ultimately depend on the adaptive capacity of fishery resources, fishers, and institutions.

Fishers' adaptive capacity will vary according to diverse factors, including the portfolio of fisheries in which a single fisher depends on to sustain individual fishers livelihoods, the level of diversification of their fishery products, markets, and livelihoods, as well as their economic condition, social network, and willingness and entrepreneurial capacity to change and improve their socio-economic condition. This EBA proposes to take advantage of the coping responses used by the fishing sector to face previous emergencies, including the COVID-19 pandemic, as opportunities to enhance fishers' adaptive capacity and resilience against future impacts, including climate change.

During the COVID-19 pandemic, Galapagos' fishers diversified their distribution channels and used new marketing strategies to increase their number of clients and sales. The most relevant strategy was home delivery, through refrigerated trucks and other vehicles, and social media, such as WhatsApp and Facebook (Castrejón et al., in prep.). On the other hand, consumers changed their consumption patterns during the COVID-19 pandemic, this included shifts in the amount and frequency of seafood consumption, the type of seafood consumed, and the factors that influence their seafood purchase decisions. For example, seafood was available and accessible to the Galapagos local community during the lockdown implemented in the archipelago (between March16th and July 1st, 2020). However, the frequency of consumption of fresh and frozen seafood during this period decreased while imported canned seafood consumption increased (Castrejón et al. (in prep.).

These results suggest that seafood security of Galapagos was not affected by the COVID-19 crisis. However, the amount and frequency of consumption of seafood overall did not increase, remarkably because residents probably prefer to consume seafood in restaurants rather than purchase it and prepare it at home. Nevertheless, the oversupply of fresh fish saturated the market, reducing seafood price, which affected the economy of the small-scale fishing sector. Thus, food security and the economy of the archipelago could improve remarkably if residents decided to increase their seafood consumption, which would be beneficial for the local small-scale sector and the entire economy of Galapagos. In addition, food imports from mainland Ecuador would be reduced, which in turn would reduce the risk of transporting new invasive species toward Galapagos (Castrejón et al., in prep.).

In summary, the EBA 3 will promote the sustainable development of the Galapagos tuna fisheries, not only to ensure the conservation of large pelagic fish affected by illegal fishing and bycatch, but to improve the productivity and competitiveness of the Galapagos small-scale fishing sector. Therefore, a comprehensive management strategy for tuna fisheries will be proposed based on four pillars: innovation and technology, the circular economy, public-private investment and the management of tuna fishing. Through the implementation of this strategy, it is expected to comprehensively improve the Galapagos small-scale fishing sector by: 1) decreasing the administrative costs of control and surveillance programs; 2) improving fishing statistics, not only for tuna fisheries but also for the rest of fisheries carried out in the GMR; 3) determining magnitude and conditions that generate illegal and incidental fishing of juvenile tunas and endangered, threatened and protected (ETP species); 4) estimates of the economic impact generated by illegal and incidental fishing; and 5) improving the sustainability of Galapagos tuna fisheries through a circular and blue economy.

The EBA 3 will promote the adoption of a circular economy through a program of soft loans and the provision of long-term capacity. The objective will be finance the creation, strengthening or expansion of seafood enterprises, based on principles of sustainability and social responsibility. This approach will help to recover part of the investment made by the GCF with a certain return. In this way, an alternative long-term financing mechanism will be generated to improving the sustainability of the Galapgos tuna fishery This management approach is expected to encourage other fishers to follow the same process, thus replicating a model of fisheries improvement.

To facilitate the overall coordination and implementation of this EBA, a Steering Committee will be appointed with representatives from GNPD, CGREG, NGO and small-scale fishing sector. The Steering Committee will facilitate successful execution of the Blue Incentives Program and G-Lab and be responsible for providing input to work planning, approving annual work plans and budgets, review and approval of key project outputs and make informed decisions regarding planning and development of actions during the execution of the program. The Steering Committee will also ensure that the Blue Incentives Program and G-Lab complies with GCF's operational standards, best practice policies and safeguard requirements.

Furthermore, a socioeconomic survey will be design an implemented, at the beginning and end-of-project, to assess the performance of those seafood enterprises supported by the Blue Action Program and G-Lab, including also the wellbeing of Galapagos small-scale fishing sector. The socioeconomic surveys will be implemented in Santa Cruz, San Cristóbal and Isabela. The aim of the survey will be establish a baseline and monitor progress of seafood enterprises supported by the Blue Action Program and G-Lab, and determine the socioeconomic conditions of small-scale fishing sector using a wider set of indicators.

5.3.2 Target indicators and beneficiaries

The target indicators for EBA 3 are described in Table 8, together with the direct and indirect expected beneficiaries.

Table 8. Target indicators and beneficiaries associated to EBA 3.

Target indicators	
At the end of the project: • The consumption of pelagic species, mainly yellowfin tuna has increased by at least 30% in comparison with the year of inception of the project. • At least 50 soft loans have been provided by the Blue Incentives Program. • At least 50 entrepreneurs have received sustained institutional and financial support by the G-Lab and Blue Incentives programe. • At least 10 sustainable and socially responsible seafood enterprises have been successfully implemented, helping to improve food security by reducing reliance on imported food. • The amount of imported seafood have been reduced by 30%. • At least five value added products are offered by the new socially responsible seafood enterprises • At least five socially responsible seafood enterprises have obtained access to new markets that pay higher prices for their products.	
Beneficiaries	
Direct	• At least 400 fishers and their families will have the opportunity to obtain sustained institutional and financial support by the G-Lab and Blue Incentives program. • At least 25,000 residents will have the opportunity to obtain sustained institutional and financial support to develop seafood enterprises.
Indirect	• New seafood enterprises have contributed to diversify the local economy, creating new sources of income for the entire province of Galapagos.

5.3.3 Activities description

Approximately, 70% of Galapagos residents planned to keep their new seafood consumption patterns after the lockdown, including the same suppliers and information channels (Castrejón et al., in prep.). This creates business opportunities to adapt fishers' livelihoods by diversifying markets and products to add value to the seafood supply chain.

Therefore, in order to take advantage of the business opportunities created by the COVID-19 crisis and enhance the adaptive capacity of small-scale fishing sector, we suggest putting in place a participatory process that involves fishers, tourism operators, retailers, intermediaries, chefs, managers, and consumers to define a more sustainable and financially viable seafood system for Galapagos. This new food system will be based on fair and equitable value chains that come from profitable and environmentally friendly SSF (outcome 3.1), as well as from new financially viable business models based on principles of sustainability and social responsibility (outcome 3.2). The successful implementation of the new system will require residents to change their consumption patterns, fishers to adopt responsible fishing practices, and government agencies to adopt cutting-edge technology and effective regulations to reduce IUU fishing and marine pollution.

To this end, Castrejón et al (in prep) suggest putting in place several actions to help reactivate the economy and adaptive capacity of Galapagos coastal communities. These include (a) increasing the consumption of pelagic species, like tuna, rather than demersal species with signs of overexploitation (e.g. sailfin grouper); (b) support the development of sustainable and socially responsible seafood enterprises, which will help to improve food security by reducing reliance on imported food; (c) improving monitoring, traceability, and trading of fisheries with state-of-the-art technology to reduce IUU fishing and promote fair trade, and, finally, (d) promoting a blue circular economy to diversify products and markets, reduce waste and add value to the small-scale fisheries. These actions will enable conditions for the development of a new seafood system that is sustainable, equitable and financially viable and enhances the adaptive capacity of Galapagos against climate change and other future crises.

It is important to highlight that during 2020 the World Bank, in collaboration with the Charles Darwin Foundation and Conservation International, will put in place a one-year project called "Ecuador Coastal Fisheries Initiative Challenge Fund". The objective of this project is to provide technical assistance to the Government of Ecuador to develop a new "seafood system vision" for Galapagos and a set of "prototypes[4]" to implement such vision. A seafood system comprising fair and equitable value chains from a wide diversity of small-scale fisheries, investable enterprises, and holding to key principles of sustainable seafood, depends upon a myriad of behaviors from multiple actors - from consumers changing their diets and fishers adopting sustainable fishing practices, to public sector agencies developing and enforcing effective regulations to curtail overfishing and illegal practices.

The goal of prototypes is to help reactivate the economy and the resilience-adaptive capacity of Galapagos coastal communities by supporting the development of sustainable and socially responsible seafood enterprises. These enterprises will help to improve food security by reducing reliance on imported food, with buy-in from the local community and the tourism sector, and will diversify products and markets, improving the monitoring and traceability of fisheries, reduce IUU fishing, and promote fair trade.

The fisheries component of the GCF has been elaborated to create strong synergies with the Challenge Fund project to ensure the scalability, replicability, and impact of both initiatives. The Challenge Fund will provide the technical assistance needed to make seafood enterprises (prototypes) investable, while the GCF will provide soft loans required for such enterprises to consolidate their development and ensure their success, according to the new Galapagos seafood vision that will be defined thanks to technical support provided by the Challenge Fund project.

To this end, this EBA proposes the creation of a Blue Incentives Program, whose main objective is to promote a blue circular economy through the financial inclusion of fishers and entrepreneurs from civil society interested in adopting sustainable fishing practices, in exchange for receiving financing for the development of enterprises with principles of sustainability and social responsibility. The intention is to provide soft loans, through the GCF or other financial entities, to those enterprises that show bankable business plans or investment prospectus, which would be developed or consolidated with technical assistance provided by the GCF, through a "Galapagos Virtual Innovation Lab". Both

[4] A prototype can be defined as an alternative seafood system that stakeholders are seeking to establish. It can represent a new seafood product, business model, value chain, among other possibilities

outcomes of this EBA are complementary and will contribute to improve the productivity, competitiveness and social inclusion of Galapagos small-scale fishers and entrepreneurs in the financial system, based on criteria of sustainability and social responsibility. In the next sections, both initiatives are described in detail, together with the outcomes, outputs associated to their implementation.

Activity 3.1: Promotion of a blue circular economy through new sustainable and social responsible seafood enterprises

Previous projects and consultancies have failed in their effort to improve the management and marketing system of Galapagos small-scale fisheries because technical assistance and capacity building processes have been short-term, uncoordinated, and without adequate and sustained institutional and financial support to ensure the creation of necessary enabling conditions, to take advantage of the business opportunities offered by the Galapagos small-scale fisheries (Castrejón et al. 2019)

In response to this problem, this outcome proposes the creation of the "Galapagos Virtual Innovation Lab", hereafter the G-Lab, to support small-scale fishers, entrepreneurs, and other actors of the local community interested in enterprise development (e.g., farmers). The G-Lab represents the methodological, operational, and institutional framework required for the creation of an inter-institutional and interdisciplinary platform that integrates and coordinates the governmental and non-governmental programs and projects for the promotion and development of sustainable fisheries.

