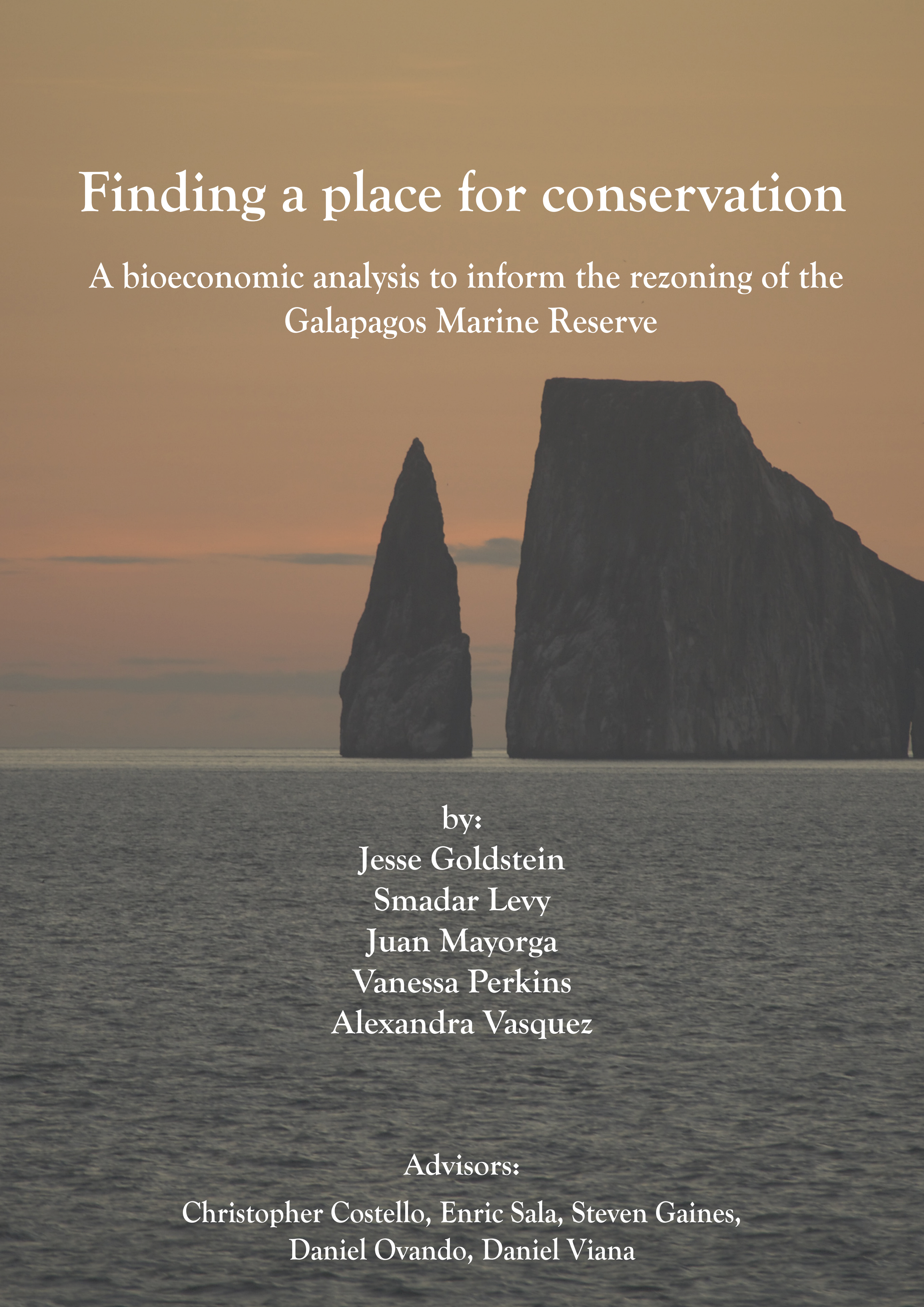

Finding a place for conservation

A bioeconomic analysis to inform the rezoning of the Galapagos Marine Reserve

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A Bren School Group Project

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Finding a place for conservation: A bioeconomic analysis to inform the rezoning of the Galapagos Marine Reserve

As members of the GeoMar Group Project, we hereby authenticate that we are the sole and original authors of this work. We are proud to archive this Final Report on the Bren School website and hereby agree to make our research and findings publically available. Our signatures on the document signify our joint responsibility in fulfilling the archiving standards set by the Bren School of Environmental Science & Management.

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The mission of the Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

Dr. Christopher Costello

----Signature Page----

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List of Abbreviations

AIS	Automatic Identification System
ASTM	Areas of Special Temporary Management
CEDENMA	Ecuadorian Coordinator of Organizations for the Defense of Nature and the Environment
CDF	Charles Darwin Foundation
EAST-GI	Economic Valuation of Marine –and Shark – based Tourism in the Galapagos Islands
FDC	Fisher Development Commission
FDF	Fisher Development Fund
FDP	Fisher Development Program
GAIAS	Galapagos Academic Institute for the Arts and Sciences
GMR	Galapagos Marine Reserve
GSL	Galapagos Special Law
GNP	Galapagos National Park
GNPS	Galapagos National Park Service
IMA	Inter-institutional Management Authority
NGO	Non-Governmental Organization
NTZ	No-take Zone
PMB	Participatory Management Board
TURF	Territorial User Rights Fishery
VMS	Vessel Monitoring System
WTP	Willingness to Pay
WWF	World Wildlife Fund

Abstract

The marine environment surrounding the Galapagos Islands is exceptionally rich and unlike any other in the world (Graham J. Edgar et al. 2008). It is also an important source of economic revenue generating nearly $178 million and $3.84 million per year for tourism and fisheries, respectively. However, protection of marine resources in Galapagos is currently limited. The Galapagos Marine Reserve (GMR) bounds 138,000 km^2 of water between and around the islands of the archipelago and is the one of the largest marine reserves in the world, yet current zoning of the GMR protects only one percent of the reserve area from extraction. Rezoning of the GMR is in progress and provides a historic opportunity to expand conservation of the Galapagos marine environment. Through our analyses, we determined that there is a strong economic argument for expanding conservation based on three key findings: 1) marine-based tourism comprises 69% of all tourism revenue, 2) ecological attributes drive the spatial distribution of marine-based tourism, and 3) conservation can be achieved at little cost to stakeholders. Using a linear model, we demonstrated that the number of diving live-aboards and land-based diving visits to different tourist sites vary positively and significantly with shark abundance while cruise visits vary positively and significantly with species richness. Based on an economic evaluation of three hypothetical no-take zone (NTZ) scenarios designed to capture areas with particularly high shark abundance or ecological richness, we found that a fee of less than one dollar per visitor to Galapagos National Park would be sufficient to compensate all fishery losses in all three NTZs. Our report concludes with a review of income generation and allocation options to support expanded marine conservation and three illustrative examples of how these options can be packaged. In conclusion, our study demonstrates that expanding NTZs is feasible and would help ensure the sustainable use of the ecological and economic resources of the GMR.

Executive Summary

Introduction

The marine environment surrounding the Galapagos Islands is exceptionally rich and unlike any other in the world. It is also an important source of economic revenue generating nearly $178 million and $3.84 million per year for tourism and fisheries, respectively. It is commonly argued that conservation can augment tourism revenue by improving the marine environment, thereby increasing the number of tourists and their willingness to pay to visit. We tested the first part of this argument by investigating whether ecological attributes drive the spatial distribution of tourist visits in Galapagos and, if so, which attributes are significant. Our results provide strong evidence that shark relative abundance and species richness are strongly correlated with marine visits in Galapagos. This suggests that conservation policies that protect sharks and species richness, coupled with economic policies that offset costs to fisheries, could be favorable to both tourists and fishermen. We demonstrate how this insight, along with spatial revenue data for fisheries and tourism, can be used to design and evaluate the costs of hypothetical no-take zones (NTZs). We also evaluate means to generate revenue and fund programs that would offset the costs of NTZs, improve fisher livelihoods, and enhance enforcement efforts. In doing so, we provide a holistic analysis to inform the current rezoning of the Galapagos Marine Reserve (GMR) and show how this information can be used in finding and building an enduring place for conservation.

Findings

To test the argument that visitors prefer improved marine environments, we first looked for evidence that the number of visits vary across ecologically distinct tourism sites. We compiled permits for tour operators in each tourism category — diving live-aboards, cruises, land-based diving, and day tours — and used estimates of average occupancy and trip days to calculate the annual number of visits to tourism sites in the GMR. Mapping revealed clear spatial heterogeneity in site visits across the GMR for all tourism categories (Chapter 1). The question, then, was what drives this variation in visits?

To answer this question, we examined the role of various ecological attributes in driving variation in marine site visits (Chapter 2). For diving live-aboards, cruises, and land-based diving tourism, we regressed the number of visits to each site against site-specific ecological traits and other characteristics relevant to tourists (e.g. price, distance from port). We found that shark relative abundance is a positively correlated and highly significant variable ($p < 0.01$) explaining the number of site visits for both diving live-aboards and land-based diving tourism. Species richness is also a positively correlated and highly significant variable ($p < 0.01$) explaining site visits by cruise tourism (Table ES.1). The occurrence of cetaceans and the richness of endemic species, although not significant, were positively correlation with the number of visits for all models tested in the cruises category. These results illustrate the importance of sharks and biodiversity in driving the spatial distribution of marine-based tourism. Because marine-based tourism comprises the majority of tourism value (69%[1]) and is estimated to provide one out of every three jobs in Galapagos (Lynham et al. 2015), these results also show the importance to the entire Galapagos economy of protecting shark populations and biodiversity.

Determining how best to protect these marine resources while providing for their continued human use is a challenge for marine managers. Knowing which resources matter to stakeholders can help decision-makers better focus management efforts. Our finding that sharks and species richness matter to tourists can inform the placement of NTZs, which protect the marine environment by prohibiting extractive uses. By mapping ecological data across the GMR, we identified two areas with exceptionally high relative shark abundances: 1) Darwin and Wolf, and 2) Northern Santa Cruz. We identified Western Isabela as an area with an exceptionally high relative abundance of cetaceans, high biodiversity, and high incidence of endemic and endangered species (e.g. flightless cormorants, fur seals, and Galapagos penguins; Chapter 3). These areas support the resources that attract tourists and contribute most substantially to the Galapagos marine-based economy. Therefore, designating these areas as NTZs is likely to provide the greatest benefits to human users while still achieving protection of the marine environment.

Table ES.1. *Results of multiple regressions for three models using price ($), distance from port (km), endemic and total species richness (# species per 2.5 km²), cetacean sightings, and relative abundance of sharks to predict tourism visits.*

	Dependent variable:		
	Cruise Ship Visits	Liveaboard Dives	Land-Based Dives
Price	47.9*	60.3**	
Distance	18.5	-0.1	16.2
Endemic_Richness	798.0	220.3	-444.4
Total_Richness	187.7**	-6.7	10.3
Cetaceans	65.1		
Sharks		1,278.8**	30,003.7**
Intercept	-30,120.8**	-9,268.5*	1,539.9
Observations	53	21	14
Adjusted R^2	0.21	0.85	0.49
Residual Std. Error	6,777.1 (df = 47)	1,348.2 (df = 15)	1,888.7 (df = 9)
F Statistic	3.8** (df = 5; 47)	23.8** (df = 5; 15)	4.1* (df = 4; 9)
Note:			*p<0.05; **p<0.01

While NTZs provide benefits to stakeholders, they also impose potential short-term costs by prohibiting fishing. To estimate the costs of NTZs to the fishing industry, we first mapped fisheries

[1] We derived marine-based tourism revenue estimates (2014) using operator permits, average occupancy, and trip days. Total tourism revenue (2014) was obtained from the Galapagos National Park.

revenues across the GMR. The data collected allowed us to map 87% and 90% of the available revenue data for the lobster and artisanal whitefish fisheries, respectively. Revenues were calculated using the most recent catch and price data for both fisheries (2014). To better capture the actual economic loss to fishermen, we estimated fishing profits to be 30% of total revenue. Because these potential costs are distributed heterogeneously across the GMR, as are tourism revenues and site visits, the placement of NTZs greatly influences the potential economic costs of achieving conservation.

Determining these costs to stakeholders is important for a number of reasons. First, it provides insight as to which NTZs have the greatest political feasibility by minimizing fisheries losses; second, it allows decision-makers to estimate the cost, which could be used to compensate fisheries losses; and third, it allows managers to determine which zones provide greatest protection per unit cost. A framework to evaluate NTZs based on their economic costs should capture all three pieces of information.

With this in mind, we designed an evaluative framework based on four economic measures:

1. Cost = Fisheries profits lost due to implementation of NTZ,
2. Cost per area = Cost / Area of NTZ (km^2),
3. Percent impact to fisheries = Cost / Total fisheries profits in the GMR, and
4. Blanket fee to offset cost to fisheries = Cost / Total # of GNP visitors.

We then applied this evaluative framework to the three NTZs previously identified – Darwin and Wolf, Northern Santa Cruz, and Western Isabela (Table ES.2).

Table ES.2. *Evaluative framework: area protected, costs, and compensatory fees of three NTZ scenarios.*

NTZ Scenarios	*Area (km^2)*	*% Area of GMR*	*Cost ($ per year)*	*Cost per unit area ($ per km^2)*	*% Impact*	*Blanket Fee ($ per GNP entry)*
Darwin and Wolf	38,000	28.6	98,260	2.59	9.0	0.46
Northern Santa Cruz	1,663	1.25	4,660	2.80	0.4	0.02
Western Isabela	12,555	9.44	97,830	7.79	9.0	0.45

The resulting framework provides a number of key insights about the costs of the three NTZ scenarios:

1. The Darwin and Wolf NTZ provides the greatest area of protection at the lowest cost ($2.59 per km^2).
2. A NTZ in Northern Santa Cruz imposes the least cost on the fishing industry ($4,660). 3. The cost per unit area of the NTZs is low, ranging from $2.50 to $8.00 per km^2.
3. Implementing all three scenarios would increase total NTZ areas from one to 39% and require only a one percent increase in the Galapagos National Park (GNP) entrance fee to offset fishery losses.

Taken together, these insights suggest that the overall cost to stakeholders of ecologically important NTZs are minimal and economically achievable. However, to ensure that NTZs meet their conservation objectives, it will be necessary to gain fishermen's cooperation and support for NTZs. We reviewed a number of options to generate and allocate income to support conservation. To illustrate how these options might be combined, we provide three sample scenarios that include a mechanism to generate income, a fisherman compensation scheme, and some combination of enforcement enhancements and short-term and long-term programs to improve fisher livelihoods.

Final Remarks

Preventing degradation of the marine environment is beneficial to all users of the GMR. A healthier environment could support more fish, higher abundances of sharks, and greater biodiversity, which would help maintain and, even potentially increase, tourism revenue. NTZs provide an effective tool for preventing degradation. However, by displacing human use they also incur costs to users. Environmental managers face the difficult task of balancing the political, social, and economic costs of NTZs with the environmental benefits provided by protection. Our study provides valuable information for helping decision-makers to achieve the right balance, and presents a number of policy options to help ensure that NTZs remain effective in the long term. As a whole, our findings show that:

- Protecting sharks and biodiversity is essential for maintaining the economic health of the Galapagos Islands.
- Protection can be achieved at low overall cost to stakeholders.
- There are many feasible options to support effective expansion of marine conservation in the GMR, which merit further investigation.

Project Significance

The Galapagos Islands are internationally famed for their unique wildlife and geography, which attract a large and growing number of tourists each year, and are credited with inspiring Darwin's formulation of his theory of evolution by natural selection over a century and a half ago. Regarded as a living laboratory, Galapagos represents one of the last remaining Edens on our planet and is a designated World Heritage Site. Unfortunately, the natural environment of Galapagos has come under increasing threat from development, and conflicts amongst stakeholders have hindered the successful implementation of a sustainable development plan for the region.

Since its establishment in 1998, the Galapagos Marine Reserve (GMR) has been a source of conflict amongst tour operators, fishers, government institutions, and the scientific community, which has resulted in little implementation of effective policy to promote its sustainable use. Less than one percent of the reserve's 138,000 km^2 area is currently protected from extraction, and compliance within existing NTZs is minimal. Lack of enforcement has resulted in overharvesting of regulated fisheries species as well as the illegal depletion of key species, such as sharks.

Throughout the past year the zoning of the GMR has been under review and will continue to be under review for the next few months. This presents a historic opportunity to expand protection for the Galapagos marine environment. Pristine Seas, led by National Geographic Explorer-in-Residence Enric Sala, is working to augment NTZs in the final zoning plan. Two collaborative projects between Pristine Seas and the Bren School were established to support this mission. The Economic Valuation of Marine and Shark–Based Tourism in the Galapagos Islands (EAST-GI) project focused on capturing the importance of marine-based tourism and live sharks for the Galapagos economy and was completed in summer 2015. The project presented in this report examines the economic importance and implications of expanding marine conservation. We demonstrate that marine-based tourism contributes significantly to the Galapagos economy, ecological features (such as shark abundance) drive marine-based visits in Galapagos, and conservation can be achieved at very little cost to stakeholders.

The marine environment in Galapagos is like no other on this planet. As one of the only regions that remain free from severe anthropogenic alteration, it is crucial that every effort is made to conserve its environmental resources. Our project illustrates that, with strategic management, it is possible to conserve the unique biodiversity of the Galapagos Islands while simultaneously enhancing the economic wellbeing of its people (Schiller et al. 2014).

Objectives

Our project sought to analyze the expansion of no-take zones from a bioeconomic perspective in order to inform the rezoning of the Galapagos Marine Reserve. Specifically, we determined the following:

1. **The contribution of marine-based tourism to revenue generated by the GMR and the importance of marine-based tourism to the entire Galapagos economy.**
   If marine-based tourism comprises a significant amount of revenue, strong economic incentives exist to adopt policies that promote sustainable use of the marine environment.
2. **Whether ecological variables influence and are important to the distribution of marine-based tourism in the GMR.**
   If ecological variables explain patterns of marine-based tourism, this strongly suggests that ecology matters to tourists and protection of marine ecosystems is necessary to sustain the significant revenue stream provided by marine-based tourism.
3. **Places where protection should be prioritized to best benefit both the ecology and economy of Galapagos.**
   Using the results of objective two, managers can design NTZs that protect areas rich in the ecological attributes of importance to marine-based tourists, and thus, maximize the economic benefits of conservation.
4. **The cost to stakeholders of expanded NTZs.**
   If the costs are low, the important economic benefits of conservation demonstrated by objective 2 outweigh costs, making conservation an economically sound policy decision.
5. **Feasible options to offset fisheries losses and support the future sustainability of Galapagos fisheries.**
   NTZs will likely impose short-term costs on fishermen, which may lead to substantial political opposition and lack of compliance with new zoning regulations. Generating revenue to offset fishers' profit losses is key to the success of rezoning and presents an opportunity to support other projects that will ensure fishers' compliance, such as programs to support alternative livelihoods and improve the sustainability of Galapagos fisheries.

Introduction

The Galapagos Archipelago

The Galapagos Islands are widely regarded as one of the most universally valued natural sites on Earth today. Often referred to as a living laboratory, the archipelago displays unique biogeographic characteristics that have led to the evolution of exceptionally high endemism, with 95% of its mammal and reptile species found exclusively in the region (Schiller et al. 2014). Due to the convergence of both hot and cold currents within this relatively small region of ocean temperate, tropical, and typically Southern Ocean species can all be found in close proximity (Schiller et al. 2014). In 1998, the marine environment extending from the islands' shores to 40 miles beyond the imaginary line bounding the archipelago was designated a marine reserve. In total, the GMR encompasses 138,000 km^2 of water, making it one of the largest marine reserves in the world (Figure I.1). The Galapagos archipelago is located about 1,000 km^2 west of continental Ecuador and includes over 127 islands and islets, of which four are inhabited.

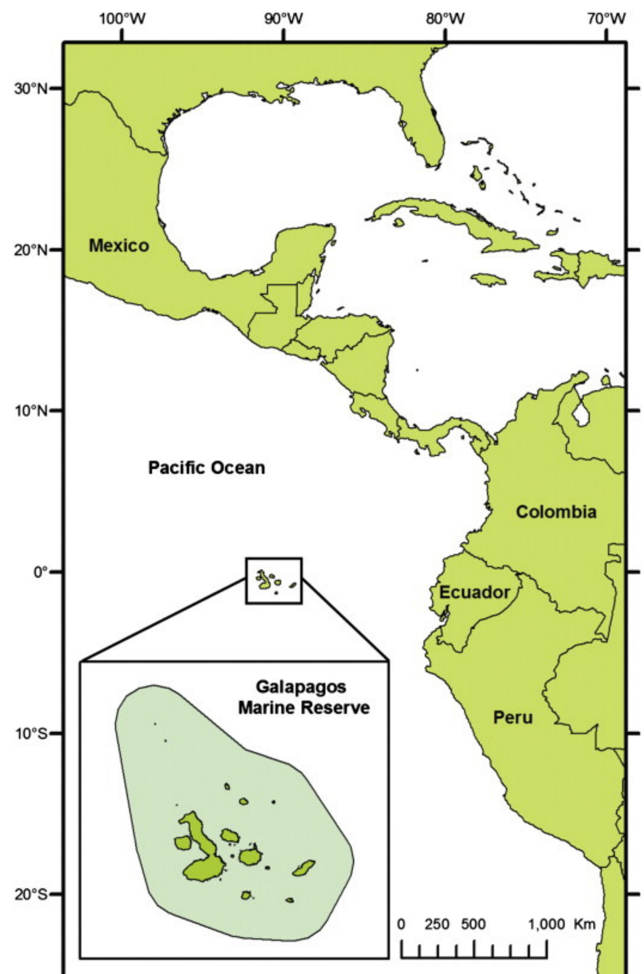


Figure I.1. *Location and map of the Galapagos Islands. The blue area represents the GMR. (Source: Castrejon et al., 2013)*

Each of the four populated islands has a distinct culture, population, and economy. Santa Cruz has the most developed economy and largest population with approximately 16,000 people ("Fasciculo Provincial Galapagos" 2010). San Cristobal is the province capital and home to the greatest number of active fishers (Jones 2013). Isabela is the largest island, but sparsely populated with less than 2,250 residents; it also hosts the greatest number of marine-based visitor sites (Directorate of the Galapagos National Park 2012). Floreana has the smallest human population of the inhabited islands with less than 150 residents ("Fasciculo Provincial Galapagos" 2010).