The main objective of the G-Lab is to provide long-term capacity building, knowledge sharing, and technical advice to fishers, cooperatives, associations, seafood companies, and civil society entrepreneurs, in aspects related to social innovation for sustainable development and circular economy, such as:

- Design and development of ventures or start-ups.
- Transfer of technology and innovation.
- Development of business models.
- Development of fishery products with added value.
- Design of marketing strategies.

- Promote responsible fishing practices.
- Adoption of adequate harvest and post-harvest techniques to improve and keep seafood quality.
- Fishery Improvement Projects (FIP).
- Fisheries certification by the Marine Stewardship Council (MSC) or other programs (e.g., Fair Trade).
- Organizational strengthening and business capacity, among others.

The G-Lab represents one of the key intervention strategies agreed upon by GNPD and 13 governmental and non-governmental organizations, including WWF and small-scale fishing sector, to maximize the economic value of the Galapagos tuna fishery and minimize its ecological impact (Viteri et al. 2018; Castrejón et al. 2019). Therefore, this ongoing participatory process represents an opportunity to create a more sustainable and financially viable seafood system not only for the small-scale tuna fishery but to the entire Galapagos seafood system as a whole.

The G-Lab will be beneficial not only to the small-scale fishing sector but to any person who is interested in the development of sustainable and socially responsible enterprises in Galapagos or other parts of Ecuador. Therefore, though the GCF project, the intention is to create, sustain and enrich the G-Lab to extend its benefits to farmers and other sectors of Galapagos, like tourism.

The G-Lab will have two main components. The first one will be a digital repository that will contain relevant publications, data, information, experiences, and relevant and existing resources of interest. The second one will be an online capacity-building component that will contain online training courses/processes on issues associated with the capacity needs identified to implement the Galapagos seafood system vision and new business models (prototypes). This platform will be created to have the capacity for scalability to potentially cover the needs and capacities of other key sectors to guarantee sustainable development for Galapagos, like agriculture and tourism.

Additional funding will be allocated to provide analytical services, capacity building, knowledge sharing, and facilitation services to fishers and entrepreneurs to make their seafood enterprises investment-ready. This includes technical assistance to selected teams of entrepreneurs to help them to test and refine their business models and to develop a business plan. Each business model will be tested and either accepted, improved, and re-examined, or rejected based on customers' experiences.

The G-Lab will include giving technical assistance to fishers and entrepreneurs to acquire the capacity, skills, equipment, and know-how to be able to sell and export tuna without the participation of intermediaries. A key weakness of the tuna fishery's value chain is that fishers do not know how to grade tuna to determine the quality of their catch before exporting it. As a consequence, they rely on intermediaries to grade the quality of their tuna. Therefore, a proportion of the GCF will be used to hire a tuna grading specialist to help fishers to obtain the capacity to grade the quality of their tunas, which will help them to secure more profits without increasing their current level of catch.

To make seafood enterprises successful, the role of marketing will be fundamental. Therefore, a market analysis and a behavioral insights analysis will be conducted to align the needs of consumers with the capabilities of entrepreneurs to develop a product and a story that sustainably fits these needs. Based on the results of the market analysis and behavioral science analysis, the best distribution channels, price, and markets to sell Galapagos seafood products will be identified, either at the local, national, or international market, to ensure that such products are profitable, operationally feasible and are based on a business model that can be sustained over time.

Finally, and based on the results of the implementation of the G-Lab, the program will support the creation or consolidation of selected local seafood enterprises, based on principles of sustainability and social responsibility. Technical assistance to local fishers and entrepreneurs will be delivered to comply with all technical, legal, organizational and administrative requirements for the creation or consolidation of new seafood enterprises.

At least three business models or prototypes will be promoted: an export seafood enterprise, a value-added seafood enterprise, and a by-product seafood enterprise. They are not mutually-exclusive and can be integrated into a single seafood enterprise. The three prototypes represent innovative and promising alternatives to produce systemic changes into the Galapagos seafood system. A description of each prototype and a financial feasibility analysis for each is presented in the boxes bellow:

Prototype 1. Export seafood enterprise

This is the prototype that has attracted the most attention in the small-scale fishing sector and the one that has been evaluated the most. However, this prototype has not yet been implemented by the local small-scale fishing sector. The most innovative and promising initiative to put in place this type of prototype is the Pelikan Bay Dock Fishing Shipowners Association (aka Armadores' Association), which is proposing to set up the "Galapagos Seafood Company" (GSC), a commercialization company owned by the Armadores' Association which will manage to trade the landings (305.5 t) of a 14-vessel fleet owned by the Association's members. The GSC will mirror the commercial arrangements proposed in the bankable business plan for the Galapagos tuna fishery described by Viteri et al. (2018), which recommends setting up an independent trading company to increase the benefits that fishers obtain from the value chain. The objective of this strategy is to sort out the oligopsony structure of the supply chain, and the weak managing capacity of the current fishing cooperatives. The GSC provides market incentives based upon the quality of the product supplied and alternative mechanisms for redistributing surplus.

The GSC plays an intermediary role in the commercialization of tuna caught by the Armadores' Association. Therefore, its revenues come from its sales done in the international markets, and its costs include the price paid to fishers for their product plus the logistic expenditures to place the product at the international markets. Two important assumptions are considered for estimating the costs and revenues for this company: (1) the GSC is a price taker, meaning this company cannot influence over the price of the product in the market; and (2) the international market can absorb the whole production capacity of the Armadores' Association. Therefore, the GSC reachable market is limited by its capacity to place the product in the international market.

The revenues of the GSC will be dependent on the global price of different tuna grades or quality, and the production breakdown of grades. Table 9 presents the prices for different tuna grades, and the production breakdown of grades, according to data provided by Berman et al. (2018). Based on this information, the revenues of the GSC were estimated.

Table 9 Tuna global market prices. Source: Berman et al. (2018).

Grade	% Overall quality breakdown of tuna	Global market price /lb	Weighted global market price

1	6	9.22	0.5532
2+	15	6.85	1.0275
2	50	4.39	2.195
<3	29	2.93	0.8497
Weighted price for export			**4.6254**

The main cost of the GSC is the ex-vessel price paid to fishers for the tuna. According to Berman et al. (2018), fishers are paid US $1.75 per pound for export quality tuna placed at COPROPAG's processing facilities. A COPROPAG's quality inspector deems if the product meets the quality requirements and accept or reject the product. Fishers do not receive their payment immediately. Instead, they have to wait several days before receiving their payment. Sometimes they receive an extra $0.5 to $1 per pound for their tuna if the buyer's quality inspector at Miami reassesses the quality of the product. According to Berman et al. (2019), grade 1 and grade 2+ are the type of tuna rewarded with the extra cash. Therefore, the GSC's cost structure includes the payment of a quality incentive for grade 1 tuna ($1 extra per pound) and grade 2+ ($0.5 extra per pound). Besides, this analysis considers a redistribution mechanism of the net earnings before taxes of 60% among the Armadores' Association distributed pro-rata by volume sold by them. Table 10 shows a summary of the revenues and costs estimated for the GSC, including the market target assumptions which were estimated according to the Armadores' Association capacity to produce the required tuna export quality.

Table 10. Summary of costs, revenues, market share and capacity use by year.

Items	1	2	3	4	5
Volume					
Exports (Lb)	134 400	268 800	403 200	477 120	477 120
Sales					
Exports US $	714 724	1 429 448	2 144 172	2 537 270	2 537 270
Costs					
Exports US $	454 944	909 888	1 364 832	1 615 051	1 615 051
Sales comission (1% total sales)	13 719	29 721	41 156	45 087	45 087
Operational costs	117 360	129 960	142 560	142 560	142 560

Market Share & capacity use					
Market share (1)	20%	40%	60%	71%	71%
Installed capacity use	20%	40%	60%	71%	71%

(1) Total Market calculated as total installed capacity.

The assumptions considered for estimating the revenues and cost of the GSC are the following:

- Market share calculated based on installed capacity. Ranges from 20% on 1st year to 71% on 5th year.
- 71% equals the share of landings that corresponds to export quality grade of tuna (1,2+, and 2).
- Tuna's weighted price: US$ 5.32 per lb
- Price paid to fishers per pound of tuna: US$ 1.75
- Eco packing and national-international freight: US$ 1.5 per lb.
- Quality incentive (paid extra to fishers): Grade 1 US$1 per lb; Grade 2+ US$0.5 per lb.
- Work force: manager (1), quality and seller (1), operations (2). Employees in operations increases to four on month 19th due to production growth.
- Lending interest rate paid over loan 8.53% per year.

The cash flow analysis, built on the cost structure and revenues projections, suggest that the GSC will be a profitable investment as the IRR equals 79%, the net present value (NPV) is positive reaching US$ 912 320; and the recovery of investment is just 21 months (Table 11). Such analysis was run for a period of five years and considers an investment of US$ 208 681 which includes working capital and investments on training and office equipment. These results are very auspicious considering the conservative assumptions regarding market target projections.

Table 11. Cash flow and profitability analysis for the GSC.

Total USD	**1**	**2**	**3**	**4**	**5**
Revenues	714 724	1 429 448	2 144 172	2 537 270	2 537 270
Direct Costs	-454 944	-909 888	-1 364 832	-1 615 051	-1 615 051
Sales comission (1% total sales)	-7 147	-14 294	-21 442	-25 373	-25 373
Variable Margin	252 633	505 266	757 898	896 846	896 846

Salaries	-100 800	-113 400	-126 000	-126 000	-126 000
Other Costs	-16 560	-16 560	-16 560	-16 560	-16 560
EBIT	135 273	375 306	615 338	754 286	754 286
Interest	-16 169	-12 609	-9 049	5 488	1 928
EBT	254 377	738 003	1 221 628	1 514 061	1 510 501
Bonus (60% EBT distributed among fishers who supplied to the GSC)	-152 626	-442 802	-732 977	-908 437	-906 301
Tax (25%)	-25 438	-73 800	-122 163	-151 406	-151 050
Workers share of earnings (15%)	-11 447	-33 210	-54 973	-68 133	-67 973
Net Earnings	64 866	188 191	311 515	386 086	385 178
Initial Investment	-208 681				
NPV	912 320				
Investment recovery (Months)	21.08				
IRR (5 Years)	79%				

The GSC will produce benefits to the fishers who supply the fish to the enterprise, and to the enterprise's employees. Furthermore, the company will be able to pay a market-condition loan (8.5% annual interest), which will be used for investing on basic equipment and working capital. The assumptions under this company are profitable are very conservative. For example the use of the GSC's production capacity that equals the landing capacity of the Armadores' Association, grows at slow pace and never reaches 100%. It starts at 20% and reaches to 71% in the fourth year. It also includes benefits for fishers supplying to the GSC such as quality incentives, and a 60% of the company's earnings before taxes bonus granted to the fishers.

The sensitivity analysis shows that the investment profitability of the GSC could be vulnerable to a fall of tuna's price below $4 per pound (price assumed for analysis is $5.32 per lb), but it also shows there are very profitable alternative markets such as the local tourism market and the mainland market. For sensitivity analysis and its results see Annex 1.

Prototype 2. Value-added seafood enterprise

The best and only example of this prototype in Galapagos has been “Pescado Azul”. This seafood enterprise was founded in 2001 by a small group of entrepreneurial women from Puerto Villamil, Isabela. It was an initiative supported by USAID, WWF and WildAid (Bigue et al., 2006). The association provided jobs for unemployed women and sustainable economic alternatives for fishers. Pescado Azul produced marketable smoked food products using yellowfin tuna, which was sourced from local fishers who followed fishing rules and regulations. All suppliers had to meet standards of measurement and control relating to catch size and fishing gear to sell their catch to Pescado Azul. Once processed, the value-added products were sold to the tourism sector (cruise ships and restaurants) and local communities. This small-scale company contributed to reduce fishing pressure on overexploited coastal fisheries and advancing an alternative prototype of sustainable development. Unfortunately, administrative and personal issues led to the failure of this prototype around 2008. Since then, no other prototype of this kind has been put in place again. However, new local entrepreneurs are trying to put in place this prototype again in Isabela and Puerto Ayora, Galápagos. According to USFQ (2020) resuming the operations of Pescado Azul will require an investment of US$ 79 124. Such an investment will be spent on new facilities, and brand-new equipment for making the product (smoked-tuna pâté). This value-added enterprise will also require an investment on training and building capacity for about $US 34,196, which is assumed to be delivered as a grant. To figure out the costs structure and revenues for Pescado Azul operations, data were obtained from Bigue et al. (2006). According to this study, Pescado Azul implemented a plan for improving its production process from May 2005 to September 2006 with technical support provided by WildAid and WWF. During this time the company was able upgrade its production process and sales by buying and installing a new oven, and by gaining new customers from the tourism sector. For instance, Bigue et al. (2006) reports Pescado Azul was able to sell an average of 550 lb of smoked-tuna pâté to 12 consumers during 2006, at an average price of 5.5 $/lb. The clients were made up by cruise-ships (5), restaurants (3) and retail stores (4). This information was used to reconstruct the cost structure and revenues of Pescado Azul’s operations during the first year using a price of US$ 8.1/lb. Such a price is the equivalent of 5.5 US$/lb (2006) in dollars as of December 2019. We used the price indexes published by INEC (2020) to transform dollars of 2006 into dollars of 2019. Note this price is about the middle point of the prices found for similar products in the literature. Ochoa (2009) reports a price of 5.33 US$/lb (in 2019 dollars), while Herpac (2020) shows a price of 23.1 US$/lb in its online store.

Sales from 2nd to 5th year were projected considering that on 2nd year the number of customers increased by 50%, on 3rd year by 39%, on 4th year by 4% and on 5th year by 7.7%. This growth’s rate double the number of customers on 3rd year. The projection is reasonable as the tourism’s market share served by Pescado Azul ranged from 7%

on 1st year to 20% on 5th year. Regarding the costs, the literature reports that direct production costs of a pound of pâté could range from 57% of the price (Lovo, 2018) to 71% of the price (Ochoa, 2009). The financial feasibility analysis expects that after the training and capacity building process Pescado Azul could reach a point of efficiency where their direct cost is 57% of its price. The cost structure also includes operational costs reported by USFQ (2020) and a sales commission of 1% over sales. Table 12 shows a summary of the sales, revenues, costs and market share projections. The main Pescado Azul revenues and costs' assumptions are the following:

- Market share rate of growth. 2nd year: 50%; 3rd year 39%; 4th year: 4%; 5th: 7.7%.
- The number of customers increase from 12 on the 1st year to 28 on the 5th year.
- The increase of customers only happen ion the tourism sector.
- The number of retail stores remain constant (four in total).
- Price: US$8.1
- Cost as % of price: 57% (Lovo, 2018).
- Operational costs include: manager / sales person (1).
- Direct labor: 10 partners.
- Lending interest rate paid over loan: 8.53% per year.

Table 12. Pescado Azul's summary of costs, revenues, and market share by year.

Items	1	2	3	4	5
Volume					
Pâté (Lb)	6 600	9 900	13 750	14 300	15 400
Sales					
Pâté ($)	53 764	80 646	112 008	116 489	125 449
Costs					
Direct cost of pâté production	30 746	46 119	64 055	66 617	71 741
Sales commission (1% total sales)	538	806	1 120	1 165	1 254
Operational costs	6 636	6 636	6 636	6 636	6 636
Market share & capacity use					
Number of customers	12	18	25	26	28
Tourism market share (%)	7%	12%	18%	19%	20%

Based on a cash flow analysis, built on the cost structure and revenues projections, it was estimated that Pescado Azul will be a profitable investment as the IRR equals 28% in a period of 10 years, the NPV is positive reaching US$ 100 850; and the ROI is 1.27, yielding US$1.27 per each dollar invested (Table 12). The investment could be recovered in 52.1 months and it is possible for Pescado Azul to manage a market condition loan (8.5% interest rate). Although the market share growth projections assumptions are conservative, the results are still favorable allowing to recover the investment in less than five years. Such analysis was run for a period of 10 years and considers an investment of US$ 79 174 in new facilities, training and equipment. According to the sensibility analysis, the profitability of Pescado Azul is quite sensitive to the direct production costs. Therefore, the training and capacity building grants should focus on helping Pescado Azul to gain efficiency in its production process. For sensibility analysis and its results see Annex 1.

Table 13. Pescado Azul's cash flow and profitability analysis.

Total USD	1	2	3	4	5
Revenues	53 764	80 646	112 008	116 489	125 449
Direct costs	-30 746	-46 119	-64 055	-66 617	-71 741
Sales comission (1% total sales)	-538	-806	-1,120	-1,165	-1,254
Variable margin	22 480	33 720	46 833	48 707	52 453
Salaries	-6 636	-6 636	-6 636	-6 636	-6 636
Other costs	0	0	0	0	0
EBIT	15 844	27 084	40 198	42 071	45 818
Interest	-6 134	-4 784	-3 433	-2 082	-732
EBT	9 710	22 300	36 765	39 989	45 086
Tax (25%)	-2 427	-5 575	-9 191	-9 997	-11 271
Workers share of earnings (15%)	-1 092	-2 509	-4 136	-4 499	-5 072
Net earnings	6 190	14 217	23 437	25 493	28 742
Initial investment	-79 174				
NPV (10 years)	100 856				

Investment recovery (months)	52.11	
IRR (10 Years)	28%	
ROI (10 year)	1.27	

Prototype3. By-products seafood enterprise
This is the less explored prototype, but the most promising to promote a circular economy and contribute to the mitigation of climate change by reducing greenhouse gases. For example, fish waste (bones, heads and viscera) could be used to reduce agrochemical fertilizers in Galapagos. The extensive use of agrochemicals to increase harvest, reduce production cost and meet a growing demand of food by tourist and local population is potentially leading to degradation of Galapagos native and endemic terrestrial biodiversity and valuable ecosystem services, including freshwater provision in catchment areas and carbon storage. In response, organic agriculture is being promoted by the Ecuadorian government to increase local food production without using environmentally harmful fertilizers, and to decrease the risk of accidentally introducing new invasive species by reducing the heavy reliance of Galapagos on food imports from the continent. To achieve these two objectives, alternative cost-effective methods of agricultural production are required to create economic incentives that promote the adoption of sustainable agricultural practices. One innovative and promising option is the production of organic fertilizers by using fish waste. It is estimated that 2.2 t of fish waste is generated every week in Puerto Ayora, Galápagos, consisting primarily of fish skin and bones. Once the fish are processed, fish waste is entirely treated as garbage and trucked off to the landfill for disposal. This disposal requirement poses significant environmental and public health threats to vulnerable archipelago ecosystems and communities. However, it also represents a cost burden for fishers and municipalities, and most importantly it ignores the fact that fish waste is a valuable raw material for organic fertilizers that could be turned into an income stream and become an important factor in contributing to the sustainability of Galapagos food production.

Activity 3.2: Long-term financing mechanism in place to improve sustainability and competitiveness of Galapagos small-scale fishing sector.

One of the main challenges to improve the productivity, sustainability and competitiveness of Galapagos small-scale fishing sector is obtaining long-term financing. To meet this objective, capital is required from several funding sources (i.e., public, philanthropic and private) willing to invest in actions that contribute to improving the profitability of fisheries with principles of sustainability and social responsibility. This could include investments to: (1) improve monitoring programs for target and incidental species, (2) prevent or mitigate ecological impacts produced by fishing activities, (3) implement marketing and marketing-strategies to improve quality and add value to fishery resources, (4) promote fair, equitable trade, and respect of human rights, and (5) comprehensively improve the governance of fisheries through various regulatory actions. Unfortunately, the government budget to invest in all these activities is quite limited.

Consequently, a new management and development approach is required, whose long-term financing is generated through public-private partnerships. For this, the establishment of a soft credit line for entrepreneurs is proposed, whose objective is the financial inclusion of fishers and entrepreneurs from civil society interested in adopting sustainable fishing practices in exchange for receiving financing for the development of ventures with principles in sustainability and social responsibility that help improve the productivity, competitiveness and social inclusion of fishers in the financial system. The intention is to provide soft loans, through existing credit or financial entity based on Galapagos (i.e., credit unions aka “cooperativas de ahorro y credito” or BanEcuador), to those companies or individuals that show an attractive investment plan, which would be developed with technical assistance provided by the G-Lab described in the previous section.

The intention of the Blue Incentives Program is that the G-Lab, in collaboration with the competent government authorities, announce an annual call to inform that there is financing to invest in seafood enterprises that are sustainable, equitable, financially viable and socially responsible. Through this call, it would be expected to receive various requests for the creation, strengthening or expansion of various types of enterprises or companies.

With the help of an interdisciplinary group of specialists in fisheries, business administration, and enterprise development, the most attractive proposals will be chosen. The selected proposals would receive technical advice from the G-Lab to develop their respective business plans, or market studies, to determine the financial feasibility of success of the business model proposed. Through a selection process, those entrepreneurs who submit the most attractive, innovative business plans and with the greatest probability of generating a positive social and environmental impact would receive soft credits, through the Blue Incentive Program. In this way, it is expected that the G-Lab and the Blue Incentives Program will contribute to improving the productivity and competitiveness of the Galapagos small-scale fishing sector through the principles of a blue and circular economy.