The Galapagos Tourism Industry

Tourism is a critical sector in the Galapagos economy both in terms of the amount of revenue it generates and the number of locals it employs. The most recent analysis of the Galapagos economy published in 2007 calculated that tourism generated the majority of revenue (53%) followed by the public sector (38%); conservation and science (6%) and fishing (3%) provided most of the remaining revenue, while agriculture represented only a small part of the economy (Epler). In 2007, tourism was the biggest single employer, employing 40% of local residents. A more recent analysis estimated that marine-based expenditures generate one out of every three jobs in Galapagos (Lynham et al. 2015).

Tourism is likely to continue to be a critical component of the Galapagos economy. Since the early 1990s, tourism revenue has grown at an average rate of 14% annually (Watkins and Cruz 2007), reflecting the ever-increasing number of visitors to the islands. In 2014, 215,691 tourists visited Galapagos and generated $258 million in revenue ("Boletin Galapagos: Estadisticas de Demanda, Oferta Y Economia Del Turismo En Las Islas" 2015). The vast majority of visitors to Galapagos arrive in Santa Cruz, which has been the main tourism hub in the archipelago since the tourism industry began. As a direct consequence, Santa Cruz houses the majority of the tourism industry's employees and is the most developed of the islands (Penaherrera, Llerena, and Inti 2013).

The tourists who visit Galapagos display diversity in their demographic attributes, preferences, and economic impacts (Schep et al. 2014). Previous studies have found it useful to categorize tourists into two groups that broadly capture some of these differences: live-aboard tourists and land-based tourists. Live-aboard tourists embark on cruise ships and eat and sleep onboard, disembarking only for excursions to visitor sites. Land-based tourists spend most of their time on the inhabited islands, eating and sleeping at local restaurants and hotels. These two types of tourists spend money quite differently, and in differing amounts, during their time in Galapagos. Live-aboard tourists currently provide the vast majority of revenue entering the tourism industry, but spend proportionally less of their expenditures at local, land-based businesses (Epler 2007). Live-aboard and land-based tourists are also associated with different demographic attributes. The income distribution of live-aboard tourists, for example, is higher than that of land-based tourists as would be expected due to the much higher cost of live-aboard tourism (Schep et al. 2014). In addition, the vast majority of live-aboards originate from Europe or the U.S., while land-based tourists hail primarily from Ecuador (30.27%), other Central and South American countries (22.45%), Europe (21.09%), and the U.S. (16.67%; Schep et al. 2014).

The Galapagos Fishing Industry

While tourism is the most important component of the economy in Galapagos, fishing plays an important role for many residents, especially on islands other than Santa Cruz where tourism is not as much of a presence (Schiller et al. 2014). Artisanal fishing, the only type of fishing permitted in the GMR, employs about 5% of the total Galapagos population (Jones 2013) and generated about $7 million in 2003 (Hearn, Murillo, and Reyes 2007). However, the profitability of the fishing sector has decreased significantly over time due to overharvesting of fishery resources (Hearn, Murillo, and Reyes 2007). Hearn et al. estimate that the gross annual income per fisher dropped from approximately $8,000 in 2002 to only $3,400 in 2006. The profitability of fishing also varies greatly across the islands with San Cristobal traditionally being the most profitable for fishers and helmsmen due to higher catches per unit effort and higher pricing for products. For example, in 2006 the mean net income of small-boat fishers in Isabela and Santa Cruz was only $20 per fishing-day, compared to $67 per fishing-day in San Cristobal (Hearn, Murillo, and Reyes 2007).

Overfishing has indelibly altered the composition of the Galapagos fishing industry in the past decade. Until recently, the top two Galapagos fisheries were spiny lobster (red: *Panulirus penicillatus* and green: *P. gracilis*) and sea cucumber (*Isostichopus fuscus)*. Due to high demand from Asian markets and perverse price incentives to fish more as the cucumber population declined, the fishery has been overfished to the point of collapse and a moratorium on fishing has been in place since 2012. The fishery was briefly re-opened from late August to early September of 2015, but is unlikely to be re-opened any time soon. The lobster fishery has also seen drastic declines and is still thought to be over-exploited (Schiller et al. 2014) although accurate stock assessments have yet to be completed. Despite its marked depletion, the lobster fishery remains a large revenue source for Galapagos fishermen today, and generated about $1.77 million in 2014 (Galapagos National Park, "Lobster Catch Dataset: 2014–2015").

In addition to the seasonal lobster fishery, a year-round whitefish fishery supplies local consumers, markets, and the hospitality industry, as well as consumers and wholesalers based in mainland Ecuador. The whitefish fishery includes many benthic, coastal, and pelagic fish species, but is dominated by wahoo (*Acanthocybium solandri*), tuna (albacore, *Thunnus alalunga*; yellowfin, *Thunnus albacares;* and bigeye, *Thunnus obesus*), and swordfish (*Xiphias gladius*). In 2012, it was estimated that 40% of active fishermen did not participate in the whitefish fishery (Castrejon 2012). Nevertheless, with the collapse of the sea cucumber industry and growth of the local hospitality industry, the economic importance of the whitefish fishery may be increasing. The magnitude of its economic significance is difficult to estimate because sales data are unavailable for exports, which account for a substantial portion of total whitefish catch.

Galapagos Fishers

All fishers in Galapagos require a license to fish. In an effort to limit fishing, no new fishing licenses have been issued since 2002 (Heylings and Bravo 2007). Fishermen sell their fish directly to consumers, the hospitality industry, wholesalers, or fishery cooperatives, which in turn distribute locally or export products to the mainland. San Cristobal, Santa Cruz, and Isabela each have their own fishery cooperative based in the main ports of each island—Puerto Moreno, Puerto Ayora, and Puerto Villamil, respectively (Castrejon 2012). Total membership in all three cooperatives numbered 1,010 fishers in 2013, with 50% of all members in San Cristobal, 28% in Santa Cruz, and 22% in Isabela. However, the number of active fishers was only about 400 people, and of these, only about 240 (60%) fished year-round with the remaining 160 (40%) participating only in the highly lucrative, seasonal lobster and sea cucumber fisheries (Castrejon, 2012). Even before the moratorium on sea cucumber, both of these fisheries were closed for the majority of the year. This, coupled with declining profitability, has led many fishermen to engage in economic alternatives to fishing in order to supplement their income. Alternatives include tourism, inter-island transport, and construction (Hearn, Murillo, and Reyes 2007).

Challenges to Sustainable Development

Galapagos faces a number of challenges to its sustainable development that arise from rapid human population growth, its rich, but vulnerable, ecological resources, isolation from the continent, and weak institutions. The rise of the sea cucumber and lobster fisheries and exponential growth in the tourism industry created a gold-rush scenario that brought thousands of mainland Ecuadorians to Galapagos in the 1990s. Many of these immigrants remained causing the population of Galapagos to grow from 1,346 in 1950 to 18,640 individuals in 2001 (González et al. 2008). The booming population and over-capitalization of local fishing fleets had serious environmental consequences, including the increased introduction of invasive species (Snell et al. 2002) and dramatic decline of the sea-cucumber and lobster fisheries (Toral-Granda 2008). In addition, because of its great distance from the mainland, businesses and consumers in Galapagos pay a high transportation cost for goods, which reduces the local income available for long-term investment. Human capital is also limited and access to quality education is more difficult than in mainland Ecuador. Finally, weak institutions hinder sustainable development through a lack of leadership and accountability, resulting in weak enforcement of regulations and a reluctance to adopt policies that may slow economic growth or lead to political conflicts amongst institutions and stakeholders.

The Galapagos Marine Reserve

The history of the GMR illustrates how rapid population growth, weak institutions, and easy access to economically and ecologically valuable resources have challenged the sustainable development of the Galapagos marine environment. By the mid-1990s, rising tensions between development and conservation interests posed serious challenges for marine management (Castrejón and Charles 2013). The Galapagos Special Law (GSL) was passed in 1998 to address these ecological concerns and social conflicts by restricting migration, increasing the stringency of quarantine and inspection measures, providing a new institutional framework to enhance ecosystem protection, and creating the GMR (González et al. 2008). The establishment of the GMR was accompanied by a number of directives, which included (Heylings and Bravo 2007):

- The extension of reserve boundaries to 40 miles offshore from the baseline, which was defined as an imaginary line joining the outer islands of the archipelago. In total, the reserve encompasses about 138,000 km^2.
- The creation of exclusive fishing rights for the local artisanal fishing sector and banning of

industrial fishing.

- A moratorium on the registration of new local artisanal fishermen (implemented in 2002).
- The assignment of jurisdictional responsibility for management of the GMR to the Galapagos National Park Service (GNPS) under principles of participatory and adaptive management.
- Inclusion of local stakeholders within the two primary policy-making bodies of the GMR:
  - The Inter-institutional Management Authority (IMA): an inter-ministerial body composed of the Ministry of Environment, the Ministries of Industry and Fisheries, Tourism, and Defense, and representatives from the umbrella organization for environmental NGOs (The Ecuadorian Coordinator of Organizations for the Defense of Nature and the Environment (CEDENMA)).
  - The Participatory Management Board (PMB): the local consensus-building body composed of representatives from the fishing sector, tourism sector, the Charles Darwin Research Station, GNP, and naturalist guides.

Via the establishment of the GMR, GNPS sought to balance the interests of its stakeholders by designating specific use zones in the reserve through a participatory planning process. Planning of the reserve zones involved representatives from the fishing and tourism industries, NGOs, and GNPS and was not completed and implemented until 2000 (Castrejón and Charles 2013). The current zoning plan of the GMR divides the marine reserve into three zones: a multiple use zone, limited use zone, and port zone (Castrejón and Charles 2013). The multiple use zone includes deep waters (> 300 m) and permits all activities. The limited use zone includes coastal waters (< 300 m) and is divided into four subzones:

(1) conservation,
(2) conservation and non-extractive use (i.e. tourism),
(3) conservation, extractive and non-extractive (i.e. fishing), and
(4) areas of special temporary management (ASTM).

These subzones can be implemented anywhere, anytime to facilitate recovery of species or implement experimental management schemes.

The current zoning plan has been criticized for a number of reasons. First, only one percent of the reserve is protected from extraction and these areas are dispersed throughout the reserve, making enforcement difficult and protection of mobile species largely ineffective (Lynham et al. 2015). Second, small-scale illegal fishing in NTZs continues to occur due to lack of enforcement and non-compliance by fishers who consider management measures illegitimate (César Viteri and Chávez 2007); this includes both fishing of managed species and protected species, such as sharks. Third, fishing and tourism interests, rather than ecological interests, dominated the original zoning process, resulting in a lack of protection of fishery species, and inadequate protection of several threatened species and key biodiversity areas (Graham J. Edgar et al. 2008). Fourth, confusion about zone names and poor visibility of zone demarcations at night make it difficult for fishermen to comply with zoning boundaries. Finally, NGOs and GNPS promised compensation payment to fishers in the form of alternative livelihoods in exchange for closing 18% of their fishing grounds. However, rather than incentivizing compliance, this promise lured non-fishery individuals, primarily from mainland Ecuador, to obtain fishing licenses in order to get access to fisheries and the promised alternative livelihoods. As a result, fishing efforts increased, fishery health decreased, and fishermen became more distrustful and non-compliant because promised alternatives were realized more slowly than expected (Castrejón and Charles 2013).

Protecting the Marine Resources of Galapagos

There are a number of anthropogenic factors threatening the future health and sustainability the Galapagos Marine Reserve including legal fishing, illegal harvesting of sharks, and development. Fishing has had its most obvious effects on fishery species, which have either been overfished to the point of collapse, as in the sea cucumber fishery, or have greatly declined in number and size, as in the lobster fishery (Hearn, Murillo, and Reyes 2007). Fishing has also altered the structure of reef and pelagic communities by removing urchin predators (i.e. lobsters) and top predators (i.e. large fish, sharks), respectively (Sonnenholzner, Ladah, and Lafferty 2009; Schiller et al. 2014).

Illegal harvesting of sharks has intensified since the 1980s in response to rising demand and value of shark fins (Schiller et al. 2014). It is estimated that over 105,500 tons of sharks have been harvested by the Ecuador fleet alone since 1950 from the GMR (Schiller et al. 2014); fishers from other countries, such as Costa Rica, Colombia, and Japan are also known to fish for sharks in Galapagos, so this is a minimum estimate .This is of great concern both because of the threat to shark populations–seventeen shark species found in the Galapagos are on the IUCN Red List– and because of the important role sharks play as apex predators in maintaining a stable and healthy ecosystems (Schiller et al. 2014).

Development presents a whole slew of issues for the GMR's marine resources, such as pollution, nutrification, the introduction of invasive species, increasing pressure on fished species, and physical degradation of the marine environment (Caveen et al. 2015). While the direct effects of fishing and development, such as trophic changes and nutrification, do not always pose immediate threats, they can severely weaken the resilience of an ecosystem to further stressors. The strong effects of El Niño events have been noted in penguins (Vargas et al. 2006), marine iguanas (Laurie 1990), corals (Glynn 1994), seabirds (Valle et al. 1987) and other denizens of the Galapagos marine environment. Minimizing anthropogenic impacts, through the implementation of no-take zones for example, could help improve the ability of Galapagos marine communities to rebound and recover from such major events (Micheli et al. 2012).

NTZs are demarcated areas in the ocean where fishing is not permitted. NTZs can provide both ecological and economic benefits (Caveen et al. 2015) and have been described as savings accounts where biodiversity can accrue over time and replenish nearby habitats that become degraded (Sala et al. 2013). Establishing NTZs in ecologically important areas like mangrove nurseries and spawning grounds is particularly important in supporting biodiversity because it protects species at key stages for growth and productivity. NTZs are beneficial to fisheries because they protect breeding stocks, promote recruitment, and replenish target stocks. Following the implementation of NTZs, fishers often report an increase in the number and size of target species, even after the target species had been depleted previously (Forcada et al. 2009). NTZs can provide economic benefits to the marine tourism industry as well. Marine tourists, such as divers and snorkelers, are more inclined to visit protected areas than unprotected ones. For instance, 50% of all diving in the Caribbean takes place in protected areas (Sala et al. 2013). NTZs also serve as useful control sites for understanding the effects of humans on the marine environment. Because NTZs can benefit tourism, the marine environment, and potentially fishers as well, they present a particularly attractive tool with which to protect the marine resources of the GMR.

Chapter 1.

Spatial Economics of the Galapagos Marine Reserve:

Mapping the spatial distribution of tourism and fishery revenues and tourist site visits across the Galapagos Marine Reserve

Overview

The GMR is integral to the tourism and fishing industries of Galapagos. For live-aboard tourists, the reserve is their home and primary attraction during their time in Galapagos, while for land-based tourists it is the next day's adventure. For fishermen, the GMR is their place of employment and the only body of water productive enough to provide enough goods to catch and sell year after year. The GMR is large, however — roughly 138,000 km^2 — and not all of it constitutes good tourism sites or fishing grounds. Our first step to understanding the economic implications of expanding conservation in the GMR was to visualize the spatial distribution of tourism and fishing revenues and tourist site visits across the reserve.

Mapping revenues and tourism site visits allowed us to clearly identify areas of greater economic importance to both tourism and fishing industries and to observe that the use of the reserve is spatially heterogeneous. Spatial heterogeneity in revenues and use exists in the GMR at multiple levels. First, not all of the reserve is of equal benefit to tourism and fishing industries. Second, of the sites being used, not all sites provide equal benefit to tourism and fisheries. Third, the same site provides different levels of benefit to different fisheries and different categories of tourists. The following chapter builds on the finding that spatial heterogeneity exists in site use by tourists and seeks to explain why this heterogeneity exists.

I. Fisheries: Mapping Lobster and Whitefish Revenues

Background

The Galapagos Islands have historically hosted a number of economically important fisheries including spiny lobster, sea cucumber, coastal whitefish, and pelagic whitefish. However, due to overfishing, the sea cucumber fishery is currently considered unviable and is under a long-term moratorium; the only brief, sporadic re-opening since 2012 occurred in late August through early September of 2015. In addition, longlining was banned in 2005 (Ocearch 2014), which effectively shut down the pelagic whitefish fishery. Pilot projects using modified long lines have occurred in the past, but have not been permitted to continue. For these reasons, lobster and coastal whitefish remain the only two significant fisheries in Galapagos and are the only fisheries included in our analyses.

A. Lobster

To map spatial lobster revenues across the GMR, we obtained a lobster catch dataset for the 2014-2015 season from GNP with assistance from Conservation International. This dataset included information on lobster species (red or green spiny lobster), number of individuals caught, pounds of catch, fishing site, vessel name, and date of catch. To estimate revenue from catch, we applied average 2014 ex-vessel lobster prices per pound to catch data. The prices used were $5.20 per pound for whole lobster and $10.30 per pound for lobster tail, which were the average 2014 prices. Revenue for each fishing trip was consolidated by site to generate site-specific lobster revenue data for the GMR (Carlos Viteri 2014). Coordinates for fishing sites were provided by GNP and were available for 87% of lobster catch by weight. Catch data without coordinates were not included in our spatial analyses, resulting in an underestimation of revenue generated by the lobster fishery. Data were cleaned and processed in Microsoft Excel 2013, and revenue data were visualized using ArcMap 10.3.1.

B. Whitefish

Spatial Data

Whitefish data (species, number of individuals caught, pounds caught, fishing site, and trip days) were obtained from the GNP database of whitefish landing certificates for 2014. Landing certificates are completed by vessels that come into port during GNP work hours or are self-reported by phone or in person to Fisheries Department officials. The dataset includes both commercial catches and recreational catches; for example, Ecuadorian visitors who want to take a fish caught in Galapagos back to the mainland must report their catch. Many of the seafood markets and hospitality buyers require whitefish suppliers to report their catch as a prerequisite for doing business. Due to these stipulations, it is believed that landing certificates do capture the majority of all whitefish caught and sold locally, but the exact percentage captured is unknown (Jules Jarrín, personal communications, August 2015). Nonetheless, this means that our analyses could be underestimating the revenue generated by whitefish. In addition, 13% of the whitefish landing certificate data did not have usable spatial information and so could not be included in any spatial analyses.

Price Data

To determine the revenue generated from the pounds captured, we needed price data for each fish species listed. We obtained fish price data from three sources: the local fish market, a 2014 analysis of the commercial fish market in Galapagos conducted by CORAMIR S.A., and the Santa Cruz fishery cooperative (COPROPRAG) which provided the average price of products in 2013 (Table 1.1). Because the price list for 2015 was impacted by the opening of the sea cucumber fishery during our visit, and because we were told by COPROPRAG employees that prices were usually closer to the 2013 price sheet, we used the 2013 average price list, rather than the most current, non-average price list.

Table 1.1. *Price source and prices ($/ lb) for whitefish species.*

Source	Species	Price ($/lb)
Fish market (8/2015)	Blanquillo	2.20
	Vieja spp.	2.20
(Plaza, Solis, and Gonzalez 2014)	Lisa spp.	0.45
2013 COPROPRAG price list	Tuna	2.26
	Bacalao (grouper)	2.47
	Brujo	2.80
	Camotillo	2.61
	Pez Espada (Swordfish)	2.37
	Mero	2.28
	Miramelindo	0.73
	Palometa	2.40
	Pargo	2.14
	Wahoo	1.71

We were not able to obtain pricing for 17 fish species, which in total comprised 6.2% of the whitefish caught (unknown price n = 108; total whitefish n = 1,733). To assign prices (Table 1.2), all species —priced and unpriced — were categorized by their fish group. Unpriced species that shared the same group as priced species were given the price of the priced species in their group; for example, barrilete negro is a grouper and so was assigned the same price as bacalao, also a grouper. In cases where multiple priced species were in the same group (e.g. tuna and wahoo), the average of tuna price and wahoo price was calculated and applied to the unpriced species. Some unpriced species did not share priced fish groups, but physically resembled other priced species so they were given the price of the species they most closely resembled, the idea being that they could act as a substitute good. For data entries where no species was specified, or there was no similarity to a priced species, fish were assigned the average weighted price for the entire priced dataset (average price = $2.24). While unpriced species comprised 6.2% of the data entries, they only comprised 0.4% of the weight captured, and only 0.4% of the total revenue (given our assumptions), so price uncertainty likely had little effect on the accuracy of subsequent analyses.

Data Processing

The final whitefish dataset in this study built upon a "clean" GNP whitefish dataset produced by Jorge Ramirez and Mauricio Castrejon. Many certificates had been excluded from the clean dataset resulting in the removal of the majority of the total 2014 whitefish revenue. To recover more revenue, all the certificates that did not appear in the clean dataset were restored. Any obvious recording errors — such as a transposition of values for the weight and number of individuals caught — were corrected. The final dataset used the entire clean dataset along with any of the reintroduced data for which spatial coordinates could be determined.

Table 1.2. *Estimated prices for unpriced whitefish species.*

Species	**Estimated Price ($/lb)**
Barracuda	1.71
Barrilete negro	2.45
Bonito	1.99
Cabrilla piedrera	1.99
Carabali	2.80
Cherna	2.45
Dorado	2.45
Huayaipe	2.40
Jurel Negro	2.40
Norteno	2.45
Ojo de Uva	2.45
Ojon species	2.45
Palma	2.14
Pampano acerado	2.40
Picudo	2.37
Plumero	1.99
Sierra	2.45

Coordinates were assigned to all entries in the reintroduced dataset for which coordinates were available (e.g. Floreana and Banco Ruso). For entries that had two site names listed, each with known coordinates, catch data (and thus, revenue data) were halved between the two sites. For example, an entry with "Cowley, Cartago: 793 lbs" was transformed into: "Cowley: 396.5 lbs, Cartago: 396.5 lbs". Finally, the reintroduced data with site coordinates were combined with the clean dataset. Information for each site was consolidated to obtain total pounds captured and total revenue for each site. These data were then mapped in ArcMap 10.3.1 for viewing and analysis.