The blue economy promotes the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health. Similarly, a circular economy promotes shifting from a linear take-do-throw-away model to one that keeps products and materials in circulation for as long as possible, minimizing the use of resources and the generation of waste, and reusing products when they reach the end of its useful life to generate more value.

Based on the business plan prepared by Viteri et al. (2018) to improve the Galapagos tuna fishery, it is estimated that a credit line of US $ 1 000 000 for the fishing sector would generate an internal rate of return of 31%, considering loans for a maximum amount of US $ 40,000 an interest rate of 17% for a term of six years. The estimated return for the social impact investor is 5.25%, while the estimated return for the financial entity responsible for managing the loans would be 8.06%. Finally, the return for fishers or entrepreneurs would be 116% in a period of 10 years (Viteri et al. 2018).

The estimated interest rate suggested by Viteri et al. (2018), although lower than that established by the banks, is not attractive to fishers, who seek lower interest rates. Considering that the GCF is non-refundable, a new financial feasibility analysis was conducted considering a credit line of US $ 750 000 and a lower interest rate between

5% and 8%. The intention is creating long-term financing mechanisms that sustain the impact of the GCF in the long-term.

The financial feasibility analysis of the Blue Incentives Program involved the assessment of the basic cost structure of the financial entity that will administer the soft credit line, and the management of each soft loan by the beneficiaries to guarantee the execution of investments needed to improve their seafood enterprise and for the repayment of the loan.

The cost structure of the financial entity includes the cost of capital; i.e., the interests paid over the capital available for lending (US$ 750 000) at 1% annual interest rate; the operational costs (credit officer, communications and facilities), and provisions to cope with credit risk. Besides, the Blue Incentives Program will generate revenue for the financial entity, represented by the lending interests applied to the soft loans granted to beneficiaries. It is assumed there will be at maximum 25 credit operations of an average amount of US$ 30 000 each. This amount is calculated based upon the investment required to upgrade fish handling facilities and work capital needs. The investment on facilities ($20,000) comprises the purchase of new equipment as a fridge, shelves and a back-up power generator. The work capital ($10,000) is equivalent to 1.7 months of the seafood store's gross revenues. For instance, a soft loan granted to a seafood enterprise will be charged an annual interest rate of 5% over the amount borrowed (Table 14).

Table 14. Financial entity's cost and revenues for managing the Blue Incentives Program.

Items	US$ / year
Income	
Interest produce by small loans (lending rate 5%)	33 203.1
Total income	33 203.1
Expenses	
Principal interest paid (1%)	7 500.0
Local credit agent/advisor (25% of time)	4 800.0
Operative expenditures (office supplies, lease, communications, utilities and transportation)	2 400.0
Default credits (Galápagos default rate: 2%)	10 000.0

Total Expenses	24 700.0
Income - Expenses	8 503.1

The estimated lending interest rate considers the lending interest rate's ceiling set by the Central Bank of Ecuador (aka BCE, acronym in Spanish). As an example, the maximum annual lending interest rate for agriculture and livestock activities is 8.53% (BCE, 2020). On the side of the borrower, the beneficiary commits to adopt responsible fishing practices and trade responsible-sourced fish. It is assumed that such conditions will contribute to upgrade the quality of seafood products, allowing entrepreneurs to charge a 10% premium over their current price.

Then, the financial feasibility analysis evaluated the incremental costs and revenues resulted from the application of the Blue Incentives Program. Table 15 presents the incremental revenues generated by charging a premium over the product, the cost of capital employed to apply better practices for handling the product (interest rate paid over the loan: $30,000 at 5% of annual interest rate), and other incremental costs generated by the application of these practices (i.e. extra consumption of energy). This analysis assumed the seafood enterprise is able to reach to 3% of the target market for fish consumption (1 580 pounds per month) . The target market includes the household's demand for fish plus 50% of local restaurant's demand. Finally, it is assumed that seafood enterprise remain serving their customers with an improved quality. Revenues in Table 7 includes the charging of a 10% premium on tuna and other fish to their current prices (tuna: US$ 2.5 lb; other fish: US$ 3.5 lb).

Table 15. Typical/average seafood store incremental cost and revenues.

Items	Year 1
Incremental revenues from tuna	663.7
Incremental revenues from other fish	5 707.8
Total revenues	6 371.5
Interests	1 362.5
Other incremental costs	720.0

Total Costs	2 082.5
Revenues - Costs	4 289.0

The financial feasibility analysis for the Blue Incentives Program indicates that providing soft credits of US$ 30 000 to small seafood enterprises will result in a profitable investment yielding about 10% of internal rate of return (IRR), a positive investment net present value of US$ 6 779, and a recovery of the investment in less than six years. The allocation of the soft credit is also beneficial for the financial entity that performs it, as the lending interest rate charge to the soft credit will be enough to recover the operational cost and obtain a small gain.

According to the sensitivity analysis, the Blue Incentives Program is only possible if the reimbursable fund's cost is less than 6%, and if the lending interest rate charge to the soft credit is kept around 5%. Both conditions are non-market conditions, as the corporative interest lending rate at which the financial entity will be able to access funds is around 9% per year; and, in the case of small enterprise, the lending interest rate reaches around 25%. Thus, this investment profile matches for a social impact investor or a grant. The sensitivity analysis and its results are presented in Annex 1.

The sub-activities that will be put in place to accomplish the two activities associated to EBA 3 are described in Table 16.

Table 16. Activities and subactivities of EBA 3

EBA 3: Enhanced climate change resilient local value chains to improve Galapagos seafood system access to markets.	
Activities	**Subactivities**
3.1 Promotion of a blue circular economy through new sustainable and social responsible seafood enterprises	3.1.1.Design and develop a G-Lab platform to provide analytical services, capacity building, knowledge sharing and facilitation services to fishers and entrepreneurs to make their seafood enterprises investment-ready.
	3.1.2Conduct a market and behavioral science analysis.

	3.1.3 Provide technical assistance to local fishers and entrepreneurs, to comply with all technical, legal, organizational and administrative requirements for the creation or consolidation of new seafood enterprises
	3.1.4 Train fishers and entrepreneurs on tuna grading and production of seafood value added products.
3.2 Long-term financing mechanism in place to improve sustainability and competitiveness of Galapagos small-scale fishing sector.	3.2.1 Design, establishment and administration of a soft credit line for entrepreneurs interested in adopting sustainable fishing practices.
	3.2.1 Allocate soft loans to those entrepreneurs who submit the most attractive, innovative business plans and with the greatest probability of generating a positive social and environmental impact.
3.3 Socioeconomic monitoring in place to follow-up performance of seafood enterprises and wellbeing of Galapagos small-scale fishing sector.	3.3.1 Steering Committee in place to follow-up implementation of the Blue Incentives Program and G-Lab 3.3.2 Determine the performance of those seafood enterprises supported by the Blue Action Program and G-Lab, and the wellbeing of Galapagos small-scale fishing sector.

5.3.4 Impact on the resilience of the Galapagos marine ecosystems

The implementation of responsible fishing practices thanks to the successful implementation of the C-FIP's action plan, the technical and financial support provided by the G-Lab and Blue Incentives Program, will contribute to reduce the impact of fishery over overexploited, endangered, threatened and protected species, increasing the resilience of Galapagos marine ecosystems.

5.3.5 Description of the species that make up the module

Target species are the same species described in EBA 2 (see section 5.2.4)

6 GLOBAL ENVIRONMENTAL BENEFITS

The Galapagos Islands are worldwide recognized by its particular oceanographic and geological features, which influenced the origin of unique terrestrial and marine ecosystems composed by a high biological endemism. This unique biodiversity hotspot is considered among the most important marine regions of exceptional biodiversity in the world, which makes its conservation of utmost importance to conservation efforts.

Galapagos provides habitat for over 2 900 fish species, aquatic invertebrates, and marine mammals, 20% of which are endemic (Schiller et al. 2014). Such features inspired the naturalist Charles Darwin to conceive his famed theory of evolution by natural selection following his visit in 1835, and were the responsible of the designation of the Galapagos Islands as World Heritage site by UNESCO in 1978.

However, Galapagos marine ecosystems also provide important services to humans at regional and global levels. Scientific evidence suggest that the creation of the GMR has contributed to increase the productivity of yellowfin tuna and skipjack tuna around Galapagos through a spill over effect (Bucaram et al. 2018). As tuna are highly migratory species, the GMR contributes to the economy and food security of Ecuador and the rest of countries from the ETP, including Panama, Costa Rica and Colombia by enhancing the productivity and sustainability of tuna fisheries.

There is also scientific evidence, that several of the species that are protected within the GMR travel between the Galapagos, Cocos, Malpelo, and Coiba islands through "swimways"; that is, transboundary underwater corridors used by migratory species, such as sharks, sea turtles and whales that migrate along the ETP (Ketchum et al. 2014; Nasar et al. 2016; Peñaherrera-Palma et al. 2018). The GMR contributes to the conservation of endangered, threatened and protected species, such as hammerhead shark (*Sphyrna lewinni*), whale shark (*Rhincodon typus*), silky shark (*Carcharhinus falciformis*), hawksbill turtle (*Eretmochelis imbricata*), green turtle (*Chelonia mydas*) and sperm whale (*Physeter macrocephalus*). All these species are important for the tourism industry. Therefore, the GMR also contribute to the economy of Ecuador and countries of the ETP through the protection of those species that, in turn, attract tourists to the Galapagos, Cocos, Malpelo, and Coiba.

Furhtermore, the GMR also contributes through global carbon storage services. According to Tanner et al. (2019), approximately 778 000 tons of carbon are stored in Galapagos mangroves, with mean belowground carbon being 211.03 ± 179.65 Mg C/ha, valued at US$2 940/ha or US$22 838/ha depending on the valuation methodology. This study also estimated the value of mangroves for the local finfish fishery, being the net benefit of $US 245 ha^{-1}, while the value of mangrove-based recreation was estimated at US$16 958/ha, contributing US$62 million to the tourism industry.

7 SOCIAL BENEFITS FOR LOCAL ISLAND COMMUNITIES

The improvement, effective implementation and enforcement of the new Galapagos zoning will promote the recovery of overfished commercial species and degraded critical habitats and marine ecosystems, in climate change scenarios. As fishing is one of the most important services provided by Galapagos marine ecosystems to humans, increasing the effectiveness and adaptive co-management of the new Galapagos marine zoning as fishery management and marine biodiversity conservation tool will contribute to sustain SSF, conserve marine biodiversity, and support human wellbeing into the future. In addition, the reconciliation of fishery and conservation objectives will improve the acceptability, legitimacy, and compliance of what could be a valuable tool to ensure the adaptive and precautionary co-management of SSF and to increase the resilience and protection of HEVAS across the GMR.