Results

Mapping lobster and whitefish revenue revealed clear spatial heterogeneity in fishing revenues across the GMR. According to the landings data provided by GNP, total catch from both lobster and whitefish generated $3.84 million in revenue. However, we could only represent 87% of lobster revenue and 90% of whitefish revenue in our spatial analysis due to some of the landings lacking site coordinates. Therefore, spatially assigned revenues for both fisheries totaled $3.64 million throughout the archipelago. Total lobster revenue was estimated at $1.77 million, and total whitefish revenue was estimated at $1.87 million. Applying our assumption that 70% of fishing revenue would have to cover the costs of fishing, we calculated profits of $531,000 and $561,000 for lobster and whitefish, respectively. In total, spatial fishing profits in the GMR totaled about $1.1 million.

The total revenue generated by sites within approximately 16 kilometers of each of the most populated islands was about $1.99 million (Figure 1.1). Fishing sites within about 16 kilometers of Isabela generated almost $1 million in lobster and whitefish revenues per year, with a little more than half of this coming from lobster. This included sites on the nearby island of Fernandina. Total lobster and whitefish revenues generated by sites within approximately 16 kilometers of the island of San Cristobal were $557,000, with 70% coming from lobster. Sites within approximately 16 kilometers of Santa Cruz generated about $438,000 in revenues, with 97% coming from lobster.

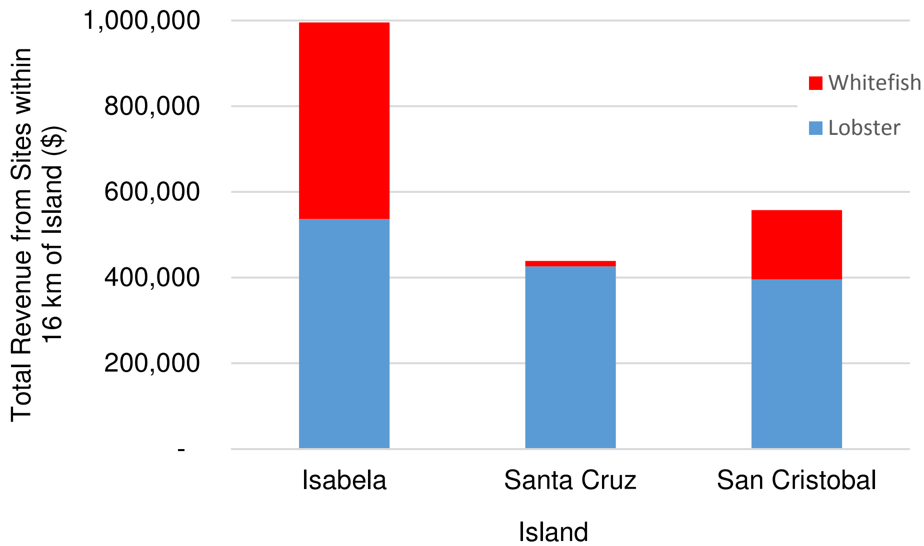


Figure 1.1. *Revenues from lobster and whitefish generated by sites surrounding the three most populated islands: Isabela (n = 59), Santa Cruz (n = 39), and San Cristobal (n = 33). Sites counted in each island's total revenue were within approximately 16 km of the coastline of each island. Revenues from Fernandina and Isabela were aggregated under the latter's name. Santa Cruz isand's total revenues includes those generated by Pinzon, a neighboring island. Whitefish revenues are represented in blue and lobster revenues in red.*

Lobster and whitefish site revenue data were assigned to the current fishing zones within the GMR to determine the relative values of official fishing zones (Figure 1.2). Most fishing zones within the GMR generated under $100,000 in revenues. The southern San Cristobal zone had the highest concentration of fishing revenues, generating between $500,000 and $600,000. Higher value fishing zones were also found at Roca Redonda (between $300,000 and $400,000) and southern Santa Cruz (between $200,000 and $300,000). However, zones in northern Santa Cruz were less valuable, representing less than $100,000 in revenues. Fishing zones surrounding Darwin and Wolf islands represented sites that generated between $100,000 and $200,000 except for one zone on Darwin, which generated under $100,000. Fishing zones in the southern part of Isabela Island generated more revenues ($100,000 to $200,000) than the fishing zones surrounding the rest of the island and neighboring Fernandina (under $100,000). Finally, on the three populated islands of Isabela, Santa Cruz, and San Cristobal, higher value fishing zones were located in the southern regions of each island.

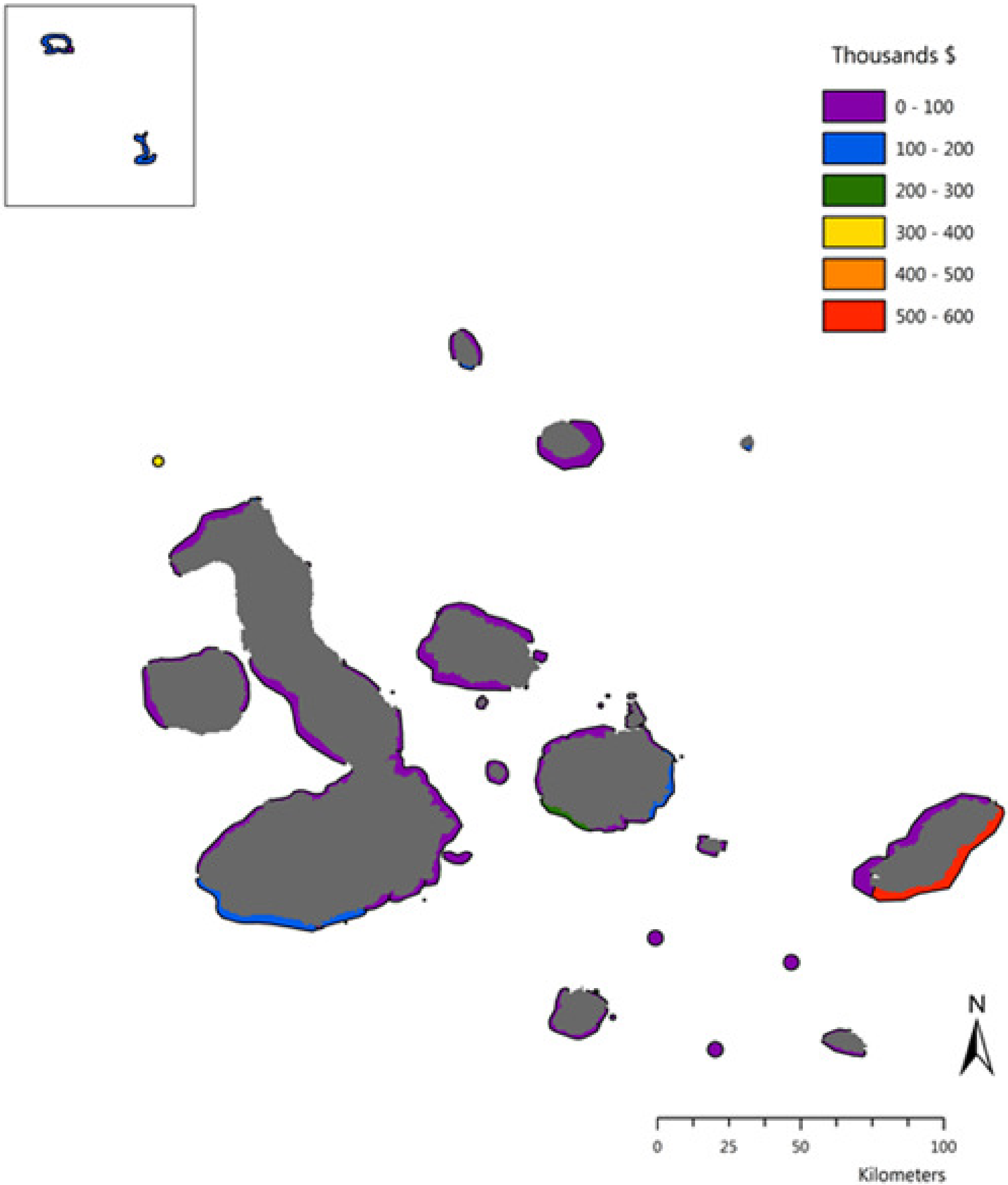


Figure 1.2. *Total annual fisheries revenue generated by fishing zones in the GMR.* *Fisheries included are lobster and whitefish. Fishing zone colors indicate the total revenues generated within each zone as described by the symbology in the right-hand corner.*

Discussion

Even though our appraisal of total fishing revenues may underestimate actual fishing revenues, our results provide additional evidence that fishing brings a much smaller amount of revenue to the overall Galapagos economy than does tourism. It is likely that if catches were unreported they would be of whitefish as opposed to lobster, which is more strictly monitored and of higher value. Hypothetically, let us imagine that the value of unreported whitefish exports was discovered and resulted in a doubling of total whitefish revenue estimates to $3.7 million. Overall fisheries revenues would still only total $5.4 million, which is dwarfed by marine tourism revenues, estimated to be $178 million per year by our study.

Fishermen from the three port islands (Isabela, Santa Cruz, and San Cristobal) tend to visit sites closer to their home islands (Bucaram et al. 2013). Therefore, examining sites proximate to the edges of the islands, within about 16 kilometers, shows which regions are important to fishermen and, consequently, which areas are the least feasible for NTZ implementation. The designating of NTZs would likely face the most opposition at these sites because of the higher costs fishermen would bear if they were closed. However, the majority of each populated island's coastline represented relatively low value fishing zones. Many regions along Isabela, Santa Cruz, San Cristobal, and throughout the GMR each generated less than $100,000 in fishing revenue per year. This suggests that many potential low cost sites exist for NTZs that would face minimal opposition from the fishing sector. Relatively low value fishing zones that are designated as no-take would theoretically be offset by their high tourism value. Therefore, heterogeneous distribution of fishing revenues suggests that there are opportunities for easy wins for conservation and multiple feasible locations for the placement of NTZs to ensure continued ecosystem-driven benefits to the economy.

II. Tourism: Mapping Tourism Visits and Revenue by Site

Background

Tourism Categories

Marine-based tourism in Galapagos is differentiated into four categories that reflect different types of users with different preferences and different demographic attributes. These categories of tourism are: diving live-aboard, cruises, land-based diving, and day tours. "Diving live-aboard" tourism refers to cruises targeted specifically to SCUBA divers. These are week long cruises that cater up to 16 divers, cost between $2,000 and $6,000, and may include extensive travel to reach remote locations, such as Darwin and Wolf. There are seven boats registered in this category and 39 tourism sites are open to this tourism category. "Cruise" tourism refers to any of the multi-day cruise packages not targeted specifically to divers, which offer a blend of marine and terrestrial activities. These tours cater up to 100 tourists and can cost up to $9,000. There are 67 boats in this category, which are further subdivided in three tiers according to the luxury of the tourism experience. In total, there are 53 tourism sites open to this category. "Land-based diving" tourism refers to the one-day diving or snorkeling packages that can be purchased at tour operator kiosks on Santa Cruz, and, to a lesser extent, San Cristobal and Isabela. These tours take groups of about 12 divers to two nearby sites and charge around $150 for two dives. There are 18 boats registered in this category and 29 tourism sites are open to this type of tourism. Day tours are also land-based, but are distinguished from land-based diving tourism in that they do not offer diving; instead, they offer snorkeling that may be paired with terrestrial excursions or other activities. These boats carry groups of up to 20 tourists and charge between $100 and $200 per tour. Seventeen boats are registered in this category and 21 sites are open to this type of tourism.

Tour Operator Permits

GNP uses a permit system to regulate tourism operations in Galapagos. All tour operators must apply for a permit annually, which grants them itineraries for each day of the week from October through September of the following year. Itineraries are set for either a one or two-week period, which can be repeated throughout the year as desired; a single cruise operator does not run every day of the year. Permits also set a maximum capacity of visitors for each itinerary. Thus, tourism permits allow GNP to control number of tourists, where tourism occurs, and site visit frequencies. Importantly, for cruise vessels, the permitted itineraries provide choices from which cruise operators select two sites to visit each day.

Tourism permits are divided into eight categories:

1—3) three tiers of cruises (A, B, and C),
4) diving live-aboards,
5) day tours,
6) land-based diving,
7) bay tours, and
8) vessels permitted to operate as both land-based diving and bay tours.

The different cruise tiers are based on the amenities and quality of services provided with A-tiered cruises offering the highest levels of amenities and services. Permits are priced based on the permit category and the maximum number of passengers permitted by the itinerary.

Data & Methods

Data Sources

Four different sources of data were utilized to estimate the number of visits and revenue for each site: tour operator permits, logbooks, personal interviews, and internet searches.

Permits

Permit information was used to estimate the number of visits for each site for all four categories of tourism. Permits issued to tour boat operators for 2015-2016 were obtained from GNP for 92 of the 119 active operators; each permit represents one vessel. For each permit, the number of vessel visits to each site, the class of tour, the total number of sites visited per tour, and the maximum tourist capacity of each vessel were recorded.

For the purposes of this study the eight classes of tour permits were grouped into four functional categories:

1) cruises (A, B, and C),
2) diving live-aboards,
3) land-based diving, and
4) day tours, bay tours, and vessels permitted to operate as both day land-based diving and bay tours.

All the A, B, and C tours were classified together as cruises. Even though cruise operators offer grouped tour packages, which are assigned the same number of visitors for each operator, there was sufficient heterogeneity among tour packages for significant variability in site visitation to be detected. Bay tours were consolidated under the day tour category as the products these operations offered are similar in terms of pricing and itineraries. Vessels with permits allowing both land-based diving and bay tours were included with the land-based diving permits.

Logbooks

We obtained permits from the GNP for operators based on the island of Santa Cruz, the central tourism hub of Galapagos. The 27 absent permits were from tour operators based on the islands of San Cristobal and Isabela. The San Cristobal and Isabela land-based diving and day tour operators visit only a few tourism sites, so their itineraries are very uniform in comparison to those for Santa Cruz-based operators. Of the 27 permits not acquired from GNP, two were eventually obtained directly from operators, as were three dive logbooks. Logbooks were firsthand accounts by tour guides stating the exact number of visitors that operators brought to each site by date. Site visit frequencies were extrapolated from these permits and logbooks to the other San Cristobal and Isabela land-based diving and day tour operators, respective of island and category. We believe this approach provides a robust substitute for the permit approach because tourists seem to be unaware of operator reputation and prices were uniform on these islands. This implies that the number of visits to San Cristobal and Isabela sites captured by our small sample of operator permits and logbooks is likely representative of what other operators offer, respective of tourism class and island.

In order to use the number of site visits permitted as a proxy for the real number of site visits, we had to make the key assumption that permits reflect tourist demand for specific sites. Our assumption was based upon conversations with tour operators and GNP officials who confirmed that both parties are currently content with itineraries and that previous lobbying of GNP to change itineraries had been successful. Operators also concurred that their site preferences were determined by the desires of their clients.

Personal Interviews

Personal interviews of 26-day tour and land-based diving operators were conducted in August 2015. The following questions were posed to staff at the tour operator kiosks and the results recorded:

"What tours do you offer and at what prices?"
"Do you visit every site listed on your permit?"

The first question provided price information for day tours and land-based diving operations, which was used to estimate site **revenue** generated by these two tourism categories. The second question allowed us to determine which sites on the itinerary were actually being visited.

Internet Searches

Internet searches were performed to obtain the prices of all cruises and diving live-aboards, which were used to calculate **site revenue** generated by these tourism categories. In a few cases when pricing was not readily available online, prices were obtained via email communication with operators. Land-based diving and day tour prices were collected in August 2015, the same month when personal interviews were collected. For operators that had different prices for different tours, a weighted average was calculated by site visit frequency and applied to all tours within the same tourism category. Some cruise and diving live-aboard operators provided two prices: one for peak season (December) and one for regular season. In such cases, we used the high season price because that was the rate most often paid. Most tour operators also provide tours of different lengths. Week-long tour prices were chosen to represent all tour pricing because these were the most popular and because they aligned most easily within the typical two-week permit cycle. Tourists who experienced longer or shorter tours were covered under multiple permit cycles. When the number of available cabins of each type and corresponding prices were known, an average cabin price was calculated. When unknown, the least expensive cabin was chosen to keep estimates conservative. When available, 2016 prices were chosen over 2015 prices to provide a more relevant analysis for the near future. Prices were not found for 13 of the 92 vessels. In these cases, an average of the other prices in that class was substituted.

Methods

Estimating Site Visits

We estimated the total number of visits to each site for each tour category using four pieces of information. (1) The number of visits scheduled per two-week period and (2) the maximum tourist capacity of each vessel were obtained directly from GNP permits. Adjustments were made based on the (3) average number of operating days and (4) average percent occupancy for each tourism category. To estimate the annual visits per site by category ($V_{i,k}$), we first multiplied the number of visits scheduled per two-week period for each tour operator ($v_{i,j}$) by the maximum capacity for each vessel (C_j). This gave us the maximum number of visitors to a site by each tour operator within a two-week period. We then multiplied this number by 26 — because there are 26 two-week periods per year — to get the maximum possible number of annual visits to each site by each tour operator. We aggregated the outcomes by tour category to get the number of total annual visits to each site by tourism category. Next, we corrected for the fact that tours do not run every day of the year, nor at maximum capacity. We multiplied the possible number of annual visits to each site per tour category by a correction factor, CF_k, which is the product of the percent occupancy rate per tourism category (O_k) and the proportion of days worked per year, per tourism category (W_k). For cruises, diving live-aboards, and day tours, CF_k was obtained from a study by Viteri and Rodriguez (2014). For the land-based diving category, O_k and W_k were calculated from three dive log books. The total number of visits was calculated by summing total visits at each site.

These calculations are described by the following equations:

$$CF_k = O_k \times W_k$$

$$V_i = \sum_k \sum_j 26 \times v_{i,j} \times C_j \times CF_k$$

$$V = \sum_i V_i$$

It is important to note that the frequency of visits to a given site reflects the total number of **visits** to a site, rather than the total number of individuals visiting a site; consequently, individuals who visit the same site twice contribute two visits to the total. This clarification is particularly salient for diving live-aboards who regularly dive twice at the same site in a single day; each dive counts as one visit. Therefore, in this analysis, the total number of visits at all sites does not equal the total number of visitors to the GMR. Any sites reported as unvisited were removed from the aggregation. Site visit data were processed in Microsoft Excel 2013.

Estimating Site Revenues

Annual site revenues were estimated using site visit estimates and price data, which were obtained through either personal interviews or Internet searches. To estimate the revenue generated by each site (R_i), we assumed that all sites in an itinerary — including both marine and terrestrial — generated an equal amount of revenue. We calculated revenue per site per visit by dividing the total package price by the number of sites visited, both marine and terrestrial, by each operator (P_j/N_j). We then multiplied the revenue per site per visit by the total number of annual visits to each site by each operator to get the maximum total annual revenue per site. Revenues were aggregated by tourism category to get the total revenue of each site by category ($R_{i,k}$). The total revenue per site (R_i) was obtained by summing $R_{i,k}$ across categories, and the total tourism revenue for the marine reserve (R) was obtained by summing all $R_{i,k}$ across sites. Revenue assigned to terrestrial tourism sites was systematically omitted from this analysis by not recording frequencies of visits to these sites but nonetheless dividing tour revenue by the ***total*** number of sites listed on each permit, marine ***and terrestrial***. These calculations are described by the following equations:

$$R_i = \sum_k \sum_j 26 \times v_{i,j} \times C_j \times CF_k \times \frac{P_j}{N_j}$$

$$R = \sum_i R_i$$

This approach assumes that any costs of amenities to cruises and diving live-aboards, such as lodging and food, were generated by the GMR, while the costs of amenities borne by day tour and land-based diving tourists could not necessarily be attributed to the GMR. The former group of tourists in fact slept and ate in the GMR, while the latter group was land-based.

Data Visualization

To map tourism site visits and revenue, site names were paired with geographic coordinate data from the Ecuador Ministry of Tourism database in Tableau. Sites without coordinates were assigned coordinates based on two GNP documents, "Technical Annex I. Maps and References of Visitor Sites for the Realization of Accessory Activities" and "2014 Galapagos Protected Areas Management Plan". Using ModelBuilder, data for the four tourism categories were exported into ArcMap 10.3.1 in the geographic coordinate system WGS 1984. The base map used for Galapagos was created in SeaSketch by the Sustainable Fisheries Group at UC Santa Barbara. Fishery data were exported into the map so that revenue distributions could be compared more easily.

Results

Mapping revealed clear spatial heterogeneity in tourism site visits and revenues across the GMR. This was true for total visits (Figure 1.3) and revenue (Figure 1.4) as well as for within each of the four tourism categories (see appendix: Figures A3 – A9). Cruises represented the majority of both tourism site visits at over 570,000 visits (64% of total visits; Figure 1.5) and revenues at $149.4 million (84% of total revenue; Figure 1.6). Diving live-aboards was second in both measures and grossed $18.9 million in revenue. Day tours made up over 15% of total annual visits at almost 130,000 visits, but only 3% of total revenue at $5.7 million. We estimated total annual visits in the GMR to be over 839,000 and tourism revenue to be $177.9 million annually. Of the 93 tourism sites, only Seymour Norte (Baltra) and Bartolome (Santiago) received over 30,000 total visits a year (see appendix: Figure A1, Table A2). These were also the only two sites to earn over $6.5 million. Revenues across the sites ranged from about $2,000 at Islote Five Fingers (San Cristobal) to over $6.6 million at Seymour Norte (see appendix: Figure A2, Table A3), and averaged over $1.9 million per site. Overall, visits (Figure 1.3) were more evenly distributed across categories than were revenues (Figure 1.4).

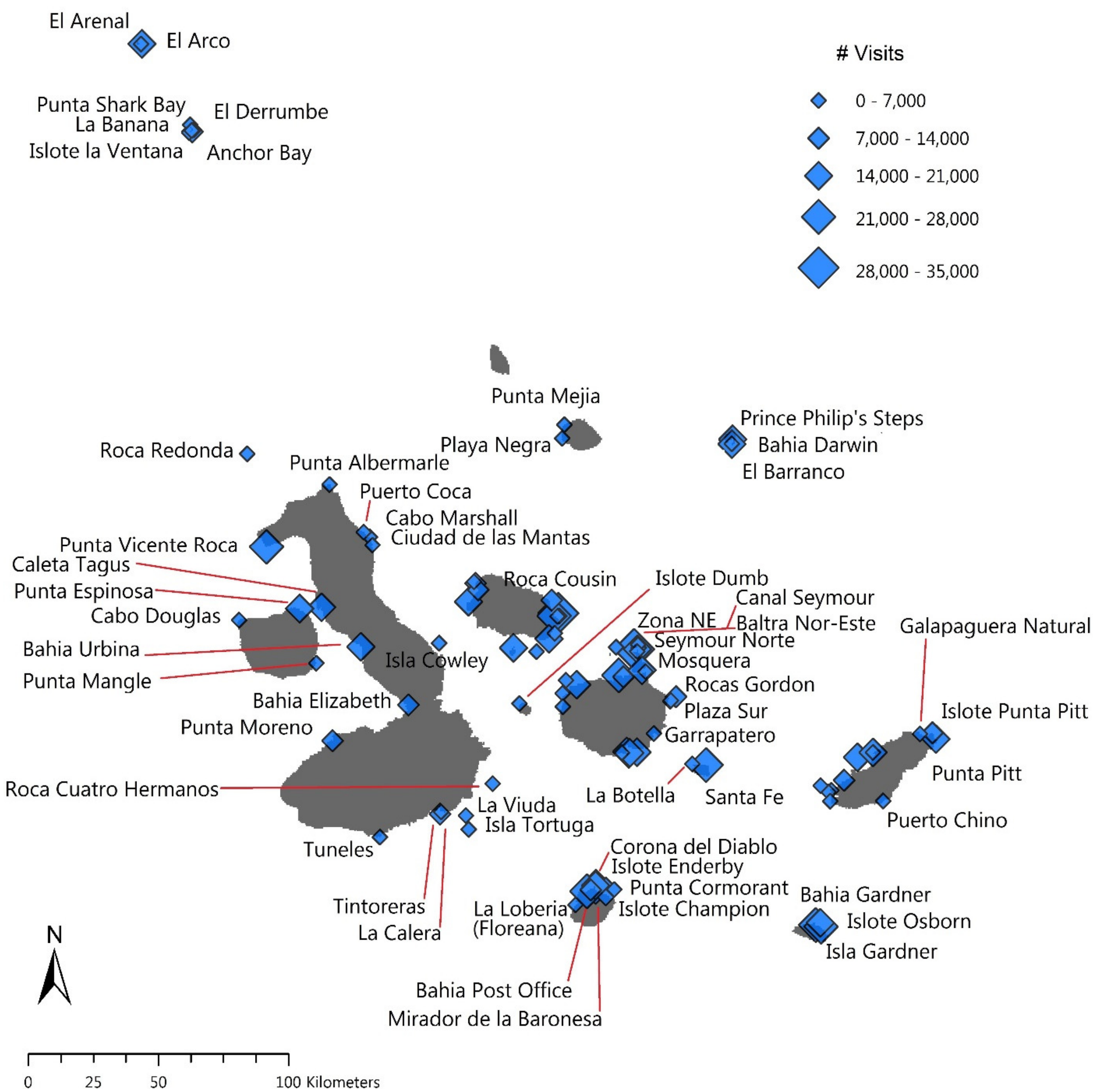


Figure 1.3. *Spatial distribution of estimated annual visits to marine tourism sites in the GMR. Blue diamonds indicate tourism sites and diamonds are sized based on the number of visits, with larger diamonds representing more visits and smaller diamonds representing fewer visits; symbology is given in the upper right-hand corner. Some tourism sites have been labeled for reference. See Figure 1.4 for remaining site locations.*

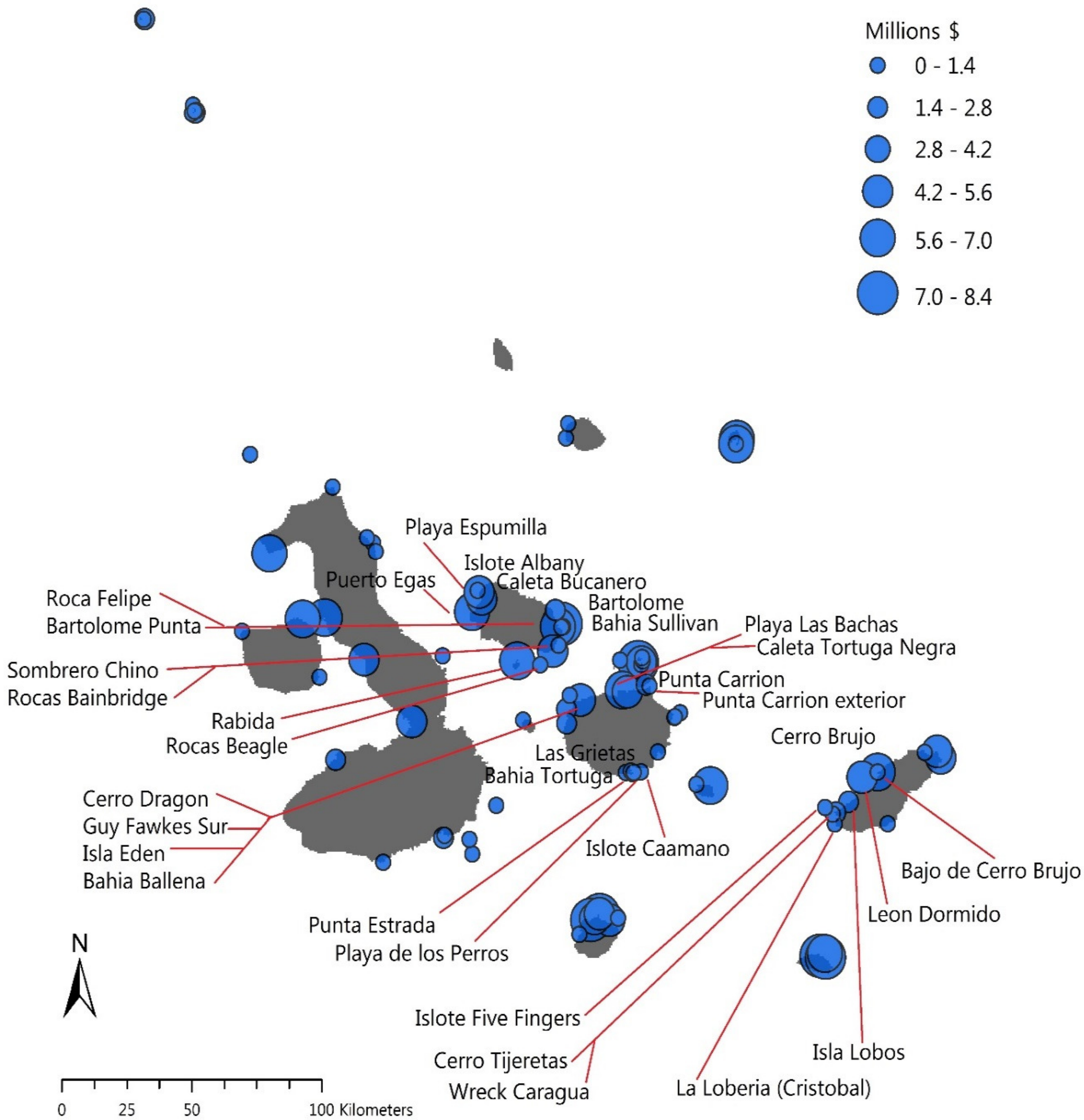


Figure 1.4. *Spatial distribution of estimated annual revenue (millions $) from marine tourism sites in the GMR. Blue circles indicate tourism sites, with larger circles representing more visits and smaller circles representing fewer visits; symbology is given in the upper right-hand corner. Some tourism sites have been labeled for reference. See Figure 1.3 for remaining site locations.*

Spatial Heterogeneity by Tourism Category

Cruises visited 53 of the 93 GMR tourism sites and revenues averaged over $2.8 million annually per site. The most visited sites in this tourism category were Seymour Norte, Bahia Gardner (Española), Bahia Post Office (Floreana), and Bartolome. Cruise revenues ranged from under $24,000 at Rocas Bainbridge (Santiago) to over $5.7 million at Bahia Gardner, Punta Cormorant (Floreana), and Seymour Norte (Baltra). **Diving live-aboards** accounted for over 89,000 visits and averaged over $484,000 across the 39 sites visited. El Arco (Darwin Island) was the most visited site in this category with a visitation rate more than double that of any other site. This site also more than doubled any of the other 39 sites in terms of revenue, generating nearly $3.4 million. The 18 sites visited by **day tours** had an average revenue of approximately $319,000, with Seymour Norte grossing the most at over $757,000. Sombrero Chino (Santiago), Isla Eden (Santa Cruz), and Bahia Ballena (Santa Cruz) were the lowest revenue generating sites in the day tour category at about $31,000 each. The most visited day tour sites were Playa de los Perros (Santa Cruz), Punta Estrada (Santa Cruz), Las Grietas (Santa Cruz), and Islote Caamano (Santa Cruz) at over 15,500 visits each. **Land-based diving** visits totaled just short of 51,000 a year and revenue averaged over $123,000 across the 31 sites visited. Within this category, Mosquera (Baltra) was the most visited site at just below 7,900 visits and generated the most revenue at almost $612,000.

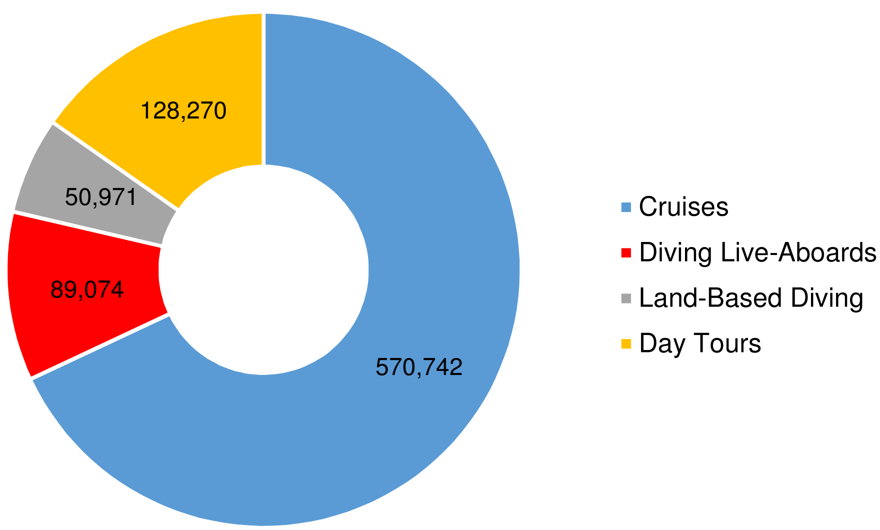


Figure 1.5. *Distribution of estimated annual marine visits by tourism category. Annual visits for cruises (blue), diving live-aboards (red), land-based diving (grey), and day tours (yellow) totaled 839,057.*

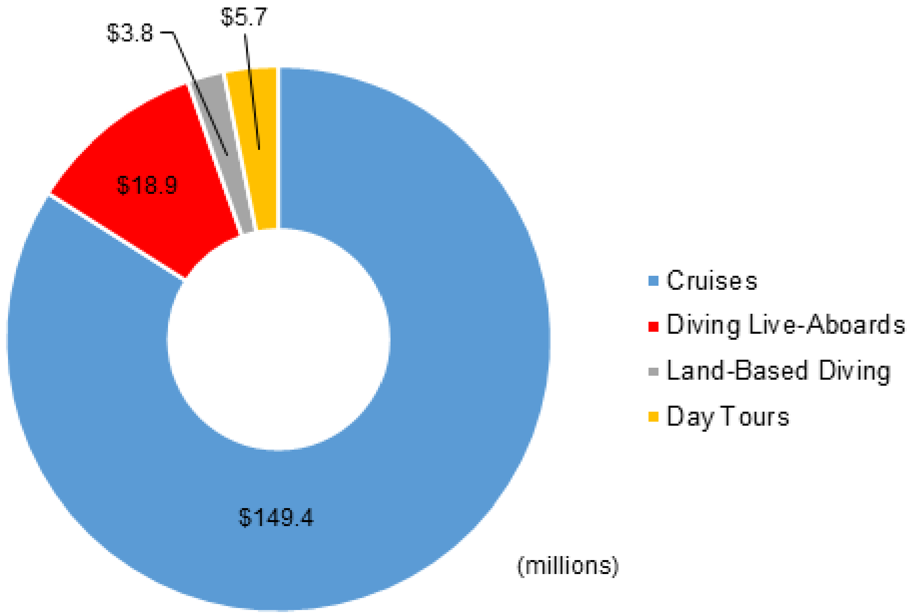


Figure 1.6. *Distribution of estimated annual marine-based revenue (millions $) by tourism category. Annual estimated marine tourism revenue for cruises (blue), diving live-aboards (red), land-based diving (grey), and day tours (yellow) totaled $177.9 million.*

Discussion

Our results highlight the relative economic importance of marine-based tourism to the tourism industry, and, consequently, the importance of marine-based tourism to the entire Galapagos economy. Our revenue estimates likely under-report the contribution of the marine environment to the tourism industry for a number of reasons. First, live-aboard cruises, which generate the largest amount of marine-based tourism revenue, are entirely dependent on the marine environment. Yet in our methodology, we apportioned revenue equally to all sites in an itinerary, which includes terrestrial sites. Second, the marine environment directly sustains much of the terrestrial wildlife attractions that make up the remaining portion of the tourism economy. Third, the majority of species portrayed in advertising by Galapagos tourism operators are either marine or directly rely on the sea for their survival (i.e., foraging, mating, etc.). These iconic species draw tourists to Galapagos who generate tourism revenues outside of marine-based activities, such as through the purchase of souvenirs.

Other studies have noted the relative importance of the marine environment to the Galapagos tourist experience. World Wildlife Fund (WWF) conducted exit interviews with tourists which revealed the number one trip highlight to be marine life and that, on average, tourists are willing to pay $240 more than the current $100 park entrance fee, if those funds were to be allocated to the GMR. Conversely, tourists are willing to pay only $140 in addition to the park entrance fee for terrestrial conservation (Schep et al., 2014). An independent study estimated that sharks found in the Galapagos Marine Reserve are the most valuable in the world in terms of revenue generated from marine-based tourism. A single hammerhead shark in Galapagos can generate up to $5.4 million over its lifetime (Lynham et al. 2015).

Improvements to this component of our study might be achieved if more data were available. For instance, the actual number of times a given operator visits a site was not available, and so correction factors had to be used; the price per tour was not readily available either. Other methodologies that capture the relative importance of the marine environment and specific aspects of the marine environment to the Galapagos tourism industry could be explored in the future. For example, the relative importance of iconic species or sites to tourists could be gauged through a study utilizing online marketing and reviews of Galapagos tourism.

Chapter 2.

Ecology as a Driver of Marine-Based Tourism in Galapagos

Analyzing the importance of ecological attributes in driving tourism site visits using statistical models

Overview

The Galapagos Islands are internationally famed for the unique creatures that inhabit their lands and waters. Tourists come from all over the world hoping and expecting to see its iconic species. Images of blue-footed boobies, giant tortoises, marine iguanas, and hammerheads dominate the souvenir stores of Galapagos. It is unclear, however, which biological features tourists really care about. It is also unclear if these biological preferences influence where tourists choose to visit during their time in Galapagos. Another way to think about this is that we currently do not know which ecological products of Galapagos are popular and which ones people actually buy. Answering these questions is fundamental to sustaining a successful tourism business and central in determining how best to prioritize protection of GMR resources.

We answered these two questions — which biological attributes tourists care about, and if tourists "buy" these biological attributes — specifically for marine-based tourism in Galapagos. Using multiple regression analysis, we determined whether ecological variables explain the sites that tourists visit. We found that ecological attributes do explain where marine-based tourists go during their time in Galapagos. We also found that tourists care about sharks and species richness, and different types of tourists care about different biological attributes. Together, these findings provide a very clear message: sustaining sharks and areas with rich, diverse ecosystems is critical for sustaining the marine-based tourism business of Galapagos. These findings also identify areas where win-win scenarios are possible — i.e. where conservation can greatly benefit both the Galapagos marine environment and the Galapagos economy. In the following chapter, we illustrate how the information our models provide, along with revenue data from Chapter 1, can be used to design NTZs and evaluate their costs.

I. Modeling Tourism Site Visits

Background

Different categories of Galapagos tourists fit different demographic profiles and have different preferences for their travel experiences. Wealthier, older visitors usually experience Galapagos via cruises, which offer fine dining, amenities, onboard activities, and easier travel. Sites are offered in bundles and so passengers select their cruise based on the bundle of sites and accompanying amenities. For this category of tourists, amenities may greatly influence which cruise tourists select, and consequently, which sites they visit. Diving live-aboards come to Galapagos specifically to dive in locations that offer incredible diving. They also pick a package of sites and the sites included relative to amenities offered more likely influences their cruise selection than for regular cruise tourists. In contrast to live-aboards, land-based divers and day tourists can select the specific sites they want to visit, constrained only by scheduling and possibly pricing.

Tourists in different categories engage with the Galapagos marine environment in very different ways. Cruises and day tours generally offer on-surface or near-surface activities such as snorkeling, kayaking, and swimming, while dive cruises and land-based dive trips are focused on dives and go deeper beneath the surface. On the other hand, live-aboards are able to reach locations remote from land-based tourism sites that are located in other bio-regions of Galapagos and so have access to a greater diversity of ecosystems. This influences what tourists in each category can see and expect to see in the marine environment. For example, it is unlikely for non-divers or land-based divers to see whale sharks or other, more pelagic, northern shark species. These important differences among tourism categories make it clear that a single model for explaining marine site visits by all tourists is not appropriate for the GMR. Instead, we constructed models for three tourism categories: cruises, diving live-aboards, and land-based diving.

Data & Methods

To investigate the relationship between visitation rates and the physical and biological attributes of sites, we conducted multiple linear regression models using RStudio software for R 3.2.2. We developed separate models for cruise, diving live-aboards, and land-based diving categories tourism categories to account for different tourism profiles. The day tour category was not included in our analysis due to insufficient data.

We regressed the number of visits to a site against average price per visits, distance, and ecological variables that we considered relevant for each category. We chose to include price to account for potential price sensitivity of tourists and also as a proxy for the amenities and luxury of the tourism experience. We included distance to port because distance influences the length of the trip and also what tourists can see and experience. Ecological variables included total species richness, endemic species richness, frequency of cetacean sightings, and the relative abundances of the following iconic species: sharks, turtles, sea lions, fur seals, penguins, sea birds, rays, and marine iguanas.

$$\mathrm{V} = \beta_0 + \beta_p + \beta_d distance + \sum_i \beta_i \,\mathrm{Ecological}_i + \in$$

Spatial data on endemic species richness and total species richness were obtained from GNP through the SeaSketch Galapagos project database. These data had been interpolated across the GMR with a 500 m^2 grid size. Records of cetacean sightings across the GMR were obtained from GNP. This 25-year dataset (1986 to 2011) includes sightings of 36 different species of six families: Balaenopteridae (n = 850), Delphinidae (n = 1,207), Kogidae (n = 7), Otaridae (n = 363), Physeteridae (n = 175), Ziphiidae (n = 36). Data on the relative abundances of iconic species were obtained from GNP as part of the INCOFISH project carried out in 2006 - 2007. The data were obtained through visual surveys done either snorkeling or SCUBA diving at 48 tourism sites distributed across the GMR. The relative abundance of a species *i* at a site *j* was defined as:

$$D_{i,j} = \frac{S_{i,j} + 2F_{i,j} + 3M_{i,j} + 4A_{i,j}}{N_j}$$

where N_j is the number of visual surveys conducted at site *j* and $S_{i,j}$, $F_{i,j}$, $M_{i,j}$, $A_{i,j}$ are the number of times species *i* was seen in the following four abundance categories: Single (1 individual), Few (1-10 individuals), Many (10 - 100 individuals) and Abundant (>100 individuals). For our analysis, we aggregated the relative abundances of five shark species – whale sharks, Galapagos sharks, silky sharks, hammerhead shark and whitetip shark – into a single metric of shark abundance.

Additionally we obtained an ecological database of occurrence of charismatic species (i.e., sharks, rays, sea lions, and turtles). This database was collected by the Charles Darwin Foundation (CDF) using SCUBA diving transects at two depths (10 and 25 meters) at 81 sites across the GMR with an average of ten transects per site. As a proxy for frequency of sighting, we estimated the number of individuals per transect for each site and species in this dataset. We used both ecological datasets in our analysis.

For the cruise, diving live-aboard, and land-based diving categories we examined nine, eight, and five different models, respectively. In each case, we regressed the number of visits per year against the average price per visit ($), distance from port (km), and a combination of ecological variables that could be considered relevant for tourists in each tourism category. The number of sites in each model varied depending on the dataset used for iconic species.