The recovery of sailfin groupers and sea cucumber stocks will contribute to improve the socioeconomic condition of the small-scale fishing sector and the food security of the Galapagos coastal communities. The potential pharmaceutical and nutraceutical properties of *I. fuscus* represent an opportunity to generate new sources of food and income by developing anticancer, anti-hypertensive, anti-angiogenic, anti-inflammatory, antidiabetic, anti-coagulation, antimicrobial, antioxidation, and anti- osteoclastogenic products. Furthermore, the active involvement of local communities in the co-management of strategically placed TURF could contribute, under certain enabling conditions, to generate a sense of exclusive use and ownership among fishers, promoting the implementation of effective monitoring, control and surveillance procedures, and the accomplishment of objectives for management and conservation (Castrejón and Charles 2020).

Supporting sustainable and more profitable tuna fishing in Galapagos will alleviate pressure on locally threatened species, while expanding market opportunities for local fishers. This will contribute to achieve better food security in the islands by strengthening the local supply chain of high-quality protein. Besides, the reduction of seafood imports will reduce the probability of introduction of new invasive species from mainland Ecuador.

Improvements of on-board and shore-based seafood handling, storage and quality management will improve product quality and increase catch value, enabling potential price premiums for higher quality tuna in local, national and foreign markets.

Finally, the adoption of a circular economy by promoting the utilization of by-products, from processing and reducing waste along the value chain, will contribute to stabilizing the availability of nutritious food and securing income for the Galapagos coastal communities that are directly or indirectly dependent on capture fisheries for their livelihoods. Safeguarding a stable supply of fish and fisheries products will enable the development of stronger social systems and create alternative livelihood options. The adoption of a circular economy will enhance the adaptive capacity of the Galapagos small-scale fishing sector, reduce waste and diversify livelihoods. A circular economy will improve the quality of fishery products, rather than increasing their quantity, through the adoption of innovative and responsible fishing practices, that will help fishers and entrepreneurs to take advantage of the business opportunities offered Galapagos tuna fishery with principles of sustainability and social responsibility.

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9 ANNEX 1. SENSITIVITY ANALYSIS

9.1 Blue Incentives Program

The sensitivity analysis of Blue Incentives Program focused in two aspects: (1) the credit operation run by the financial entity, and (2) the investment done by the typical seafood enterprise. Regarding the financial entity, the sensitivity analysis evaluated the effect of two key variables over the break-even number of credit operations, and the surplus obtained when the financial entity is able to place the whole capital available for lending. These variables are: (i) the cost of capital or interest rate paid by the financial entity; and, (ii) the interest rate paid by the seafood enterprise for the loan borrowed.

Table 1 shows a matrix where its columns represent the variation of the interest rate paid by the financial entity, while the rows present the variation of interest rate paid by the seafood enterprise. The crossing cell of a row and a column displays the number of credit operations the financial entity need to place in order to cover its operational costs, or the break-even point. For instance, if the financial entity pays 6% of interest over the capital used for lending and charges an annual rate of 10 % of interest on the loans lent to its clients, it should place at least 23 credits or loans to cover its operational costs. There is an area marked within the matrix, it highlights an area where is desirable to operate. It does not go beyond 10% on the interest rate over loans, and does not surpass 6% on the interest rate paid by the financial institution over the capital use to run its credit product.

Table 2 presents the same matrix as before composed by columns representing the interest rate paid by the financial entity, and rows representing the interest paid over the loan by the seafood store/intermediary, but the matrix's cells deliver the potential gross profits or losses the financial entity will have if it places the whole capital on credit operations. For instance, if the financial entity pays 6% of interest over the capital, and charges 10% of interest over the loans granted, it will get a gross profit of US$4,206 per year if it is able to place all the capital for lending on credits (25 credits). This table also highlights a desirable area of the matrix where the financial entity could be operating and obtaining a surplus considering it will not be desirable to charge beyond 10% of annual interest rate on the loans granted.

Table 1. Number of credits break-even point sensitivity analysis.

Interest Rate Paid by a typical seafood store	Interest Rate paid by the Local Financial Entity 0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%
1%	65	93	121	149	178	206	234	262	291	319	347	375	404
2%	32	46	61	75	89	103	117	131	145	159	174	188	202
3%	22	31	40	50	59	69	78	87	97	106	116	125	135
4%	16	23	30	37	44	51	59	66	73	80	87	94	101
5%	13	19	24	30	36	41	47	52	58	64	69	75	81
6%	11	15	20	25	30	34	39	44	48	53	58	63	67
7%	9	13	17	21	25	29	33	37	42	46	50	54	58
8%	8	12	15	19	22	26	29	33	36	40	43	47	50
9%	7	10	13	17	20	23	26	29	32	35	39	42	45
10%	6	9	12	15	18	21	23	26	29	32	35	38	40
11%	6	8	11	14	16	19	21	24	26	29	32	34	37
12%	5	8	10	12	15	17	20	22	24	27	29	31	34
13%	5	7	9	11	14	16	18	20	22	25	27	29	31
14%	5	7	9	11	13	15	17	19	21	23	25	27	29
15%	4	6	8	10	12	14	16	17	19	21	23	25	27
16%	4	6	8	9	11	13	15	16	18	20	22	23	25
17%	4	5	7	9	10	12	14	15	17	19	20	22	24
18%	4	5	7	8	10	11	13	15	16	18	19	21	22
19%	3	5	6	8	9	11	12	14	15	17	18	20	21
20%	3	5	6	7	9	10	12	13	15	16	17	19	20
21%	3	4	6	7	8	10	11	12	14	15	17	18	19
22%	3	4	6	7	8	9	11	12	13	14	16	17	18
23%	3	4	5	6	8	9	10	11	13	14	15	16	18
24%	3	4	5	6	7	9	10	11	12	13	14	16	17
25%	3	4	5	6	7	8	9	10	12	13	14	15	16
26%	2	4	5	6	7	8	9	10	11	12	13	14	16
27%	2	3	4	6	7	8	9	10	11	12	13	14	15

Table 2. Potential gross profits/losses per year (US$).

Interest Rate Paid by a typical seafood store	Interest Rate paid by the Local Financial Entity 0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%
1%	$ (10,559)	$ (18,059)	$ (25,559)	$ (33,059)	$ (40,559)	$ (48,059)	$ (55,559)	$ (63,059)	$ (70,559)	$ (78,059)	$ (85,559)	$ (93,059)	$ (100,559)
2%	$ (3,919)	$ (11,419)	$ (18,919)	$ (26,419)	$ (33,919)	$ (41,419)	$ (48,919)	$ (56,419)	$ (63,919)	$ (71,419)	$ (78,919)	$ (86,419)	$ (93,919)
3%	$ 2,722	$ (4,778)	$ (12,278)	$ (19,778)	$ (27,278)	$ (34,778)	$ (42,278)	$ (49,778)	$ (57,278)	$ (64,778)	$ (72,278)	$ (79,778)	$ (87,278)
4%	$ 9,363	$ 1,863	$ (5,638)	$ (13,138)	$ (20,638)	$ (28,138)	$ (35,638)	$ (43,138)	$ (50,638)	$ (58,138)	$ (65,638)	$ (73,138)	$ (80,638)
5%	$ 16,003	$ 8,503	$ 1,003	$ (6,497)	$ (13,997)	$ (21,497)	$ (28,997)	$ (36,497)	$ (43,997)	$ (51,497)	$ (58,997)	$ (66,497)	$ (73,997)
6%	$ 22,644	$ 15,144	$ 7,644	$ 144	$ (7,356)	$ (14,856)	$ (22,356)	$ (29,856)	$ (37,356)	$ (44,856)	$ (52,356)	$ (59,856)	$ (67,356)
7%	$ 29,284	$ 21,784	$ 14,284	$ 6,784	$ (716)	$ (8,216)	$ (15,716)	$ (23,216)	$ (30,716)	$ (38,216)	$ (45,716)	$ (53,216)	$ (60,716)
8%	$ 35,925	$ 28,425	$ 20,925	$ 13,425	$ 5,925	$ (1,575)	$ (9,075)	$ (16,575)	$ (24,075)	$ (31,575)	$ (39,075)	$ (46,575)	$ (54,075)
9%	$ 42,566	$ 35,066	$ 27,566	$ 20,066	$ 12,566	$ 5,066	$ (2,434)	$ (9,934)	$ (17,434)	$ (24,934)	$ (32,434)	$ (39,934)	$ (47,434)
10%	$ 49,206	$ 41,706	$ 34,206	$ 26,706	$ 19,206	$ 11,706	$ 4,206	$ (3,294)	$ (10,794)	$ (18,294)	$ (25,794)	$ (33,294)	$ (40,794)
11%	$ 55,847	$ 48,347	$ 40,847	$ 33,347	$ 25,847	$ 18,347	$ 10,847	$ 3,347	$ (4,153)	$ (11,653)	$ (19,153)	$ (26,653)	$ (34,153)
12%	$ 62,488	$ 54,988	$ 47,488	$ 39,988	$ 32,488	$ 24,988	$ 17,488	$ 9,988	$ 2,488	$ (5,013)	$ (12,513)	$ (20,013)	$ (27,513)
13%	$ 69,128	$ 61,628	$ 54,128	$ 46,628	$ 39,128	$ 31,628	$ 24,128	$ 16,628	$ 9,128	$ 1,628	$ (5,872)	$ (13,372)	$ (20,872)
14%	$ 75,769	$ 68,269	$ 60,769	$ 53,269	$ 45,769	$ 38,269	$ 30,769	$ 23,269	$ 15,769	$ 8,269	$ 769	$ (6,731)	$ (14,231)
15%	$ 82,409	$ 74,909	$ 67,409	$ 59,909	$ 52,409	$ 44,909	$ 37,409	$ 29,909	$ 22,409	$ 14,909	$ 7,409	$ (91)	$ (7,591)
16%	$ 89,050	$ 81,550	$ 74,050	$ 66,550	$ 59,050	$ 51,550	$ 44,050	$ 36,550	$ 29,050	$ 21,550	$ 14,050	$ 6,550	$ (950)
17%	$ 95,691	$ 88,191	$ 80,691	$ 73,191	$ 65,691	$ 58,191	$ 50,691	$ 43,191	$ 35,691	$ 28,191	$ 20,691	$ 13,191	$ 5,691
18%	$ 102,331	$ 94,831	$ 87,331	$ 79,831	$ 72,331	$ 64,831	$ 57,331	$ 49,831	$ 42,331	$ 34,831	$ 27,331	$ 19,831	$ 12,331
19%	$ 108,972	$ 101,472	$ 93,972	$ 86,472	$ 78,972	$ 71,472	$ 63,972	$ 56,472	$ 48,972	$ 41,472	$ 33,972	$ 26,472	$ 18,972
20%	$ 115,613	$ 108,113	$ 100,613	$ 93,113	$ 85,613	$ 78,113	$ 70,613	$ 63,113	$ 55,613	$ 48,113	$ 40,613	$ 33,113	$ 25,613
21%	$ 122,253	$ 114,753	$ 107,253	$ 99,753	$ 92,253	$ 84,753	$ 77,253	$ 69,753	$ 62,253	$ 54,753	$ 47,253	$ 39,753	$ 32,253
22%	$ 128,894	$ 121,394	$ 113,894	$ 106,394	$ 98,894	$ 91,394	$ 83,894	$ 76,394	$ 68,894	$ 61,394	$ 53,894	$ 46,394	$ 38,894
23%	$ 135,534	$ 128,034	$ 120,534	$ 113,034	$ 105,534	$ 98,034	$ 90,534	$ 83,034	$ 75,534	$ 68,034	$ 60,534	$ 53,034	$ 45,534
24%	$ 142,175	$ 134,675	$ 127,175	$ 119,675	$ 112,175	$ 104,675	$ 97,175	$ 89,675	$ 82,175	$ 74,675	$ 67,175	$ 59,675	$ 52,175
25%	$ 148,816	$ 141,316	$ 133,816	$ 126,316	$ 118,816	$ 111,316	$ 103,816	$ 96,316	$ 88,816	$ 81,316	$ 73,816	$ 66,316	$ 58,816
26%	$ 155,456	$ 147,956	$ 140,456	$ 132,956	$ 125,456	$ 117,956	$ 110,456	$ 102,956	$ 95,456	$ 87,956	$ 80,456	$ 72,956	$ 65,456
27%	$ 162,097	$ 154,597	$ 147,097	$ 139,597	$ 132,097	$ 124,597	$ 117,097	$ 109,597	$ 102,097	$ 94,597	$ 87,097	$ 79,597	$ 72,097