Results

Cruises

In all the models examined in this category (see appendix: Table A1), the variables of endemic species richness, total species richness, incidence of cetaceans and the relative abundance of seabirds and marine iguanas showed a positive correlation with the number of site visits. In six of the nine models, only total species richness was significantly correlated with number of visits ($p < 0.05$). The relative abundances of sea lions, turtles, and sharks were consistently and negatively correlated with the number of site visits, however none of these variables were significant. The signs of the correlation coefficients for the remaining ecological variables analyzed were not consistent across all models.

The models that did not include relative abundances of iconic species had the highest sample size ($n = 53$; see appendix: Table A1, models 1 and 2). These models significantly predicted the number of visits to a site ($p < 0.001$) and in both cases total species richness and average price per visit showed a positive and significant correlation with the number of site visits ($p < 0.001$). The models that included relative abundance of iconic species had a lower sample size ($n = 27$; see appendix: Table A1, models 3 - 9) and did not significantly predict number of site visits.

The correlation coefficients of the physical variables included are not consistent across all models. The average price per visit shows a significant and positive correlation in the two models with the highest sample size and a negative and non-significant correlation for the remaining models. Distance from nearest port shows a positive correlation for all except one of the models.

Diving Live-Aboards

In all the models examined in this category (Table 2.1), the relative abundance of sharks and the average price per visit were positively correlated with the number of site visits. The relative abundance of sharks was significantly correlated with visits in five of the eight models examined and price was significant in four models. In contrast, distance from nearest port was consistently negatively correlated with site visits although not significant. The signs of the correlation coefficients for the remaining variables analyzed were not consistent across all models.

The models that incorporated the dataset of *relative abundance* of iconic species (Table 2.1, odd model numbers) had a sample size of 21 sites and all models significantly predicted the number of site visits ($p < 0.001$). In comparison, the models that used the dataset of *occurrence* of iconic species (Table 2.1, even model number) had a smaller sample size of 17 sites and only two out of four models were significant.

Table 2.1. *Results of diving live-aboard regression models.*

	Dependent variable: Diving Live-aboard Visits							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Price	60.3***	39.2	64.0***	52.3	70.3***	52.4	100.2***	52.4
Distance	-0.1	-2.9	-0.5	-9.7	-2.8	-10.2	-17.7	-9.8
Endemic Richness	220.3	-155.8	171.2	-378.8	206.1	-428.4	-319.7	-369.9
Total Richness	-6.7	-8.0	-2.7	-40.3	-2.3	-49.0	26.4	-41.4
Sharks	1,278.8***	589.5**	1,435.5***	580.7**	932.9	579.9**	645.1	578.9
Turtles			-2,201.7	4,655.1	6,317.1	5,047.3	11,321.7	4,670.4
Rays					-6,245.6	404.8	-9,910.3**	98.6
Sea lion							-4,613.9	-6,608.7
Intercept	-9,268.5**	-2,894.5	-9,965.1**	88.6	-11,088.0**	1,273.6	-14,510.9***	206.7
Observations	21	15	21	15	21	15	21	15
Adjusted R^2	0.85	0.58	0.84	0.61	0.86	0.56	0.88	0.49
Residual Std. Error	1,348.2 (df = 15)	2,394.4 (df = 9)	1,376.6 (df = 14)	2,306.0 (df = 8)	1,299.5 (df = 13)	2,459.7 (df = 7)	1,191.8 (df = 12)	2,641.1 (df = 6)
F Statistic	23.8*** (df = 5; 15)	4.9** (df = 5; 9)	19.1*** (df = 6; 14)	4.6** (df = 6; 8)	18.8*** (df = 7; 13)	3.5 (df = 7; 7)	19.9*** (df = 8; 12)	2.6 (df = 8; 6)

Note: **p<0.05; ***p<0.01

Land-Based Diving

In all the models examined in this category (Table 2.2) the relative abundance of sharks was positively and significantly correlated with the number of sites visits ($p < 0.05$). Distance from nearest port, total species richness, and relative abundance of rays were positively correlated with site visits although not significantly. Average price per visit, endemic species richness and the relative abundances of sea lions and turtles were negatively but not significantly correlated with the number of site visits. Two of the five models examined significantly predict the number of site visits ($p < 0.05$).

Table 2.2. *Results of land-based diving regression models.*

	Dependent variable:				
	Land-based Diving Visits				
	(1)	(2)	(3)	(4)	(5)
Price		-246.7	-222.1	-317.8	-259.6
Distance	16.2	19.0	17.5	12.7	25.1
Endemic Richness	-444.4	-775.3	-672.0	-947.3	-820.0
Total Richness	10.3	48.4	41.3	73.8	59.7
Sharks	30,003.7***	28,614.2***	28,790.5**	27,825.0**	35,092.5**
Rays			727.2	197.6	453.5
Sea lion				-3,908.9	-2,496.2
Turtles					-12,825.1
Intercept	1,539.9	18,103.3	16,397.6	22,480.4	18,135.8
Observations	14	14	14	14	14
Adjusted R^2	0.49	0.53	0.47	0.50	0.52
Residual Std. Error	1,888.7 (df = 9)	1,810.0 (df = 8)	1,910.5 (df = 7)	1,866.7 (df = 6)	1,823.8 (df = 5)
F Statistic	4.1** (df = 4; 9)	3.9** (df = 5; 8)	2.9 (df = 6; 7)	2.8 (df = 7; 6)	2.7 (df = 8; 5)
Note:					**p<0.05; ***p<0.01

Discussion

Cruises

The results of the models in this category suggest that the total species richness at a site is strongly and significantly correlated with the number of tourists that visit that site. Similarly, the richness of endemic species, the occurrence of cetaceans, and the relative abundance of seabirds, are positively correlated with the number of visits. Even though these three variables were not significant in the model, we consider them to be important ecological attributes that may enhance the tourism experience.

None of the other ecological variables regarding individual species abundance seem to have a significant or consistent correlation with site visits. Because the variables of total and endemic species richness already capture presence of the individual species analyzed, we argue that the lack of significance and correlation may be a reflection of tourist's interest in total biodiversity and endemism rather than in the abundance of a specific species.

Using the results of the models and a conceptual understanding of the potential ecological attributes that interest this particular category of tourist, we selected the model that regressed visits against price, distance, total species richness, endemic species richness, and occurrence of cetaceans as the most robust model (Table 2.3). In this model the average price per visit is positively correlated with the number of visits suggesting a counterintuitive relationship between price and visitation rates. One explanation for this relationship is that tourists in this category may have very low price sensibility and/ or that they consider the luxury of the boat an important factor of the tourism experience.

Finally, it is important to recognize that we cannot infer causation from our analysis – that is, the high abundance of sharks, for example, is not necessarily why there are more site visits in one site versus another. There may be covariates or other ecological variables of importance that were not considered in this analysis. Nevertheless, these results present strong evidence that tourists in this category visit places with highest biodiversity, endemism, and occurrences of cetaceans.

Diving Live-Aboards

The results of the models in this category suggest that the number of tourists that visit a site (i.e., number of dives) is strongly and significantly correlated with the relative abundance of sharks at a given site.

None of the other ecological variables regarding individual species abundance has a significant and consistent correlation with site visits. We argue that this lack of significance and correlation may be a reflection of a very specific interest of the tourists in this category. Galapagos is widely considered one of the best destinations in the world to SCUBA dive with sharks. In particular, the opportunity to dive with huge aggregations of hammerheads, Galapagos, and silky sharks is highly advertised by tourism agencies that offer tours in this tourism category. This focus on a particular species may be overshadowing the importance of conceptually robust variables such as total biodiversity and endemism.

For this category, we selected the model that regressed visits against price, distance, total species richness, endemic species richness, and the relative abundance of sharks as the most robust (Table 2.3). In this model the average price per visit is again positively correlated with the number of visits suggesting a counterintuitive relationship between price and visitation rates. The same argument used to explain this relationship in the cruises category might apply for this category: tourists have very low price sensibility and/ or they consider the luxury of the boat an important factor of the tourism experience.

Once again, it is important to recognize that we cannot infer causation from our analysis. However, these results present strong evidence that tourists in this category visit significantly more sites with high abundances of sharks than sites with low abundances.

Land-based Diving

Similar to the diving live-aboard category, the results of the models for the land-based diving category suggest that the relative abundance of sharks at a given site is strongly and significantly correlated with the number of tourists that visit that site (i.e., number of dives). None of the other ecological variables regarding individual species abundance have a significant and consistent correlation with site visits. A similar situation to the one in the diving live-aboard category might be occurring here: a strong preference for sharks overshadows other conceptually robust variables. However, contrary to the live-aboard category, total species richness is consistently positively — but not significantly — correlated with number of visits. This makes conceptual sense and suggests that the exclusive preference for sharks may not be as strong in this category.

In this case, we selected the model that regressed visits against distance, total species richness, endemic species richness, and the relative abundance of sharks as the most robust (Table 2.3). We excluded price because within a single dive company the price of a dive tour does not change by site visited.

Again, it is important to recognize that we cannot conclude that the relative abundance of sharks predicts the number of visits to a site. However, our results present strong evidence that tourists in this category visit significantly more sites with highest abundances of sharks than they do sites with low abundances.

Table 2.3. *Results of selected regression models.*

	Dependent variable:		
	Cruise Ship Visits	Liveaboard Dives	Land-Based Dives
Price	47.9^{*}	60.3^{**}	
Distance	18.5	-0.1	16.2
Endemic_Richness	798.0	220.3	-444.4
Total_Richness	187.7^{**}	-6.7	10.3
Cetaceans	65.1		
Sharks		$1,278.8^{**}$	$30,003.7^{**}$
Intercept	$-30,120.8^{**}$	$-9,268.5^{*}$	1,539.9
Observations	53	21	14
Adjusted R^2	0.21	0.85	0.49
Residual Std. Error	6,777.1 (df = 47)	1,348.2 (df = 15)	1,888.7 (df = 9)
F Statistic	3.8^{**} (df = 5; 47)	23.8^{**} (df = 5; 15)	4.1^{*} (df = 4; 9)
Note:			$^{*}p<0.05$; $^{**}p<0.01$

Chapter 3.

The Spatial Economics of Expanding Conservation in the Galapagos Marine Reserve

Using the spatial distribution of fishery revenues to evaluate the costs of three no-take zone scenarios

Overview

The previous two chapters revealed the importance of marine-based tourism to the larger Galapagos economy and the importance of ecology in driving the spatial distribution of marine-based tourism. Together, these findings strongly argue that sustaining the marine resources of Galapagos is integral to the economic success of Galapagos. In this chapter, we illustrate how environmental managers can utilize the findings presented in the previous chapters to inform the design and evaluation of NTZs. NTZs provide managers with an important tool for protecting marine resources. By prohibiting extraction of marine resources in specific areas, NTZs allow managers to selectively protect areas that may be more ecologically vulnerable to impacts, harbor threatened species, or comprise key habitat (e.g. nursery, breeding, or feeding grounds) for economically valuable species.

The design and placement of NTZs can greatly influence their associated benefits and costs (Caveen et al. 2015). If well designed, NTZs can deliver on their potential benefits of improved ecosystem health and population recovery and/ or replenishment of key species. If poorly designed, they may provide little or no benefit. The placement of NTZs also greatly influences their benefits and costs. If placed in an area of importance to economically valuable species, a NTZ is likely to provide great benefit to those species. However, such protection may also come at a high cost. For example, if a NTZ is placed in lucrative fishing grounds, it may provide considerable protection of key fisheries species, but at a high cost to fishermen, which undermines the political feasibility of the NTZ being implemented, and further undermines the likelihood of success due to poor compliance with zoning restrictions.

Ideally, NTZ scenarios can be designed and placed to maximize the benefits conferred by protection while minimizing costs to fishermen. This principle guides the content of this chapter, which proceeds as follows. First, we identify three hypothetical NTZs that have high potential benefits because they coincide with the distribution of economically valuable species. Second, we evaluate the costs to fishermen under each NTZ scenario. Third, we evaluate the costs to GNP visitors if the costs to fishermen are entirely redistributed to tourists. We find that redistributing fishery losses poses a very minimal fee to visitors. We conclude that if redistribution is pursued, implementing

NTZs is an economically feasible and inexpensive option for protecting marine resources of value to both marine-based tourism and fisheries. In the next, and final chapter we imagine how expanded conservation can be funded and supported through programs to improve fishers' livelihoods, enhance monitoring and enforcement, and offset the short-term costs of conservation to fishermen.

I. No-take Zone Scenarios

Background

The three hypothetical NTZs evaluated in this chapter were designed to include areas rich in the ecological variables found to be important in our models for tourist visits. In addition, the three sites chosen are iconic to Galapagos tourism. Darwin and Wolf islands are world-famous dive destinations and provide important habitat to large populations of top predators and megafauna. Northern Santa Cruz region is an important region for live-aboard cruises, daily diving, and day tours. Similar to Darwin and Wolf islands, northern Santa Cruz attracts large schools of shark species. Western Isabela is unique for the many endemic species found there, such as Galapagos penguins, Galapagos fur seals, and flightless cormorants, as well as several cetacean species.

Data & Methods

We obtained shark telemetry data for five different species: whale shark (n = 37), Galapagos shark (n = 5), hammerhead shark (n = 19), silky shark (n = 16), and blacktip shark (n = 10). These data were obtained from GNP and are part of a satellite tagging project conducted between 2012 and 2014 by researchers from the Universidad San Francisco de Quito and the CDF. For each individual shark tagged, the data contain the geographic location of each satellite signal received as well as the connectivity routes across the GMR. We used ArcMap 10.3.1 to visualize the data and conducted an Optimized Hot Spot Analysis to create a map of statistically significant shark incidence hotspots (Figure 3.1). Similarly we created a cetacean sighting hotspot map (Figure 3.2) using the dataset provided by GNP and the Optimized Hot Spot Analysis tool in ArcMap 10.3.1.

Additionally, we obtained spatial data on key habitats for endemic species. Data on nesting and feeding grounds as well as connectivity between islands were obtained for Galapagos penguins. Similarly, we collected data on feeding grounds of Galapagos fur seals and Galapagos sea lions, nesting and feeding grounds of endemic flightless cormorants, and spatial abundances of marine iguanas. These data were provided by GNP and correspond to research and monitoring conducted by the CDF and GNP.

We used the maps of shark and cetacean hotspots in combination with the critical habit of endemic species to identify three priority areas for placement of NTZs (Figures 3.1 - 3.2).

II. Evaluative Framework for NTZ Scenarios

Data & Methods

An evaluative framework was created to illustrate how spatial revenue data can be utilized by fishery managers to economically assess different NTZ scenarios. It was designed to capture the cost to fishermen of implementing a NTZ, the cost-effectiveness of the zoning scenarios, and the potential costs to tourists of compensating fishery losses. The framework uses four economic measures:

1. Cost = Fisheries profits lost due to implementation of NTZ,
2. Cost per area = Cost / Area of NTZ (km^2),
3. Percent impact to fisheries = Cost / Total fisheries profits in the GMR, and
4. Blanket fee to offset cost to fisheries = Cost / Total # of GNP visitors.

We determined NTZ areas and associated revenues in ArcMap 10.3.1. Fishery profits were estimated as 30% of revenue based on reported profit margins for artisanal fishers found in the literature (Hearn, Murillo, and Reyes 2007). The blanket fee refers to a possible mechanism to raise funds to offset fishery losses whereby tourists are charged an extra entrance fee to directly support marine conservation. The total number of GNP visitors was obtained from GNP's annual visitor report for 2014.

Results

Our methodology allowed us to identify three priority areas for the placement of NTZs. The first area is in the northern region of Galapagos around the islands of Darwin and Wolf (Figure 3.1). This region presents the highest shark incidence in our analysis and recent research suggests that it may hold the highest shark biomass on the entire planet (Salinas de Leon et al, in press). The area encompasses 38,000 km^2, receives about 43,000 visits per year and generates around $9.7 million in tourism revenue each year. The second priority area, identified by its high abundance of sharks, is to the north of Santa Cruz Island (Figure 3.1). This area encompasses 1,600 km^2, receives around 126,000 visits per year, and generates $20 million in marine tourism revenue annually. The last priority region is in the western side of Isabela and Fernandina Islands (Figure 3.2). This region represents high species diversity, presents critical habitat for many endemic species and holds the highest incidence of cetaceans in the GMR. This area encompasses 12,500 km^2, receives around 98,000 visits per year, and generates around $25 million in marine tourism revenue. Together, these three priority regions represent 39% of the total area of GMR and generate a third of all marine tourism revenue.

The three NTZ scenarios (Figures 3.1 and 3.2) evaluated are heterogeneous in the amount of area they protect, their costs to fishermen, cost effectiveness (i.e. cost to protect/ area), impact on fisheries, and cost per tourist to compensate fisheries losses (Table 3.1). The three NTZs vary greatly in size from 1,663 km^2, or 1.25% of the GMR (Northern Santa Cruz), to 38,000 km^2, or 28.6% of the GMR (Darwin and Wolf). Closing Darwin and Wolf poses the greatest potential loss of profit to fishermen at $98,260 per year, or nine percent of total fishery profits, while Northern Santa Cruz poses the least potential loss of profit to fishermen at $4,660 per year, or 0.4% of total fishery profits. However, because the area of the Darwin and Wolf NTZ is so much larger, Darwin and Wolf actually has the lowest cost per area – i.e. greatest cost effectiveness – of all the NTZs evaluated at $2.59 per km^2; Western Isabela poses the greatest cost at $7.79 per km^2.

Redistributing the costs of NTZs to the industry that most greatly benefits from conservation – tourism – may be necessary to make expanded conservation a political reality. Over 215,000 tourists visit Galapagos each year, while there are only about 400 active fishers in Galapagos, so redistribution greatly lowers the financial burden of expanded conservation on individuals. In fact, if everyone who visited the Galapagos paid fishermen directly to offset their profit losses, each visitor would only need to pay $0.46 to protect Darwin and Wolf, $0.02 to protect Northern Santa Cruz, and $0.45 to protect Western Isabela. To put this into perspective, visitors currently pay a total of $120 to enter GNP. The cost per visitor to directly compensate fishermen is less than 0.8% of the current entrance fee.

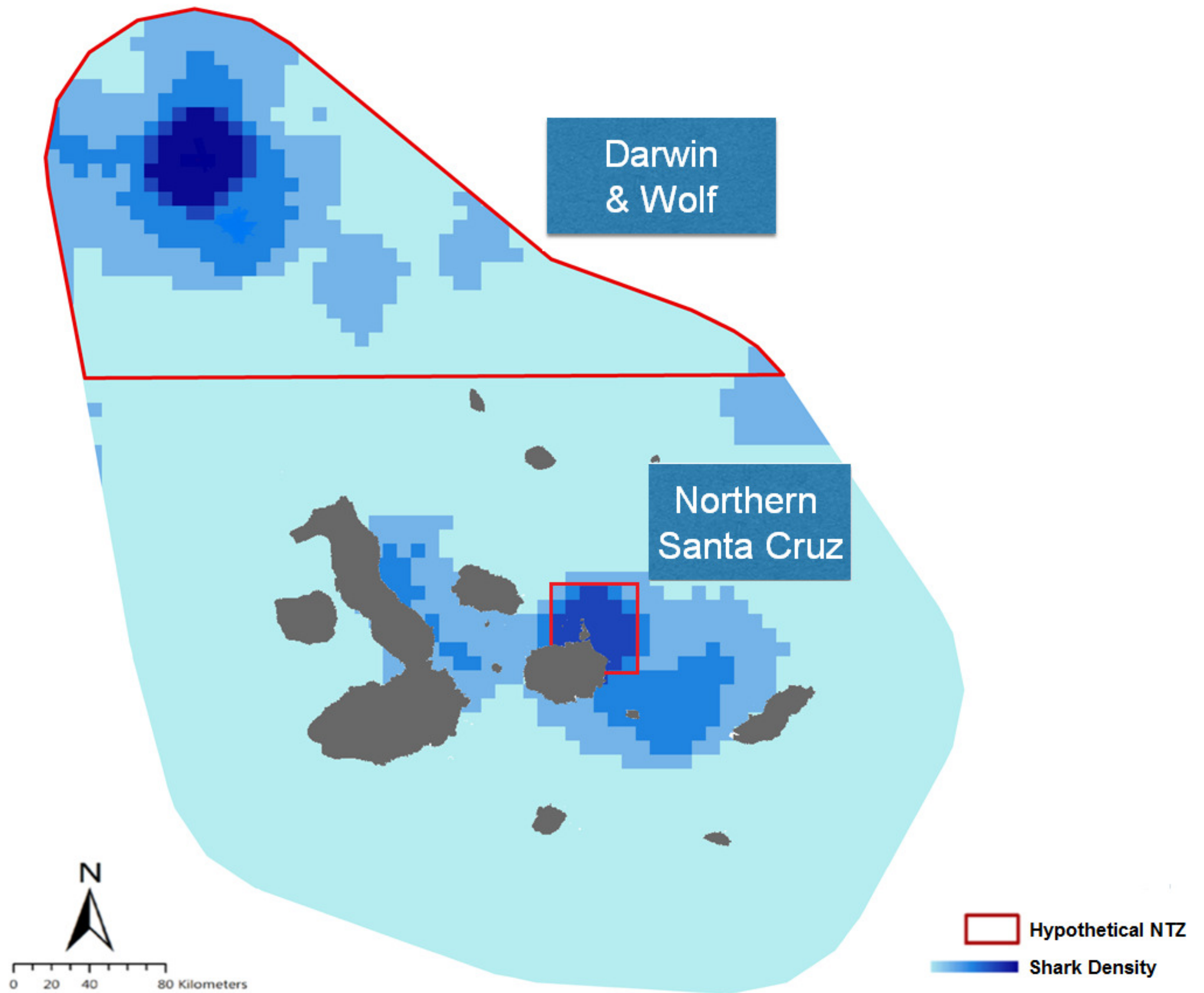


Figure 3.1. *Shark density hotspots in the GMR. Darker blue pixels indicate higher shark density and lighter blue pixels depicts lower density. Red lines outline the Darwin and Wolf and Northern Santa Cruz NTZ scenarios.*