*: The referential maximun lending annual interest rates for October 2020 vary from 4.99% for social-housing uo to 30.5% for micro enterprises on retailing. The corporative credit for priority activities on the production and commercial sectors, and for public investment have a maximun lending interest rate of 9.33%. For livestock and agriculture sectorsthe maximun lending interest rate is 8.53% (BCE, 2020). .Source: BCE.2020. Tasas de Interés, Octubre 2020. Accessed on: Octubre 3, 2020. https://contenido.bce.fin.ec/documentos/Estadisticas/SectorMonFin/TasasInteres/Indice.htm.

**: It is assumed the whole fund is used. The credit company places 25 credit operations of US$ 30 000 each.

Regarding the investment made into the seafood enterprise, two variables were evaluated: (i) the market's share attainable by the seafood enterprise; and (ii) the interest rate paid over the loan. Then, it evaluates how changes on these two variables affect the profitability metrics: internal rate of return (IRR), net present value (NPV), return on investment (ROI) and investment recovery (in years) of the seafood enterprise investment (Table 3).

Table 3. Sensitivity analysis of the seafood store investment profitability. IRR: internal rate of return; NPV: net present value; ROI: return on investment.

1. **IRR**

	Market Share						
Interest Rate	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1%	-18%	-8%	0%	7%	13%	18%	23%
2%	-19%	-8%	0%	6%	12%	17%	22%
3%	-20%	-9%	-1%	6%	11%	17%	22%
4%	-21%	-10%	-2%	5%	11%	16%	21%
5%	-22%	-11%	-2%	4%	**10%**	16%	21%
6%	-23%	-11%	-3%	4%	10%	15%	20%
7%	-24%	-12%	-4%	3%	9%	14%	19%
8%	-25%	-13%	-4%	2%	8%	14%	19%
9%	-25%	-14%	-5%	2%	8%	13%	18%
10%	-26%	-14%	-6%	1%	7%	13%	18%
11%	-27%	-15%	-6%	1%	7%	12%	17%
12%	-28%	-16%	-7%	0%	6%	11%	16%
13%	-29%	-16%	-8%	-1%	5%	11%	16%
14%	-30%	-17%	-8%	-1%	5%	10%	15%
15%	-31%	-18%	-9%	-2%	4%	10%	15%
16%	-32%	-19%	-10%	-2%	4%	9%	14%
17%	-33%	-19%	-10%	-3%	3%	9%	14%
18%	-34%	-20%	-11%	-4%	3%	8%	13%
19%	-35%	-21%	-11%	-4%	2%	8%	13%
20%	-36%	-21%	-12%	-5%	1%	7%	12%

2. **NPV**

	Market Share						
Interest Rate	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1%	-$20,574	-$12,964	-$5,355	$2,255	$9,865	$17,475	$25,085
2%	-$21,346	-$13,736	-$6,126	$1,484	$9,093	$16,703	$24,313
3%	-$22,117	-$14,508	-$6,898	$712	$8,322	$15,932	$23,542
4%	-$22,889	-$15,279	-$7,669	-$59	$7,550	$15,160	$22,770
5%	-$23,661	-$16,051	-$8,441	-$831	**$6,779**	$14,389	$21,998
6%	-$24,432	-$16,822	-$9,212	-$1,603	$6,007	$13,617	$21,227
7%	-$25,204	-$17,594	-$9,984	-$2,374	$5,236	$12,845	$20,455
8%	-$25,975	-$18,365	-$10,756	-$3,146	$4,464	$12,074	$19,684
9%	-$26,747	-$19,137	-$11,527	-$3,917	$3,693	$11,302	$18,912
10%	-$27,518	-$19,909	-$12,299	-$4,689	$2,921	$10,531	$18,141
11%	-$28,290	-$20,680	-$13,070	-$5,460	$2,149	$9,759	$17,369
12%	-$29,061	-$21,452	-$13,842	-$6,232	$1,378	$8,988	$16,597
13%	-$29,833	-$22,223	-$14,613	-$7,004	$606	$8,216	$15,826
14%	-$30,605	-$22,995	-$15,385	-$7,775	-$165	$7,445	$15,054
15%	-$31,376	-$23,766	-$16,157	-$8,547	-$937	$6,673	$14,283
16%	-$32,148	-$24,538	-$16,928	-$9,318	-$1,708	$5,901	$13,511
17%	-$32,919	-$25,309	-$17,700	-$10,090	-$2,480	$5,130	$12,740
18%	-$33,691	-$26,081	-$18,471	-$10,861	-$3,252	$4,358	$11,968
19%	-$34,462	-$26,853	-$19,243	-$11,633	-$4,023	$3,587	$11,197
20%	-$35,234	-$27,624	-$20,014	-$12,405	-$4,795	$2,815	$10,425

3. **ROI**

	Market Share						
Interest Rate	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1%	(0.69)	(0.43)	(0.18)	0.08	0.33	0.58	0.84
2%	(0.71)	(0.46)	(0.20)	0.05	0.30	0.56	0.81
3%	(0.74)	(0.48)	(0.23)	0.02	0.28	0.53	0.78
4%	(0.76)	(0.51)	(0.26)	(0.00)	0.25	0.51	0.76
5%	(0.79)	(0.54)	(0.28)	(0.03)	**0.23**	0.48	0.73
6%	(0.81)	(0.56)	(0.31)	(0.05)	0.20	0.45	0.71
7%	(0.84)	(0.59)	(0.33)	(0.08)	0.17	0.43	0.68
8%	(0.87)	(0.61)	(0.36)	(0.10)	0.15	0.40	0.66
9%	(0.89)	(0.64)	(0.38)	(0.13)	0.12	0.38	0.63
10%	(0.92)	(0.66)	(0.41)	(0.16)	0.10	0.35	0.60
11%	(0.94)	(0.69)	(0.44)	(0.18)	0.07	0.33	0.58
12%	(0.97)	(0.72)	(0.46)	(0.21)	0.05	0.30	0.55
13%	(0.99)	(0.74)	(0.49)	(0.23)	0.02	0.27	0.53
14%	(1.02)	(0.77)	(0.51)	(0.26)	(0.01)	0.25	0.50
15%	(1.05)	(0.79)	(0.54)	(0.28)	(0.03)	0.22	0.48
16%	(1.07)	(0.82)	(0.56)	(0.31)	(0.06)	0.20	0.45
17%	(1.10)	(0.84)	(0.59)	(0.34)	(0.08)	0.17	0.42
18%	(1.12)	(0.87)	(0.62)	(0.36)	(0.11)	0.15	0.40
19%	(1.15)	(0.90)	(0.64)	(0.39)	(0.13)	0.12	0.37
20%	(1.17)	(0.92)	(0.67)	(0.41)	(0.16)	0.09	0.35

4. **Investment Recovery (# of Years)**

	Market Share						
Interest Rate	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1%	9.61	9.15	8.46	6.53	5.32	4.49	3.89
2%	9.65	9.17	8.70	6.70	5.45	4.60	3.98
3%	9.70	9.19	8.95	6.87	5.58	4.71	4.07
4%	9.75	9.21	9.01	7.05	5.72	4.82	4.16
5%	9.80	9.23	9.02	7.22	**5.85**	4.93	4.26
6%	9.86	9.26	9.04	7.41	5.99	5.04	4.35
7%	9.91	9.28	9.05	7.59	6.13	5.15	4.44
8%	9.97	9.30	9.06	7.78	6.27	5.26	4.54
9%	9.00	9.33	9.08	7.96	6.42	5.38	4.63
10%	9.00	9.35	9.09	8.16	6.56	5.49	4.73
11%	9.00	9.38	9.10	8.35	6.71	5.61	4.83
12%	9.00	9.40	9.12	8.55	6.86	5.73	4.92
13%	9.00	9.43	9.13	8.75	7.01	5.85	5.02
14%	9.00	9.45	9.15	8.95	7.16	5.97	5.12
15%	9.00	9.48	9.16	9.01	7.31	6.09	5.22
16%	9.00	9.51	9.18	9.02	7.47	6.21	5.32
17%	9.00	9.54	9.20	9.03	7.62	6.34	5.43
18%	9.00	9.57	9.21	9.04	7.78	6.46	5.53
19%	9.00	9.60	9.23	9.05	7.94	6.59	5.63
20%	9.00	9.64	9.25	9.06	8.11	6.72	5.74

*: NPV is calculated using a 5% rate of discount. The investment and loan equal to US$30 000, and the IRR is evaluated over a period of 9 years.

The first panel of Table 3 shows how IRR varies due to changes on the market share attained by the seafood enterprise and the interest rate paid for its loan. For instance, if the seafood store gets a market share of 3% and pays an interest rate over its loan of 5% then the profitability of its investment (IRR) is 10%. The second panel of Table 3 presents how NPV is affected by variations on the market share and interest rate. The third panel shows how the ROI is affected by these variables, and the fourth panel indicates the effect of the market share and interest rate variation on the number of years needed to recover the investment. The main conclusion of these analysis is that as long the seafood enterprise can obtain a greater market share and pay a small interest rate over its loan, the profitability of its investment will be higher.

A further analysis was performed to evaluate the sensitivity of the investment profitability to the product's premium, and the interest rate paid over the loan. The range of variation of the premium ranges from 5% to 20%. According to Berman et al. (2018), a premium of 20% is already applied by the program EcoGourmet; this is a program run by Conservation International Colombia to promote the commercialization of responsible sourced fish in restaurants in the main cities of Colombia.

Table 4 shows the results of this analysis presenting two metrics: IRR and the investment recovery. The main conclusion of the analysis is that profitability increases when the premium grows, IRR increases up to 40% if premium could reach 20%. The previous conclusion on table 3 also holds, that is a small interest rate paid over the loan impacts positively over the profitability of the seafood enterprise investment. Finally, to recover the investment in a shorter period of time the investment's profitability needs to rise, and that can be accomplished either increasing the premium, lowering the interest rate or increasing the market share.

Table 4. Sensitivity analysis of the seafood store investment profitability when premium varies. IRR: internal rate of return; NPV: net present value; ROI: return on investment.

IRR

		Premium (%)						
		5.00	7.50	10.00	12.50	15.00	17.50	20.00
Interest Rate	1%	-8%	4%	13%	21%	28%	34%	40%
	2%	-8%	3%	12%	20%	27%	34%	40%
	3%	-9%	2%	11%	19%	26%	33%	39%
	4%	-10%	2%	11%	19%	26%	32%	39%
	5%	-11%	1%	**10%**	18%	25%	32%	38%
	6%	-11%	0%	10%	18%	25%	31%	37%
	7%	-12%	0%	9%	17%	24%	31%	37%
	8%	-13%	-1%	8%	16%	23%	30%	36%
	9%	-14%	-1%	8%	16%	23%	29%	36%
	10%	-14%	-2%	7%	15%	22%	29%	35%
	11%	-15%	-3%	7%	15%	22%	28%	35%
	12%	-16%	-3%	6%	14%	21%	28%	34%
	13%	-16%	-4%	5%	13%	21%	27%	33%
	14%	-17%	-5%	5%	13%	20%	27%	33%
	15%	-18%	-5%	4%	12%	19%	26%	32%
	16%	-19%	-6%	4%	12%	19%	26%	32%
	17%	-19%	-6%	3%	11%	18%	25%	31%
	18%	-20%	-7%	3%	11%	18%	24%	31%
	19%	-21%	-8%	2%	10%	17%	24%	30%
	20%	-21%	-8%	1%	10%	17%	23%	29%

Investment Recovery (# of Years)

		Premium (%)						
		5.00	7.50	10.00	12.50	15.00	17.50	20.00
Interest Rate	1%	9.15	7.37	5.32	4.17	3.42	2.91	2.52
	2%	9.17	7.57	5.45	4.27	3.50	2.97	2.57
	3%	9.19	7.77	5.58	4.37	3.58	3.03	2.62
	4%	9.21	7.98	5.72	4.47	3.66	3.09	2.67
	5%	9.23	8.19	**5.85**	4.57	3.74	3.15	2.72
	6%	9.26	8.40	5.99	4.67	3.82	3.22	2.77
	7%	9.28	8.62	6.13	4.77	3.90	3.28	2.82
	8%	9.30	8.84	6.27	4.87	3.99	3.35	2.88
	9%	9.33	9.00	6.42	4.98	4.07	3.41	2.93
	10%	9.35	9.01	6.56	5.08	4.15	3.48	2.99
	11%	9.38	9.03	6.71	5.19	4.24	3.55	3.05
	12%	9.40	9.04	6.86	5.30	4.32	3.62	3.11
	13%	9.43	9.05	7.01	5.40	4.40	3.70	3.16
	14%	9.45	9.06	7.16	5.51	4.49	3.77	3.22
	15%	9.48	9.07	7.31	5.62	4.57	3.85	3.28
	16%	9.51	9.09	7.47	5.73	4.66	3.92	3.34
	17%	9.54	9.10	7.62	5.85	4.75	4.00	3.40
	18%	9.57	9.11	7.78	5.96	4.83	4.07	3.47
	19%	9.60	9.13	7.94	6.07	4.92	4.14	3.53
	20%	9.64	9.14	8.11	6.19	5.01	4.22	3.60

*: The market share is kept constant on 3%. NPV is calculated using a 5% rate of discount. The investment and loan equal to US$30 000, and the IRR is evaluated over a period of 9 years.

9.2 Export seafood enterprise

The sensitivity analysis for the Seafood Galapagos Company (SGC) evaluates the impacts over the investment's profitability when two key variables change: the cost of tuna (ex-vessel price paid to fisher), and the export price of tuna. Table 5 shows the effect of changes in these variables over the SGC's profitability metrics: IRR (Panel 1), NPV (Panel 2), ROI (Panel 3) and investment recovery (# of months) (Panel 4).

The impact of changes on these two variables are as expected. An increase of the cost of fish will impact negatively on the investment profitability. For example, a rise of the cost from US$1.75 per pound to US$ 3.25, keeping the export price constant, makes the investment unfeasible as the IRR, NPV and ROI become negative, and the recovery of investment reaches 60 months. A fall in the price for export below $4 per pound, keeping the cost of tuna fixed, will make the investment unprofitable as well.

Table 5. Sensitivity analysis for the GSC. IRR: internal rate of return; NPV: net present value; ROI: return on investment.

1. IRR

Price of Tuna for Export	Cost of Tuna for Export (Paid to fishers, includes incentive for quality)									
	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25
2.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.32	13%	-26%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.82	52%	33%	9%	-28%	N/A	N/A	N/A	N/A	N/A	N/A
4.32	78%	63%	47%	29%	6%	-31%	N/A	N/A	N/A	N/A
4.82	97%	85%	72%	58%	42%	25%	3%	-33%	N/A	N/A
5.32	112%	102%	90%	**79%**	66%	53%	38%	22%	1%	-35%
5.82	125%	116%	106%	95%	85%	74%	62%	49%	35%	19%
6.32	136%	127%	118%	109%	99%	90%	80%	69%	58%	45%
6.82	145%	137%	129%	120%	112%	103%	94%	85%	75%	65%
7.32	153%	146%	138%	130%	122%	114%	106%	98%	89%	80%

2. NPV ($ thousands)

Price of Tuna for Export	Cost of Tuna for Export (Paid to fishers, includes incentive for quality)									
	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25
2.32	$ (666)	$ (856)	$(1,045)	$ (1,235)	$(1,425)	$(1,614)	$(1,804)	$(1,993)	$(2,183)	$(2,372)
2.82	$ (309)	$ (498)	$ (688)	$ (877)	$(1,067)	$(1,256)	$(1,446)	$(1,635)	$(1,825)	$(2,014)
3.32	$ 49	$ (140)	$ (330)	$ (519)	$ (709)	$ (898)	$(1,088)	$(1,277)	$(1,467)	$(1,656)
3.82	$ 407	$ 218	$ 28	$ (161)	$ (351)	$ (540)	$ (730)	$ (919)	$(1,109)	$(1,299)
4.32	$ 765	$ 576	$ 386	$ 197	$ 7	$ (183)	$ (372)	$ (562)	$ (751)	$ (941)
4.82	$ 1,123	$ 933	$ 744	$ 554	$ 365	$ 175	$ (14)	$ (204)	$ (393)	$ (583)
5.32	$ 1,481	$ 1,291	$ 1,102	**$ 912**	$ 723	$ 533	$ 344	$ 154	$ (35)	$ (225)
5.82	$ 1,839	$ 1,649	$ 1,460	$ 1,270	$ 1,081	$ 891	$ 702	$ 512	$ 323	$ 133
6.32	$ 2,197	$ 2,007	$ 1,818	$ 1,628	$ 1,438	$ 1,249	$ 1,059	$ 870	$ 680	$ 491
6.82	$ 2,554	$ 2,365	$ 2,175	$ 1,986	$ 1,796	$ 1,607	$ 1,417	$ 1,228	$ 1,038	$ 849
7.32	$ 2,912	$ 2,723	$ 2,533	$ 2,344	$ 2,154	$ 1,965	$ 1,775	$ 1,586	$ 1,396	$ 1,207

3. ROI

Price of Tuna for Export	Cost of Tuna for Export (Paid to fishers, includes incentive for quality)									
	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25
2.32	(6.2)	(7.9)	(9.7)	(11.4)	(13.2)	(15.0)	(16.7)	(18.5)	(20.2)	(22.0)
2.82	(2.5)	(4.0)	(5.5)	(7.0)	(8.6)	(10.1)	(11.6)	(13.1)	(14.6)	(16.2)
3.32	0.3	(1.0)	(2.3)	(3.7)	(5.0)	(6.3)	(7.7)	(9.0)	(10.4)	(11.7)
3.82	2.6	1.4	0.2	(1.0)	(2.2)	(3.4)	(4.6)	(5.8)	(7.0)	(8.2)
4.32	4.4	3.3	2.2	1.1	0.0	(1.0)	(2.1)	(3.2)	(4.3)	(5.4)
4.82	5.9	4.9	3.9	2.9	1.9	0.9	(0.1)	(1.1)	(2.0)	(3.0)
5.32	7.1	6.2	5.3	**4.4**	3.5	2.6	1.6	0.7	(0.2)	(1.1)
5.82	8.2	7.3	6.5	5.6	4.8	4.0	3.1	2.3	1.4	0.6
6.32	9.1	8.3	7.5	6.7	5.9	5.2	4.4	3.6	2.8	2.0
6.82	9.9	9.1	8.4	7.7	6.9	6.2	5.5	4.7	4.0	3.3
7.32	10.6	9.9	9.2	8.5	7.8	7.1	6.4	5.7	5.1	4.4

4. Investment recovery (Months)

Price of Tuna for Export	Cost of Tuna for Export (Paid to fishers, includes incentive for quality)									
	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25
2.32	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
2.82	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
3.32	47.1	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
3.82	28.1	35.6	50.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
4.32	21.6	25.2	29.5	37.3	53.0	60.0	60.0	60.0	60.0	60.0
4.82	17.7	19.9	23.1	26.3	30.9	39.0	56.1	60.0	60.0	60.0
5.32	15.7	17.0	18.7	**21.1**	24.3	27.4	32.4	40.7	59.3	60.0
5.82	14.5	15.4	16.5	17.8	19.7	22.3	25.2	28.5	33.9	42.4
6.32	13.6	14.3	15.1	16.0	17.2	18.7	20.7	23.5	26.0	29.6
6.82	13.0	13.5	14.1	14.8	15.7	16.7	17.9	19.5	21.7	24.4
7.32	12.5	13.0	13.4	14.0	14.6	15.4	16.2	17.3	18.7	20.4

*: NPV is calculated using a 5% rate of discount. The investment equal to US$208 681, and the IRR is evaluated over a period of 5 years.