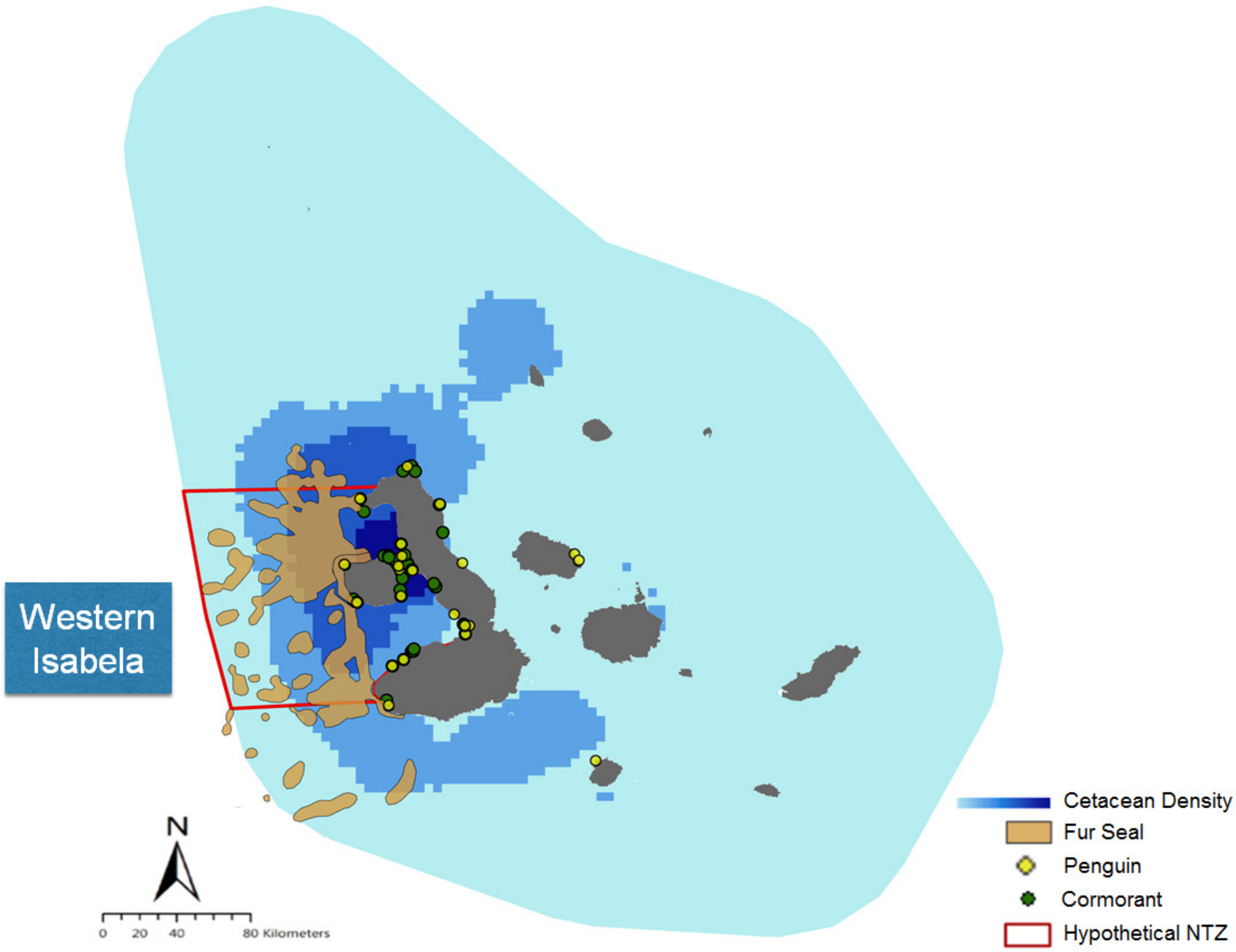


Figure 3.2. *Cetacean density hotspots in the GMR. Darker blue pixels depicts higher cetacean density and lighter blue pixels depicts lower density. Brown areas represent fur seal feeding grounds. Yellow points show nesting and feeding grounds of Galapagos penguins. Green points show nesting and feeding grounds of flightless cormorants. The red line outlines the NTZ scenario.*

Table 3.1. *Evaluative framework: area protected, costs, and compensatory fees of three NTZ scenarios.*

NTZ Scenarios	*Area (km^2)*	*% Area of GMR*	*Cost ($ per year)*	*Cost per unit area ($ per km^2)*	*% Impact*	*Blanket Fee ($ per GNP entry)*
Darwin and Wolf	38,000	28.6	98,260	2.59	9.0	0.46
Northern Santa Cruz	1,663	1.25	4,660	2.80	0.4	0.02
Western Isabela	12,555	9.44	97,830	7.79	9.0	0.45

Discussion

The results of the evaluative framework suggest that protecting large portions of the GMR is economically feasible and potentially quite cheap, if costs can be redistributed from fishers to tourists. However, while the results of the framework can be interpreted as very rough estimates of potential costs to fishermen, they should not be interpreted as the amounts that will be needed to compensate fishermen for closing fishing grounds, if such a mechanism is to be implemented. There are a number of reasons why our analyses may be underestimating the costs to compensate fishermen. First, the spatial data used in this analysis does not capture all fishery revenues. Whitefish landings are self-reported, which means that the dataset used does not capture all catch. Therefore, we could be significantly underestimating whitefish profit losses to fishermen. In addition, 15% of the lobster landing data by revenue, and 10% of the whitefish landing data by revenue could not be used due to inadequate spatial data.

While it is clear that data limitations led us to underestimate fishing profit losses in one phase of our methodology, we made a key assumption that tended to overestimate losses. Our calculations assume that in displacing fishermen from a particular area, profits from that area are entirely lost. This is unlikely to be the case. Instead, displaced fishermen will increase effort at current fishing sites and/ or seek alternative sites to compensate for lost profits (Bucaram et al. 2013). This makes it unlikely that fishermen will experience full potential profit loss due to site closure. Nevertheless, offering compensation based on historic profits in NTZs will likely be important to win fishermen buy-in and encourage compliance.

Even if profit losses have been significantly underestimated, the costs to tourists of compensating fishermen under direct redistribution remain nominal. For example, if profits are in reality three times greater than those reported in this analysis, the cost to tourists would still be less than $1.50 for Darwin and Wolf or Northern Santa Cruz. While it is useful to think of the costs of conservation as the cost to tourists to offset fishery profit losses, in reality, direct redistribution is not possible. Some sort of redistribution mechanism would be needed, which adds transaction costs and increases the real cost to tourists of compensating fishery profit losses. The mechanisms by which redistribution and compensation could occur and their estimated costs are further explored in the following chapter.

Although the evaluative framework does not provide precise estimates of the costs of expanding NTZs, it does provide a useful heuristic for comparing among NTZ scenarios. Of the three scenarios evaluated, establishing a NTZ in Darwin and Wolf is particularly attractive for a number of reasons. First, Darwin and Wolf offer the cheapest conservation per unit area in terms of costs to fishermen. Second, studies suggest that reserves with a higher proportion of NTZs are cheaper to enforce per km^2 (Ban et al. 2011). As the Darwin and Wolf NTZ protects 29% of the reserve, it would greatly increase the proportion of NTZs and will be cheaper to enforce compared to implementing many small reserves. Third, the waters surrounding Darwin and Wolf are home to some of the highest abundances of sharks in the world and one of the only places on the planet where visitors can see thousands of hammerhead sharks schooling together. Fourth, illegal harvesting of sharks often occurs in the region, which could be minimized through increased monitoring and enforcing as a consequence of NTZ designation (Carr et al. 2013; Schiller et al. 2014). Finally, Darwin and Wolf are the islands most distant from the inhabited islands of Galapagos, thus more costly to fish due to the high cost of fuel.

Chapter 4.

Achieving Expanded Marine Conservation in the Galapagos Marine Reserve

Overview

Expanding marine conservation in the GMR is economically feasible and important to the continued health and growth of the Galapagos economy. However, implementing such a policy will face a number of challenges. Most importantly, the support and cooperation of Galapagos fishers is essential for any new zoning plan to succeed in its conservation objectives. In this chapter, we explore different strategies for raising revenue that will fund programs to compensate fishers for profit losses caused by NTZs, improve monitoring and enforcement, and support fishers' economic development. In doing so, we offer possible scenarios to make the expansion of marine conservation feasible, effective, and beneficial to the entire Galapagos community.

This chapter is divided broadly into four sections. In the first section, we discuss and analyze methods for generating revenue. In the second section, we discuss and provide cost estimates for compensating fisher losses and enhancing monitoring and enforcement efforts in the GMR. In the third section, we illustrate three possible scenarios of revenue generation and allocation and provide monetary estimates for each. In the final section, we describe programs in which unallocated funds can be invested to improve fishers' livelihoods and also assess the financial feasibility of implementing such programs under each scenario.

I. Revenue Options

Fee Types and Fee Payers

New sources of revenue would be required to fund the compensation of fishers and programs to enhance the long-term sustainability of Galapagos fisheries. We propose generating revenue from two groups of GMR users — tourists and tourism operators — who are the primary beneficiaries of NTZ expansion. Revenue could be generated from these groups in two ways: a blanket fee, or a use-based fee. A "blanket fee" refers to a fee that is applied to all users, regardless of the intensity of their use of the newly established NTZs. A "use-based fee" refers to a fee that is applied to users based on their use of NTZs, so that a tourist who visits Darwin, for example, is charged a premium for visiting a protected site while a tourist who only visits unprotected sites is not charged a fee at all.

Each of the four possible fee mechanisms has its advantages and disadvantages (Table 4.1). A blanket fee applied to either fee payer is generally preferred as it is logistically simpler, has lower transaction costs, is associated with inelastic demand — that is, the number of visitors or operators will not diminish significantly due to a price increase—and a larger number of cost-bearers relative to its use-based counterpart. The principal advantage of a use-based fee is that it is likely to be perceived as more fair, which may reduce opposition to the new fee and help justify such policies. Charging tourists rather than permit-holders also has a number of notable advantages. First, there is a much larger pool of fee payers from which to generate revenue — 223,587 visitors are predicted to arrive in Galapagos in 2015, while there are only 119 permitted tourism operators in Galapagos ("Boletin Galapagos: Estadisticas de Demanda, Oferta Y Economia Del Turismo En Las Islas" 2015). This means that the cost per individual fee-payer can be much lower and more revenue can potentially be generated. Second, the number of tourists has been steadily increasing over time; it seems likely that such a trend will continue, at least in the next ten years, which translates into a growing source of revenue over time. Finally, tourists are unlikely to generate local opposition to a fee hike.

Table 4.1. *Advantages (green) and disadvantages (red) of four fee mechanisms.*

	Fee Payer			
Fee Type	Tourists		Tourism Permit-holders	
Blanket	Logistically simple	Only small portion goes to GMR if part of entrance fee	Logistically simple	Small number of cost-bearers
Blanket	Large number of cost-bearers		Current itinerary prices are only a small proportion of profits	Itinerary fees go to the GNP
Blanket	Number of tourists increasing with time			Opposition from tourism operators
Blanket	Inelastic demand		Inelastic demand	
Blanket	Low transaction costs		Low transaction costs	
Blanket	Existing channel of income generation		Existing channel of income generation	
Blanket	Large source of potential revenue			
Use-based	More "fair" (those who benefit most, pay most)	Logistical nightmare	More "fair" (those who benefit most, pay most)	Small number of cost-bearers
Use-based		No existing channel of income generation	Existing channel of income generation	
Use-based		Small number of cost-bearers	Current itinerary prices are only a small proportion of profits	Itinerary fees go to the GNP
Use-based		High transaction costs	Enables use of pricing as a management tool in the future	Opposition from tourism operators

Three of the options presented — a blanket fee on tourists and permit-holders, and a use-based fee on permit-holders — utilize revenue generation channels already in existence. All foreign tourists are currently charged a $100 entrance fee to enter GNP, as well as a $20 fee specifically to fund the Consejo de Gobierno de Galapagos, the governing body of the Galapagos province; Ecuadorian nationals are charged a six dollar entrance fee, while locals are not charged any fee. Both fees are mandated under the Galapagos Special Law. These pre-existing channels make it politically easier and institutionally feasible to increase the entrance fee or add another fee specifically to fund protection of the GMR. Similarly, tourism operators are charged annually for their permits, which dictate operator itineraries and are priced based on tourism category and maximum capacity. Increasing permit fees across the board, or adding a premium to itineraries that visit NTZs would be institutionally simple to accomplish. By law, five percent of tourist entrance fee revenue is allocated to the GMR. However, we have not been able to identify the proportion of operator permit revenue allocated to the GMR.

Revenue Streams

The four categories of fees outlined in the previous section differ in the amounts of revenue they can potentially generate. In this section, we calculate the revenue streams for three categories of fees: a blanket fee on tourists, a blanket fee on tourism permit-holders, and a use-based fee on tourism permit-holders. We have not considered a use-based fee on tourists because it would be logistically complex and require an entirely new system of fee collection to be created, along with having other notable disadvantages (see Table 4.1).

A. Blanket Fee on Tourists

To determine the revenue that would be generated by a blanket fee on tourists, we first needed to construct a model that would predict future visits under a price increase. The following model was used to regress the number of visits against year (t), fee (F) and GDP (I) for both national and foreign visitors.

$$V = a + e^{bt} + cF + dI$$

For foreign visitors, we used the per capita GDP of OECD (Organization for Economic Co-operation and Development) countries, while for national visitors we used the per capita GDP of Ecuador. Price of the park entrance fee over time was the nominal price of the entrance fee ($100 in 1998) corrected for inflation.

Our non-linear equation for tourism visits reliably models the historical number of visitors over time (Figure 4.1); this justifies our use of the model to predict the number of visitors that will come to Galapagos in the next ten years given a particular entrance fee price.

In addition, the model illustrates that price has a minimal effect on the number of international visitors, as the number of predicted visitors decreases by only nine for every one dollar increase in fee (Table 4.2). The inelasticity of visitor demand is also supported by Figure 4.2, which shows the number of visitors over time and indicates the year when the $100 entrance fee was first implemented. It is clear that the implementation of the $100 entrance fee in 1998 had no effect on the number of visitors to Galapagos. In fact, the number of visitors continued to rise.

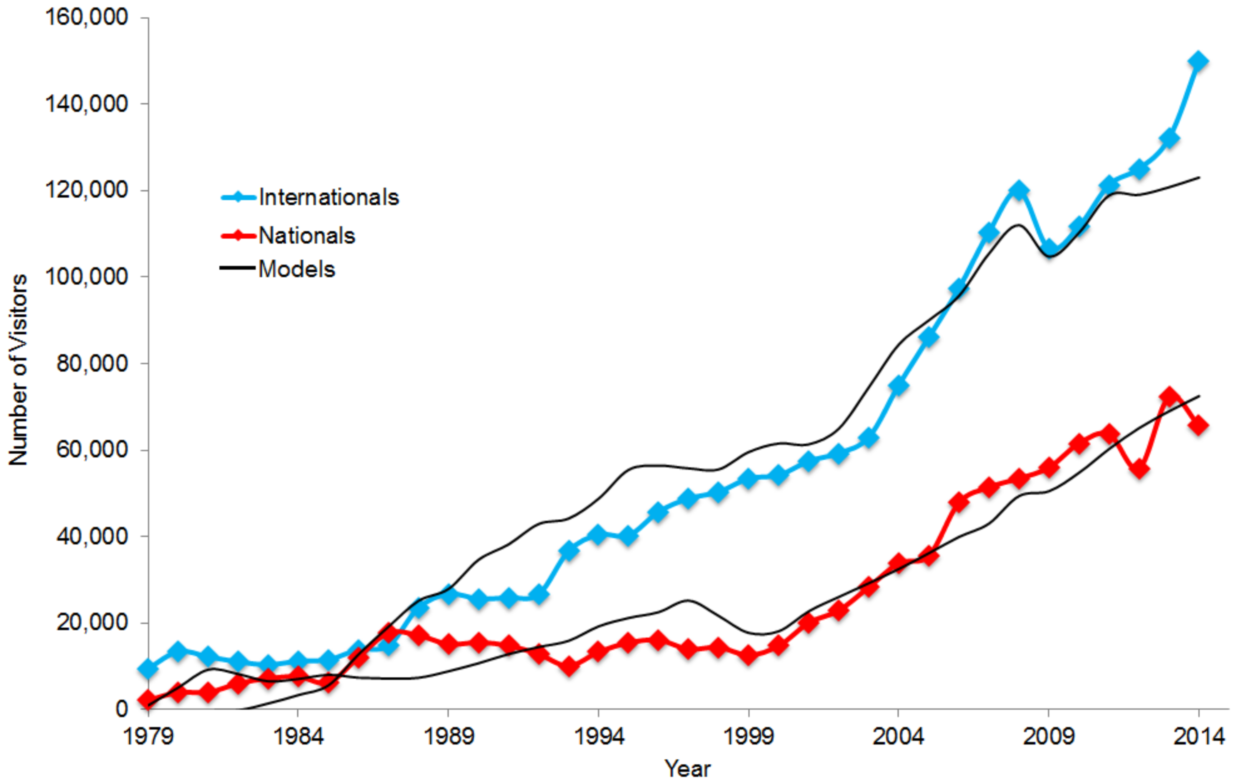


Figure 4.1. *Number of actual and modeled annual visitors to GNP over time, 1979-2014. The actual number of international visitors (blue line) and national visitors (red line) were plotted with the modeled number of international and national visitors and nationals (black lines) for comparison. Non-linear models predicting the number of visitors were constructed based on the entrance fee price, exponential of time, and revenue.*

Table 4.2. *Coefficients of non-linear model of visits to GNP (*p < 0.001).*

Tourists	*Intercept*	*Year*	*Fee*	*GDP*
Nationals	-187,061*	0.0061*	-493.3	7.2*
Internationasl	-170,513	0.0060*	-9.0	3.1*

These two findings support our assumption that foreign tourist demand for entry into Galapagos is inelastic and will not be greatly reduced by a reasonable price increase. This assumption is key in estimating the amount of revenue that could be raised by a price increase over time. Given that foreign visits are inelastic, it is likely that the implementation of NTZs would increase demand by improving the quality of the tourist experience and so shift the demand curve out. However, this effect is not captured in our model. Last, although the coefficient on price for nationals was not significant, the magnitude of the coefficient suggests that an increase in price may decrease the number of national visitors. For this reason, strategies to impose a blanket fee are evaluated on international visitors only, and not national visitors in further analyses.

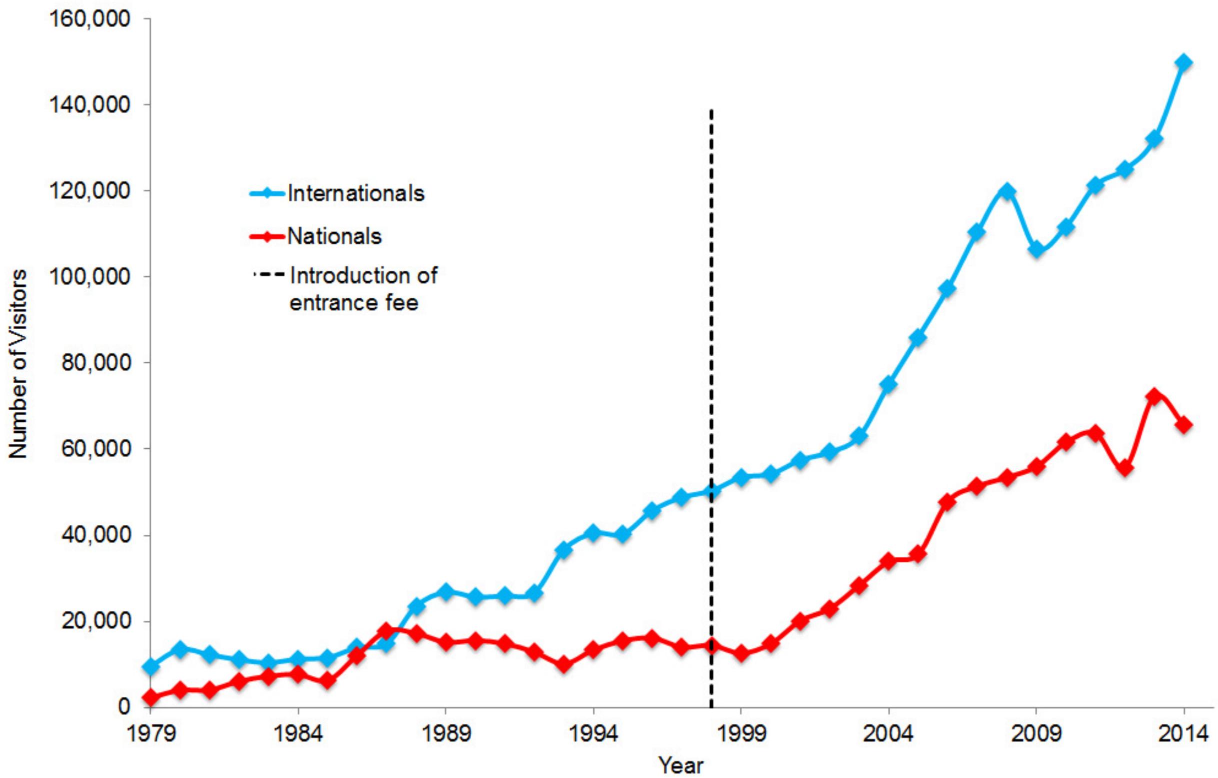


Figure 4.2. *Number of visitors to GNP, 1979–2014. The blue line indicates foreign visitors and the red line indicates national visitors. The vertical dashed line at 1998 demarcates the implementation of a $100 entrance fee. Prior to 1998, there was no entrance fee.*

Using our model to predict future visits, we explored two strategies to implement a blanket fee on tourists. In strategy one, the entrance fee (V_0) is increased (V_1) and, as mandated by law, five percent of the new fee is allocated to the GMR. The revenue stream earmarked for marine conservation is the difference between revenue generated for the GMR under the current $100 entrance fee ($p_0$) and the new, higher entrance fee (p_1):

Strategy 1

$$Revenue = 0.05[(V_1 \times p_1) - (V_0 \times p_0)]$$

In strategy two, an auxiliary fee is added to the entrance fee that is earmarked exclusively for marine conservation; p_{aux} represents the auxiliary fee and V_1 represents the number of visitors at the higher price (current entrance fee + auxiliary fee). The revenue stream is simply the amount of revenue generated through the auxiliary fee.