Due to the high production capacity of the Armadores' Association, the sensitivity analysis of the SGC includes also two further scenarios that attempt to use this capacity at 100% taking advantage of the local and mainland markets as it is suggested in the business plan presented in Viteri et al. (2019). The first scenario assumes that besides targeting an export market the GSC attempts to reach the restaurant market in Quito and Guayaquil (export-mainland scenario). The other scenario assumes the GSC reaches the export, mainland and local markets (export-mainland-local scenario). The assumptions regarding the size of the target markets and prices are taken from Berman et al. (2018). Table 6 presents how profitability changes in these scenarios. The results indicate that profitability increases in the case GSC serves not just the export market but also the mainland (restaurants) and the local market (restaurants plus cruise-ships).

Table 6. Profitability analysis under different scenarios. IRR: internal rate of return; NPV: net present value.

Scenarios	IRR	NPV ($ thousands)	Investment recovery (# months)
Export-Mainland -Local	132%	2 388.3	13.9
Export- Mainland	86%	1 099.1	19.3
Export (base)	79%	912.3	21.1

An additional analysis was performed to evaluate an export scenario when the activity of fishing tuna is integrated to the GSC, that is fishers will deliver tuna at the GSC to export. Later fishers receive a share of the earnings. This arrangement between the GSC and fishers generates an alternative cost structure where the GSC should finance the cost of fishing which, according to Berman et al. (2019), is US$ 0.5 per pound of tuna. This scenario also considered that the arrangement between GSC and fishers will include a compensation for fishers of 80% of the earnings before taxes. This higher fisher's share on the earnings before taxes is justified by the higher risk fishers are facing. The impacts on the profitability, for instance the IRR under this new scenario is 76%, that is a small reduction of 3 percentual points in relation to the base case; the NPV falls from US$ 912 300 to US$ 825 633, and the investment recovery remain in 21 months.

9.3 Value-added seafood enterprise

The sensitivity analysis for the value-added seafood enterprise evaluated how profitability responds to changes on two key variables: price and cost of the product. Results are presented on Table 7.

The IRR responds negatively to increases of the product costs. For example, a cost over 6.66 US$/lb makes unprofitable the investment at the price at which the project was evaluated: 8.14 US$/lb (IRR: -6%), that also means NPV and ROI becomes negative, and the recovery time jumps to 60 months; that is the investment recovery is at least 5 years. The opposite will occurr if Pescado Azul reduces its production cost, then all profitability metrics will improve.

In the case of changes on the product´s price, as it could be anticipated an increase of the product price will impact positively on the profitability. For instance, an increase of 1 dollar on the price (9.14 US$/lb) will boost the profitability of the project (IRR: 39%), NPV and ROI will jump to $US 166 000 and 2.1 respectively, and the number of months to recover the investment is reduced to 42. In summary, these results suggest the project should concentrate to gain efficiency in their production process in order to reduce their direct production cost and consolidate the profitability of the investment. Upward price changes are not feasible to apply given that the product commercialized by Pescado Azul is a normal good with multiple substitutes, then it has a very elastic price demand elasticity. Therefore, the product's demand will be very sensitive to price changes, making difficult for Pescado Azul to raise the price as an strategy to increase its revenues.

Table 7. Pescado Azul's Sensitivity analysis. RR: internal rate of return; NPV: net present value; ROI: return on investment.

1. IRR

Paté's price ($/lb)	Paté's Cost ($/lb) 2.66	3.66	4.66	5.66	6.66	7.66	8.66	9.66	10.66	11.66	12.66
5.14	15%	-5%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6.14	28%	14%	-5%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7.14	39%	28%	14%	-5%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8.14	48%	39%	28%	14%	-6%	N/A	N/A	N/A	N/A	N/A	N/A
9.14	57%	48%	39%	28%	14%	-6%	N/A	N/A	N/A	N/A	N/A
10.14	65%	57%	48%	39%	28%	14%	-6%	N/A	N/A	N/A	N/A
11.14	72%	65%	57%	48%	39%	27%	14%	-6%	N/A	N/A	N/A
12.14	79%	72%	65%	57%	48%	38%	27%	13%	-7%	N/A	N/A
13.14	86%	79%	72%	65%	57%	48%	38%	27%	13%	-7%	N/A
14.14	93%	86%	79%	72%	65%	57%	48%	38%	27%	13%	-7%
17.14	111%	105%	99%	93%	86%	79%	72%	64%	56%	48%	38%
20.14	129%	123%	117%	111%	105%	99%	92%	86%	79%	72%	64%
23.14	146%	140%	135%	129%	123%	117%	111%	105%	99%	92%	86%

2. NPV

Paté's price ($/lb)	Paté's Cost ($/lb) (Thousand) 2.66	3.66	4.66	5.66	6.66	7.66	8.66	9.66	10.66	11.66	12.66
5.14	$ 37	$ (29)	$ (95)	$ (161)	$ (227)	$ (292)	$ (358)	$ (424)	$ (490)	$ (556)	$ (621)
6.14	$ 102	$ 36	$ (30)	$ (96)	$ (162)	$ (227)	$ (293)	$ (359)	$ (425)	$ (491)	$ (556)
7.14	$ 167	$ 101	$ 35	$ (31)	$ (96)	$ (162)	$ (228)	$ (294)	$ (360)	$ (425)	$ (491)
8.14	$ 232	$ 166	$ 100	$ 35	$ (31)	$ (97)	$ (163)	$ (229)	$ (294)	$ (360)	$ (426)
9.14	$ 297	$ 231	$ 166	$ 100	$ 34	$ (32)	$ (98)	$ (163)	$ (229)	$ (295)	$ (361)
10.14	$ 362	$ 296	$ 231	$ 165	$ 99	$ 33	$ (33)	$ (98)	$ (164)	$ (230)	$ (296)
11.14	$ 427	$ 362	$ 296	$ 230	$ 164	$ 98	$ 33	$ (33)	$ (99)	$ (165)	$ (231)
12.14	$ 493	$ 427	$ 361	$ 295	$ 229	$ 164	$ 98	$ 32	$ (34)	$ (100)	$ (165)
13.14	$ 558	$ 492	$ 426	$ 360	$ 294	$ 229	$ 163	$ 97	$ 31	$ (35)	$ (100)
14.14	$ 623	$ 557	$ 491	$ 425	$ 360	$ 294	$ 228	$ 162	$ 96	$ 31	$ (35)
17.14	$ 818	$ 752	$ 687	$ 621	$ 555	$ 489	$ 423	$ 358	$ 292	$ 226	$ 160
20.14	$ 1,014	$ 948	$ 882	$ 816	$ 750	$ 685	$ 619	$ 553	$ 487	$ 421	$ 356
23.14	$ 1,209	$ 1,143	$ 1,077	$ 1,012	$ 946	$ 880	$ 814	$ 748	$ 683	$ 617	$ 551

3. ROI

Price of Tuna for Export	Paté's Cost ($/lb) 2.66	3.66	4.66	5.66	6.66	7.66	8.66	9.66	10.66	11.66	12.66
5.14	0.5	(0.4)	(1.2)	(2.0)	(2.9)	(3.7)	(4.5)	(5.4)	(6.2)	(7.0)	(7.8)
6.14	1.3	0.5	(0.4)	(1.2)	(2.0)	(2.9)	(3.7)	(4.5)	(5.4)	(6.2)	(7.0)
7.14	2.1	1.3	0.4	(0.4)	(1.2)	(2.0)	(2.9)	(3.7)	(4.5)	(5.4)	(6.2)
8.14	2.9	2.1	1.3	0.4	(0.4)	(1.2)	(2.1)	(2.9)	(3.7)	(4.5)	(5.4)
9.14	3.8	2.9	2.1	1.3	0.4	(0.4)	(1.2)	(2.1)	(2.9)	(3.7)	(4.6)
10.14	4.6	3.7	2.9	2.1	1.3	0.4	(0.4)	(1.2)	(2.1)	(2.9)	(3.7)
11.14	5.4	4.6	3.7	2.9	2.1	1.2	0.4	(0.4)	(1.3)	(2.1)	(2.9)
12.14	6.2	5.4	4.6	3.7	2.9	2.1	1.2	0.4	(0.4)	(1.3)	(2.1)
13.14	7.0	6.2	5.4	4.6	3.7	2.9	2.1	1.2	0.4	(0.4)	(1.3)
14.14	7.9	7.0	6.2	5.4	4.5	3.7	2.9	2.0	1.2	0.4	(0.4)
17.14	10.3	9.5	8.7	7.8	7.0	6.2	5.3	4.5	3.7	2.9	2.0
20.14	12.8	12.0	11.1	10.3	9.5	8.6	7.8	7.0	6.2	5.3	4.5
23.14	15.3	14.4	13.6	12.8	11.9	11.1	10.3	9.5	8.6	7.8	7.0

4. Investment recovery (Months)

Paté's price ($/lb)	Paté's Cost ($/lb) 2.66	3.66	4.66	5.66	6.66	7.66	8.66	9.66	10.66	11.66	12.66
5.14	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
6.14	51.9	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
7.14	41.5	52.1	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
8.14	35.1	41.6	52.2	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
9.14	30.7	35.2	41.7	52.3	60.0	60.0	60.0	60.0	60.0	60.0	60.0
10.14	27.5	30.7	35.2	41.8	52.5	60.0	60.0	60.0	60.0	60.0	60.0
11.14	25.2	27.5	30.7	35.3	41.9	52.6	60.0	60.0	60.0	60.0	60.0
12.14	23.1	25.2	27.6	30.8	35.3	42.0	52.7	60.0	60.0	60.0	60.0
13.14	21.1	23.1	25.2	27.6	30.8	35.4	42.0	52.9	60.0	60.0	60.0
14.14	19.4	21.1	23.2	25.2	27.6	30.8	35.4	42.1	53.0	60.0	60.0
17.14	15.9	16.9	18.1	19.5	21.1	23.2	25.3	27.7	31.0	35.6	42.4
20.14	13.7	14.4	15.1	16.0	16.9	18.1	19.5	21.2	23.3	25.4	27.8
23.14	12.2	12.7	13.2	13.7	14.4	15.1	16.0	17.0	18.1	19.6	21.3

*: NPV is calculated using a 5% rate of discount. The investment and loan equal to US$ 79 174; and, the IRR, NPV and ROI are evaluated over a period of 10 years.