Strategy 2

$$Revenue = V_1 \times p_{aux}$$

Under both strategies, we find that increasing tourist entrance fees has the potential to generate hundreds of thousands of dollars for marine conservation each year. If the entrance fee is increased merely to correct for inflation, so that the $100 fee set in 1998 becomes $145 in 2016 dollars (strategy one), $3,092,776 dollars are generated for marine conservation over a period of ten years at a five percent discount rate. If a five-dollar auxiliary fee to fund marine conservation is added to the entrance fee (strategy two), the revenue generated over ten years more than doubles relative to strategy one to $6,872,837. If strategy one and strategy two are combined so that the price of the entrance fee is increased to $145 and a five dollars conservation fee is added, the present value of revenue generated through tourism fees over a ten-year period is $9,964,238. These results illustrate that of the two strategies proposed, the addition of an auxiliary fee to raise revenue is able to directly generate a significantly larger sum than a fee increase alone. It also illustrates that a very large amount of money can be raised to support marine conservation simply by charging each tourist an extra five dollars.

B. Blanket Fee on Tourism Permits

Increasing the annual fees for tourism permits presents another potential revenue stream for marine conservation. As with setting a blanket fee on tourists, an increase can be implemented in a number of ways. Here, we estimate the revenue generated if a 50% price hike is applied to all itineraries. Currently, the revenue generated by tourism permits is $400,000, so a 50% price hike would generate $200,000 for conservation each year, assuming all revenue above $400,000 is allocated to conservation. This translates to approximately $1.5 million dollars over ten years at a five percent discount rate. Because the pool of fee payers is considerably smaller than for tourists, increasing fees on tourism permits generates substantially less revenue than a tourist fee, and is not included in the three sample conservation packages presented later in the chapter. Nevertheless, increasing permit prices provides an easy, feasible option for generating a considerable sum of revenue for marine conservation.

C. Use-based Fee on Tourism Permits

Another approach for raising revenue from tourism permits is through a use-based fee. A use-based fee may be more amenable to tourism operators as only those operators who visit NTZs will be charged, which may be perceived as more fair. However, because different NTZs are quite different—some are larger, some smaller, some require more funds to enforce—the design of a fair use-based fee quickly becomes complicated. One approach is to set use-based premiums for each NTZ based on the fishery losses to be compensated within that NTZ. The premium charged to a vessel would be based on the number of visitors a vessel brings to sites within the NTZ and the amount needed to offset fishery losses. An operator that brings 10% of all visitors to Darwin, for example, would be charged 10% of the cost to offset fishery losses in the Darwin and Wolf NTZ. Using such an approach, the revenue generated would always equal current fishery profits in NTZ area, or whatever percent of fishery losses is targeted for compensation through this method.

A serious issue with using a use-based fee is that only a small number of boats utilize sites in the NTZs. For example, only six vessels currently visit Darwin and Wolf. To compensate fishery losses in this region, which are about $100,000, the price of permits would need to increase by 2.7 to 5.8 times of current prices. If targets are lowered, the amount raised shrinks significantly. For example a doubling of current prices for vessels visiting Darwin and Wolf would raise only $22,000. For this reason, the use-based fee on tourism permits is also not included in the three sample conservation packages presented later in the chapter. The potential revenue generated over 10 years at a five percent discount rate by each of the revenue sources reviewed is summarized below (Table 4.3).

Table 4.3. *Potential revenue generated by three revenue sources.*

Revenue Sources		Revenue ($)
Blanket fee on tourists	Increase entrance fee to $145	3,092,776
	Add conservation fee of $5 to entrance fee	6,872,837
Blanket fee on permits	Increase current permit prices 50%	1,544,347
Use-based fee on permits	Increase permit prices on NTZ users to compensate 20% of fishery losses ($40K)	308,869

II. Allocation Options: Fisher Compensation and Enforcement

Fisher Compensation Schemes

Schemes to compensate fishers for reduced access to fishing grounds have been implemented all over the world (Begossi, 2011; Sen, 2010). Although compensation schemes vary in their design and the extent to which they compensate fishers, there are some design features shared by most compensation schemes, which are given below:

1. Fishers must prove that they will be, or are being impacted by the policy change either through reduced catch or higher operation costs. Usually, fishers must demonstrate historic use of sites that will be affected by closures through logbook or landing certificate catch data.
2. Fishers are compensated based on their historic use of the newly restricted site. For example, a fisherman who averaged 10% of historic catch at a site would be given compensation in the amount of 10% of the historic fishery value for the site.
3. The type of compensation implemented depends on the level of impact to fishers' livelihoods. Buyouts, where a fisherman is paid to exit the fishery and is compensated for the cost of capital and years of lost revenue, are usually only implemented when a fisherman's livelihood is significantly impacted. In less severe cases, compensation can come in the form of subsidies for revenue lost or free professional services, such as access to business consultants.
4. The extent of compensation – i.e. how much money to how many fishers – depends on the state of the fishery in accessible sites. In cases where the potential increase in effort from displaced

fishers threatens the health of a fishery, policies tend to encourage exiting from the fishery through more generous compensation packages.

Guided by these four design principles, we outline possible features for schemes to compensate Galapagos fishers impacted by expansion of NTZs in the GMR (Table 4.4).

To get a clearer sense of how much revenue would be required to compensate Galapagos fishers, we estimated the costs of two potential compensation schemes. Under the first scheme, all fishers who can prove that they fish in the NTZs from catch data are eligible for four years of compensation equal to their historic profits generated in the NTZs. The second scheme is the same as the first, but with a buyout option for fishers who have historically obtained more than 50% of their catch from NTZ areas. The buyout formula applied in scheme two is the one given in Table 4.3 (i.e. double the average gross revenue of three best years + purchase of all gear + some compensation for depreciation).

To estimate costs of the first scheme, we simply assumed compensation to equal the fishery profits in the NTZs for each of four years. To estimate costs of the second scheme, we used the costs of the compensation program and combined them with estimated costs for a buyout program and then subtracted out the compensation the buyouts would have received. We determined costs of the buyout program by first determining which vessels obtained more than 50% of their catch from NTZ areas. Because the whitefish dataset did not include vessel names and we had only one year of clean lobster data, we could determine eligibility using only lobster catch data for 2014. Only two vessels generated more than 50% of profits within NTZ areas. We estimated "double the average gross revenue of the three best years" for each vessel using their 2014 lobster catch data. We doubled the 2014 lobster revenue generated within NTZs for each eligible vessel, assumed that profits comprised 30% of revenue, and corrected for absent whitefish revenue data using the fact that lobster comprises 24% of fishery revenue in NTZ areas. The total revenue compensation for the two highly impacted vessels was estimated to be $89,400.

Next, we next estimated the cost of compensating all gear and depreciation. Selling prices for used fishing vessels were perused on e-Bay and a high-end estimate of $15,000 was used as the current value of a small (< 9.5 m), outboard engine, ten year-old fishing vessel; 85% of the Galapagos fishing fleet is composed of small, outboard engine fishing vessels (Hearn, 2008). Depreciation was assumed to be 20% in year one, seven percent in year two, six percent in year three, and five percent for years four through ten and only half of the depreciation was compensated; depreciation was calculated based on rule of thumb guidelines found on online fishing forums. Because lobsters are still primarily caught by hand in Galapagos, rather than by traps, no gear compensation was assumed for lobsters. Whitefish is caught using hand-lines, which are low cost (usually less than $100) and so were not included as part of the compensation package either. The total capital compensation for the two highly impacted vessels was estimated to be about $43,700.

Table 4.4. *Design options for fisher compensation schemes.*

Proof of eligibility	• Logbook or landing certificate catch data • Reported revenue • Sales ledger
Compensation (Annual subsidies)	• **Number of years:** two to five
	• **Eligibility:** o All fishers who have historically fished in the NTZs o All fishers who obtain more than five percent of annual catch in NTZs
	• **Sample compensation formulas:** o Average of three best years of profit within NTZ o The amount of current profits generated by NTZs proportional to average annual catch share within the NTZs
Buyout (One-time payment to fishers to exit fishery)	• **Eligibility:** All fishers who have historically obtained more than X% of their catch from NTZ areas are eligible to apply for a voluntary buyout.
	• **Sample buyout formula:** o Double the average gross revenue of three best years + purchase of all gear + some compensation for depreciation

The two buyouts would no longer be eligible for annual compensation and needed to be deducted from our compensation estimates. We calculated the compensation averted due to the buyout by calculating lobster profits for both vessels in NTZ areas and then correcting for the missing whitefish revenue as before. According to these calculations, total annual compensation would be reduced by $44,700 each year, or $178,850 over four years; if discounted five percent, the present value of the averted compensation is $158,500. In comparison, the total buyout package is $133,000. Thus, while the upfront costs are greater, a buyout of vessels highly impacted by NTZs actually poses a slightly lower cost than compensation alone and has the added benefit of decreasing fishery effort.

Monitoring & Enforcement

Studies have shown that the management costs of monitoring and enforcement in larger marine protected areas are lower per unit area than in smaller ones (Balmford et al. 2004). Furthermore, evidence suggests that marine protected areas with higher proportions of NTZs are between 1.2 and two times cheaper to manage (Ban et al. 2011). While funds for additional monitoring and enforcement may not be necessary, there is a need to improve current enforcement. Issues such as understaffing, unresolved legal cases, and lack of maintenance to make vessels operational currently undermine enforcement efforts. The international conservation NGO WildAid, published a thorough analysis of the status of monitoring and enforcement in the GMR in 2010 that provides a list of issues and recommendations to improve enforcement efforts. From their list of thirteen issues, we have selected ten issues and accompanying recommendations that would strongly support expanded marine conservation in Galapagos (Table 4.5).

Table 4.5. *Recommendations and estimated costs to enhance current enforcement of the GMR*

	Issue	Recommendation	Estimated Cost
1	Excessive size of artisanal fishing fleet and number of fishers. Complicates surveillance and detection of illegal activities	Retract licenses for inactive fishermen	$25,000
2	Illegal entry of industrial vessels	Enforce IMO rules protecting GMR as a designated Particularly Sensitive Sea Area. Focus patrols along the borders of the GMR	$15,000
3	Growth in number of tourism vessels. No automated control of vessels smaller than 20 tons	1. Apply vessel monitoring systems (VMS) and Automatic Identification System (AIS) technology 2. Add vessels smaller than 20 tons to AIS-VMS system 3. Create compliance mechanisms	AIS equipment: $500/ boat Owner pays for monthly service ($56-$70)
4	No onboard and dry dock maintenance program	1. Design and implement maintenance plans 2. Hire permanent staff to oversee maintenance: Head of Maintenance, electrician/ welder, naval engine technician 3. Update purchasing system 4. Provide personnel training	1. $50,000 2. $60,000/year 3. $15,000 4. $30,000/year
5	Trafficking of species and illegal fishing	1. Inspect cargo vessels prior to sailing using sniffer dogs. 2. Hire private investigators	1. $25,000/year 2. $25,000/year
6	No boarding procedures and no refresher training for personnel	1. Establish a boarding procedure for Navy, GNP, Environmental Police 2. Annual training course for boarding procedures and crime scene investigation	1. $10,000 2. $15,000/year
7	Lack of knowledge of environmental legislation by judges	Encourage annual workshops attended by Port Authorities, Judges, and GNP to review procedures	$10,000/year
8	Institutional interference in arrest and processing	Review and revise operational procedures of Navy and GNP for arrests and processing	$20,000
9	Administrative and judicial cases take too long to resolve	Hire additional lawyers	$60,000/year
10	Cases of flagrant impunity by judges	Publicize cases in the press	$5,000/year

III. Scenarios to Support Marine Conservation

There are many ways that revenue generation and allocation can be bundled to effectively support and enhance expanded NTZs in the GMR. We illustrate three possible scenarios below. Each package generates a different amount of revenue available for use by the FDP over a ten-year timeframe, which is listed as the net present value (NPV) at a five percent discount rate.

Scenario One (Figure 4.3):

Revenue Generation Mechanism

- Increase the park entrance fee on foreign visitors to $145 to correct for inflation.

Fisher Compensation Scheme

- Compensate fishers for four years based on historical profits in NTZs ($200K total per year).
- Include administrative costs of the compensation program, estimated as the salary of two administrators ($40K per year).

Fisher Development Program

Available Funding: $2,199,187

- Options: Tourism and Hospitality Program, Rare, TURF

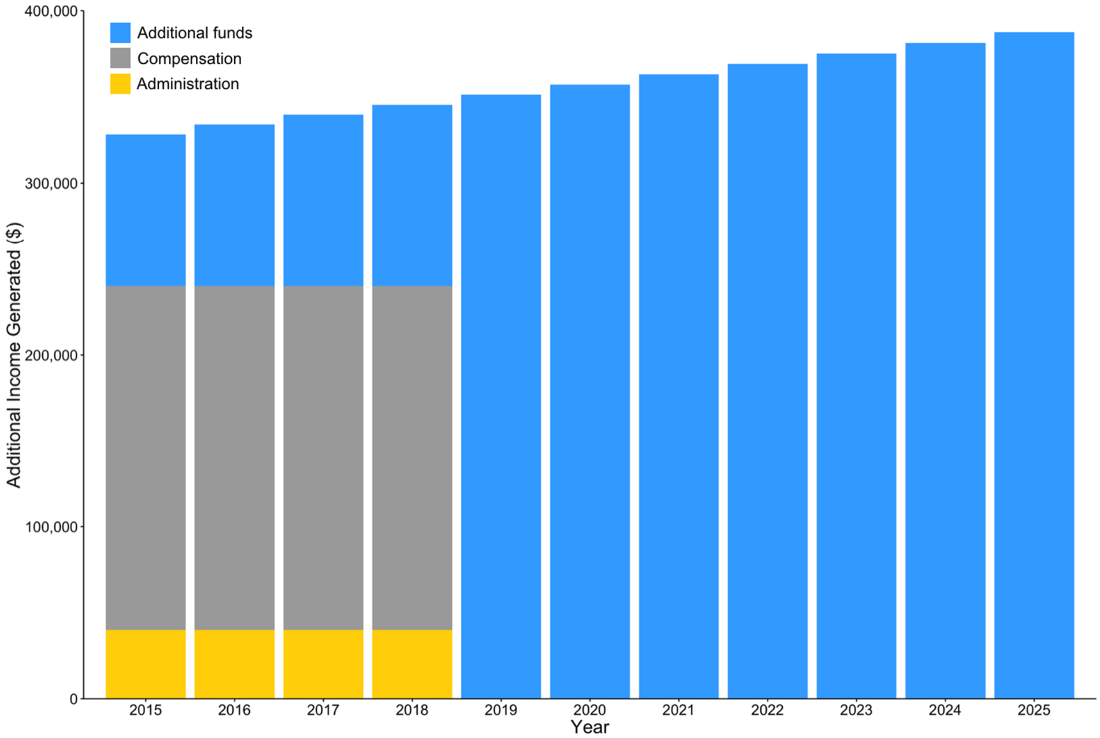


Figure 4.3. *Revenue generated and allocated in scenario one over ten years. Revenue is allocated to compensate fishers (grey) and administer the compensation scheme (yellow) in the first four years. Remaining funds available each year for FDP projects are depicted in blue.*

Scenario Two (Figure 4.4):

Revenue Generation Mechanism

- Add a conservation fee of five dollars to the current $100 entrance fee.

Fisher Compensation Scheme

- Compensate fishers for four years based on historical profits in NTZs ($200K total per year).
- Include administrative costs of the compensation program, estimated as the salary of two administrators ($40K per year).

Enforcement

- Implement recommendations for improved enforcement as outlined in the Monitoring and Enforcement section.
- Due to limited funds, initiation of recommendation implementation is staggered over the first three years.
- Enforcement aid in year one: $338K; year two: $383.5K; subsequent years: $230K

Fisher Development Fund

Available Revenue: $3,719,068

- Options: Tourism and Hospitality Program, Rare, TURF, Aquaculture

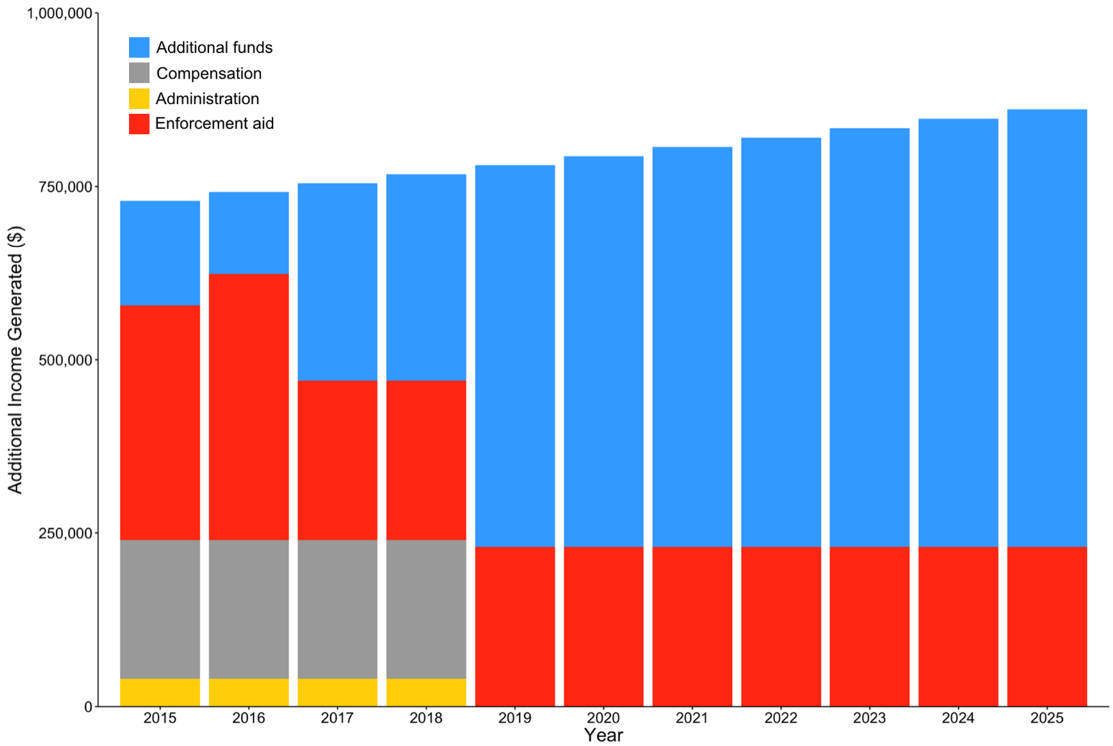


Figure 4.4. *Revenue generated and allocated in scenario two over ten years. Revenue is allocated to compensate fishers (grey) and administer the compensation scheme (yellow) in the first four years, as well as enhance monitoring and enforcement in the GMR in all years (red). Remaining funds available each year for FDP projects are depicted in blue.*

Scenario Three (Figure 4.5):

Revenue Generation Mechanism

- Increase the park entrance fee on foreign visitors to $145 to correct for inflation.
- Add an additional five dollar conservation fee to the entrance fee.

Fisher Compensation Scheme

- Compensate fishers for four years based on historical profits in NTZs ($155,286 total per year).
- Buyout fishers whose impact to revenue from NTZ implementation > 50% ($133K in first year).
- Include administrative costs of the compensation program, estimated as the salary of two administrators ($40K per year).

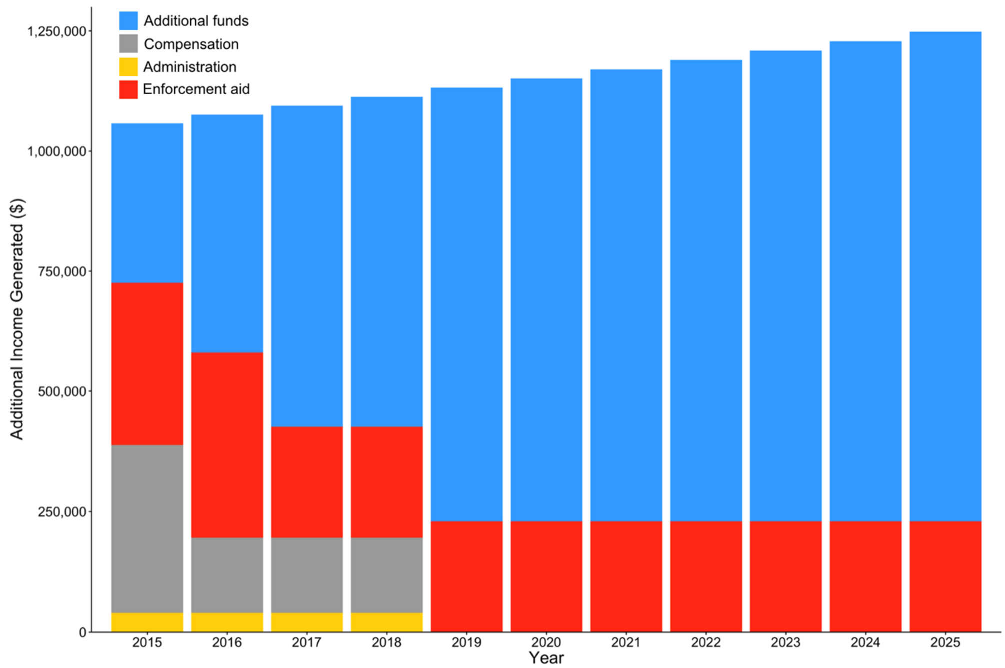
Enforcement

- Implement recommendations for improved enforcement as outlined in the Monitoring and Enforcement section.
- Due to limited funds, initiation of recommendation implementation is staggered over the first three years.
- Enforcement aid in year one: $338K; year two: $383.5K; subsequent years: $230K

Fisher Development Fund

Available Revenue: $6,797,138

- Options: Tourism and Hospitality Program, Rare, TURF, Aquaculture



Figures 4.5. *Revenue generated and allocated in scenario three over ten years. Revenue is allocated to compensate fishers (grey) and administer the compensation scheme (yellow) in the first four years, as well as enhance monitoring and enforcement in the GMR in all years (red). Remaining funds available each year for FDP projects are depicted in blue.*

IV. Fisher Development Programs

A program specifically dedicated to improving the livelihoods of Galapagos fishers should be considered as a promising option to promote marine conservation over the long-term. Studies suggest that fishers would be interested in pursuing alternative livelihoods or implementing projects that enhance the sustainability of Galapagos fisheries. One study conducted in 2014 found that 60% of Galapagos fishers interviewed were willing to transition jobs, and 91% do not want their children to also be fishermen (Denkinger and Vinueza). In addition, a 2014 Bren group project estimated that 50% of Galapagos fishers are willing to join an inter-island territorial user rights fishery (TURF; Debevec et al. 2014).

The Fisher Development Program (FDP) could be overseen by a Fisher Development Commission (FDC), which would be composed of NGO members and fisher representatives, and act as a coordinating and consulting body for Galapagos fishers. The FDC would require local support and resources. Integrating the FDC into already existing NGO programs may be the best option. Conservation International and the World Wildlife Fund are two NGOs that have done previous grassroots work with fishers in Galapagos that may take an interest in helping develop this project. Creating a network of collaborators with local expertise will help ensure the success of the project.

Tourism and Hospitality Program

Given that local ecotourism in Galapagos is on the rise and many fishers have already segued into the sector, one goal of the FDP may be to help facilitate the transition of fishers into the tourism industry. This can be done by providing the necessary training and offering career placement services. The fundamental skills required to work in the Galapagos tourism sector are proficiency in English and basic business knowledge. The Galapagos Academic Institute for Arts and Sciences (GAIAS) — a satellite campus of the Universidad San Francisco de Quito — offers undergraduate degrees in Hospitality, Culinary Arts, and Tourism as well as English courses to local Galapagueños. English courses are offered based on incoming students' English proficiency, which is determined through a placement exam. Partnering with GAIAS would provide fishers with important educational resources to assist in their transition to a new industry.

In order to provide fishers with experience in the tourism sector, local operators in the marine tourism and hospitality sectors can be invited to participate in a fisher internship program. This will offer FDP fishers with the opportunity to interact with clients and learn from already established operators about how to run successful tourism and hospitality businesses. Before such a program can be implemented, further investigation should be conducted to understand what might incentivize business-owners to join such a program and how an internship program can best contribute to the development of their business. One possible incentive is to offer operators subsidized courses at GAIAS as well.

A career placement service can help fishers secure jobs in the various sectors of the tourism industry and carry out workshops that help prepare participants to attain and maintain job placements. Workshops might include interviewing skills and professional presentation.
To estimate the cost of implementing all three tourism and hospitality programs, we budgeted amounts for each program component (Table 4.6). Both the internship and ESL program have been budgeted to allow for participation of 60 fishers and administrative support on both Santa Cruz and San Cristobal; administrators for career placement will also support the internship and ESL programs. The cost of the internship program is based on the minimum wage salary interns will receive per month ($640.60) for six months each year with a total annual cost of $230,616. A single English module at GAIAS is $70 and lasts seven weeks. Assuming that there are 20 fishers per module and we want to accommodate 60 fishers, we will offer two sessions per year with 3 modules each for a total annual cost of $25,200. The career placement program will provide the administrative and counseling resources to support the internship and ESL programs. The cost of the program is based on an annual income of $18,000 for two administrators and two counselors.

Table 4.6. *Budget for tourism and hospitality programs.*

	Tourism and Hospitality Programs		
	Internship Program	ESL Program	Career Placement Program
Components	• Placement with an operator • performance evaluations • intern pay	• English modules at GAIAS	• Four career placement coordinators
Annual Cost	$230,616	$25,200	$72,000

To assess the feasibility of implementing a tourism and hospitality program given the funds available under each scenario over ten years, we projected costs over a ten-year time frame. We assumed that the internship and ESL programs would run only in years 1-3, while the career placement program would run through year four. Under these assumptions, the total cost of implementing the tourism and hospitality programs discounted at 5% was $1,189,740. These funds are financially feasible under all scenarios (Figure 4.6).

Community Education and Outreach

One metric for long-term success of a NTZ is the compliance of the local fisher community. Community education and outreach about NTZs has been shown to contribute to long-term compliance with NTZs by promoting local knowledge about NTZ and positive attitudes toward conservation (Leisher et al. 2012).

Ensuring that the local fishing community participates in determining the allocation of the fisher development funds and guiding the implementation of fisher development programs should be a critical component of any outreach strategy. Ideally, staff and members of the FDC will act primarily as facilitators of a participatory decision-making process that will engage the entire fishing community and provide fishers with the agency to approach NTZs as an opportunity to improve their livelihoods, rather than as a top-down policy to be opposed. For this reason, allocating revenue to fund meeting coordinators and facilitators, food, and a comfortable venue is critical. We have budgeted $24,000 annually for meetings that will occur in the first, second, third, and fifth years of a ten-year time frame.

Rare is an NGO leader when it comes to community education, outreach and changing human behaviors. Rare's Pride Campaigns are designed to inspire community members to feel a sense of pride for the unique characteristics of the natural environment in which they live, while highlighting ways to avoid environmentally destructive behaviors (Butler, Green, and Galvin 2013).

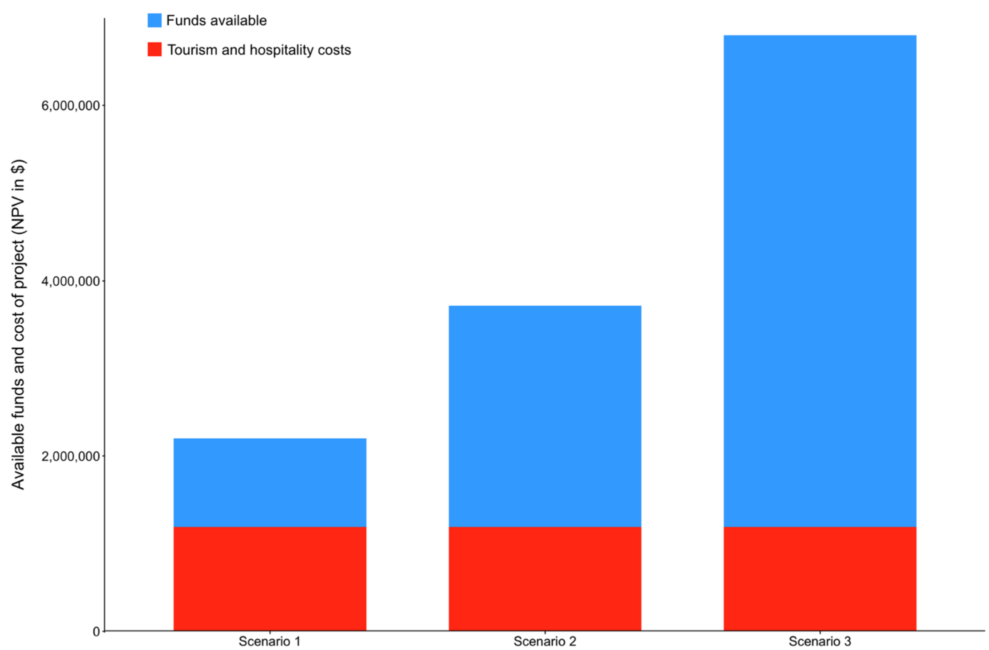


Figure 4.6. *Financial feasibility of implementing tourism and hospitality programs under three scenarios. The blue bars indicate the fishery development funds available under each scenario, while the red indicates the portion of available funds that would be needed to fund tourism and hospitality programs. The three scenarios are the bundles of revenue generation and allocation described previously in section three of this chapter.*

A basic Rare Pride Campaign costs approximately $71,000 to implement. Given that Santa Cruz and San Cristobal are the two most populated islands in Galapagos, it would be beneficial to implement two pride campaigns on those islands with two administrative staff at each site paid an annual salary of $18,000. The pride campaign would occur only in the first year making the total cost to support a pride campaign $214,000 (Table 4.7). Pride campaigns are usually funded by multiple parties; fund matching should be explored to help generate more campaign resources (Butler, Green, and Galvin 2013).

In total, the discounted cost of implementing the community education and outreach programs as described above would be $269,122.80. This is a very small cost when compared to available funds under all three scenarios (Figure 4.7).

Territorial Use Rights Fisheries

Improved co-management of the lobster fishery through the implementation of territorial use rights could help enhance profits despite the reduction in fishing grounds caused by NTZs (Debevec et al. 2014). TURFs provide fishermen exclusive access to a fishery in a defined spatial area, and in doing so, incentivize fishermen to act as stewards of their territory. TURFs are particularly well suited to demersal species, such as lobsters, that do not move great distances, and they have been shown to decrease costs of fishing and increase revenues in fisheries all over the world. If implemented in

Galapagos, a TURF can benefit individual fishers financially over the long-term, secure the longevity of the fishery, and reduce the need for monitoring and enforcement.

Table 4.7. *Budget for community education and outreach.*

Community Education and Outreach		
	Basic Pride Campaign	Initial Participatory Meetings
Components	• Basic Pride campaign at two sites • Two administrative staff	• Staff to facilitate meetings and coordinate between FDC administrators and fishers • Food and supplies for meetings
Allocation	$214,000	$24,000

Implementing TURFs for lobster is feasible in Galapagos, but there are some social, legal, and geographic barriers that would need to be addressed (Debevec et al. 2014). These barriers include a lack of social cohesion, tendencies toward a top-down management structure, and the complex geographic layout of the islands (Debevec et al. 2014). These barriers could be overcome with financial investment in new stock assessments, hiring leaders to organize fishers, education, equipment updates, and institutional support from NGOs and government agencies. For example, the non-profit 50in10 provided a matching grant for a TURF project in South Africa. For the South Africa line fish fishery, the $25,000 grant from 50in10 was matched by a government agency, which provided a local coordinator who brought participants together, educated the community, and handled other logistics for the community's transition (Megan Arneson, personal communication, March 1, 2016). In the larger Ban Tre clam fishery in Vietnam, an initial grant of $120,000 transitioned a fishing community of 8,744 households into cooperatives with assigned fishing grounds (Tindall 2012).

Galapagos has a number of characteristics that make it a likely candidate for TURF implementation, including a strong NGO presence, fishers' cooperatives on each of the three most populated islands, and an existing co-management scheme in the form of the Participatory Management Board. Furthermore, a 2014 survey found that a majority of Galapagos fishers are willing to participate in TURFs (Debevec et al. 2014). Collectively, this suggests that supporting the implementation of a lobster TURF is a strong investment option for the Fishers' Development Fund.

We estimated the costs of launching and maintaining a lobster TURF in Galapagos over a 10-year time frame based on the annual costs of the Ban Tre clam fishery TURF (Tindall 2012). We assumed that the first year would have higher expenditures totaling $190,000 due to purchase of capital and other start-up costs; all subsequent years were budgeted $70,000 and a 5% discount rate was applied. The total cost over 10 years of a TURF program was calculated to be $730,521.40, which is feasible under all three revenue generation and allocation scenarios (Figure 4.8).

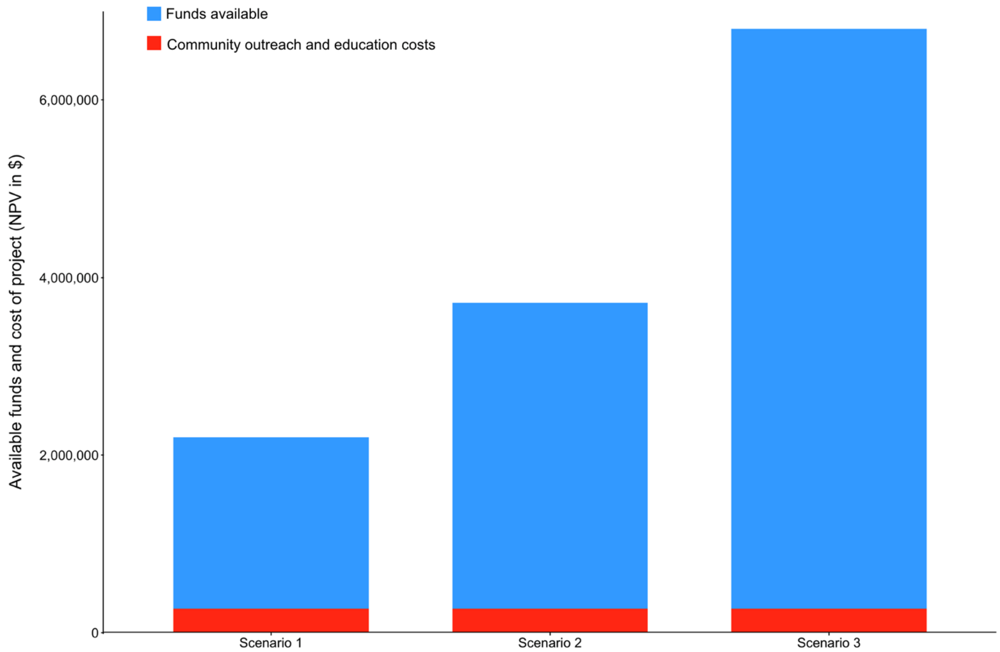


Figure 4.7. *Financial feasibility of implementing community education and outreach programs under three scenarios. The blue bars indicate the fishery development funds available under each scenario, while the red indicates the portion of available funds that would be needed to fund community education and outreach. The three scenarios are the bundles of revenue generation and allocation described previously in section three of this chapter.*

Aquaculture

Sea cucumber aquaculture is another potential investment of the FDP. Sea cucumber continues to be highly valued in Asian markets, which has led to the overexploitation of sea cucumbers worldwide (Mayol 2013), including in Galapagos (Toral-Granda 2008). As a result, several sea cucumber aquaculture projects have been launched around the world. A 2005 FAO study that found that the Galapagos sea cucumber can be successfully raised in land-based farming operations on mainland Ecuador (Mercier, Hidalgo, and Hamel 2005). Galapagos could potentially launch an aquaculture project for the endemic sea cucumber species, *Isostichopus fuscus*.

Sea cucumber aquaculture in Galapagos could be modeled after the sea cucumber farms in Malagasy, Madagascar. Blue Ventures, an international NGO based in the United Kingdom, partnered with the University of Toliara's Marine Science Institute, local Malagasy non-profit organizations, a local seafood exporter (Copefrito), and an aquaculture company (Indian Ocean Trepang) to create sea cucumber farms in the shallow coastal lagoons of Madagascar. The project provided about 170 jobs and is now a thriving source of revenue ("Aquaculture" 2016).

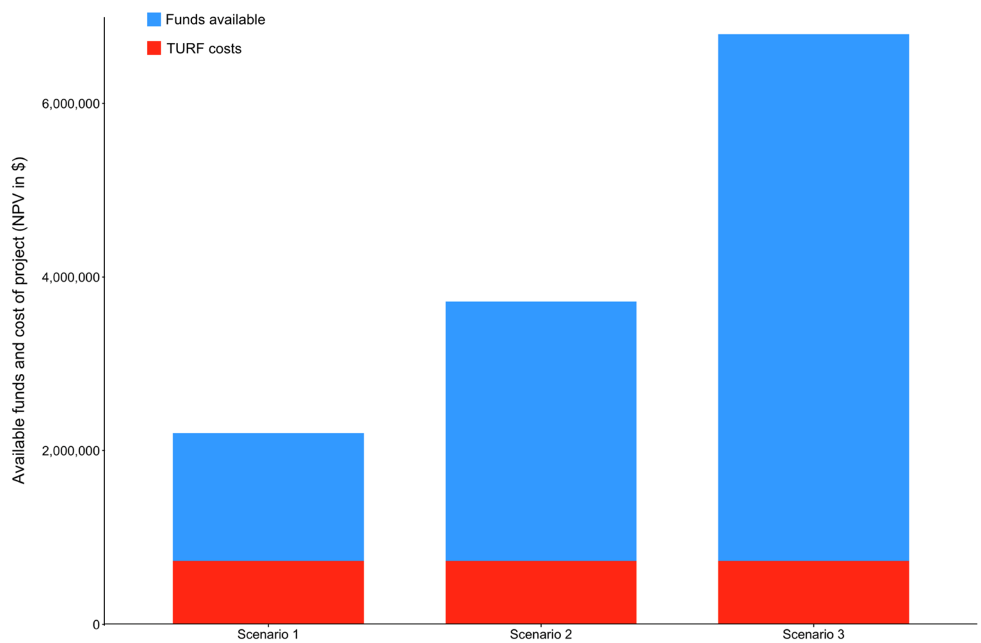


Figure 4.8. *Financial feasibility of implementing a TURF under three scenarios. The blue bars indicate the fishery development funds available under each scenario, while the red indicates the portion of available funds that would be needed to fund a TURF program. The three scenarios are the bundles of revenue generation and allocation described previously in section three of this chapter.*

In order to initiate the community-based aquaculture project, Blue Ventures launched feasibility studies, pilot projects, education and training programs, and established strong ties within the community and local organizations. The costs of each phase of this project are not publicly available, but the overall cost of launching the project is given as $2.66 million (Vincent 2016). This is the 10-year cost estimate we use to compare with funds available under each of the three scenarios (Figure 4.9). Funds raised under scenario 1 are insufficient to cover the costs of an aquaculture project of the same scale as that implemented in Madagascar by Blue Ventures.

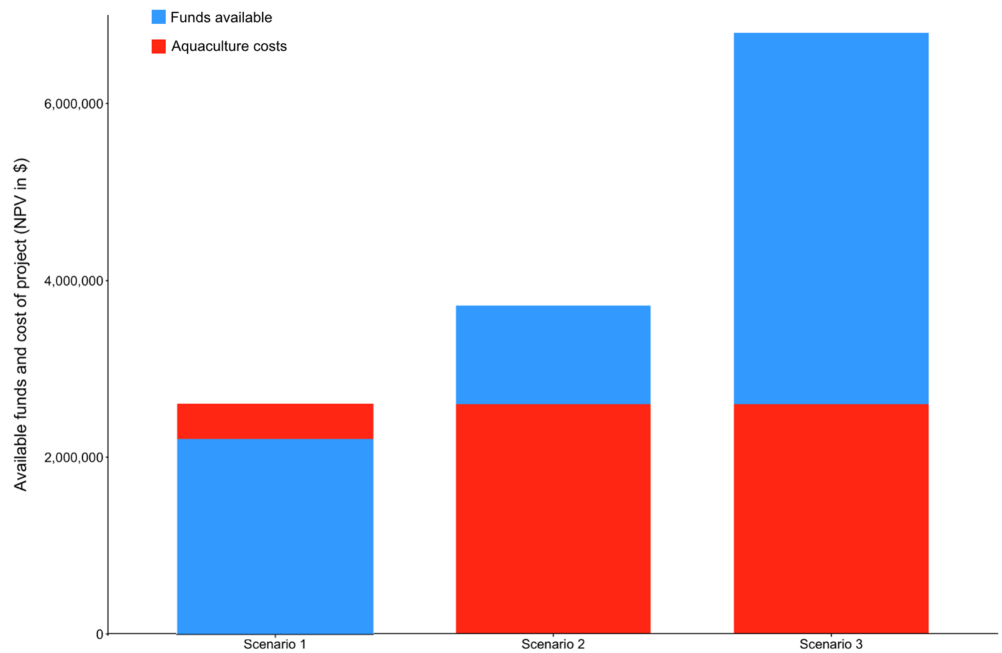


Figure 4.9. *Financial feasibility of implementing sea cucumber aquaculture under three scenarios. The blue bars indicate the fishery development funds available under each scenario, while the red indicates the portion of available funds that would be needed to fund an aquaculture project. The three scenarios are the bundles of revenue generation and allocation described previously in section three of this chapter. Not that under scenario 1, the cost of an aquaculture project actually exceeds available funds.*

Conclusion

Our work demonstrates that there is a place and need for conservation in the GMR through five key findings:

1. Marine tourism accounts for over two-thirds of total tourism revenue, which is the main driver of economic growth in Galapagos.
2. Species richness and abundance of sharks are important to marine-based tourists and help explain which tourism sites they visit.
3. Due to their species richness and/ or high abundances of sharks and cetaceans, Darwin and Wolf, Northern Santa Cruz, and Western Isabela are priorities for the placement of NTZs.
4. The cost of increasing protection in the GMR is low and can be easily offset by leveraging fees on tourists.
5. There are multiple feasible ways to leverage tourist fees to compensate fishers' losses and invest in the improvement of fishers' livelihoods.

Together, these findings make a compelling case that protecting the marine environment is critical for the continued well-being of the Galapagos economy. They clarify the connection between ecological attributes (i.e. sharks and species richness) and marine-based tourism, and the connection between marine-based tourism and the Galapagos economy as a whole. Thus, they demonstrate and define the full link between marine conservation and the economic well-being of Galapagos. In addition, our study demonstrates that expanding marine conservation is cheap and politically feasible if redistribution mechanisms are implemented, and provides ideas on how conservation success can be incentivized through policies that benefit impacted stakeholders.

Relevance Beyond the GMR

Our study presents a uniquely holistic and tailored approach to marine spatial planning. It begins with the insight that the economy and ecology of a reserve is heterogeneous, which is the foundation of many spatial planning approaches. However, while other approaches next look to optimize ecological benefits while minimizing costs, in our approach we instead emphasize the need to understand which ecological attributes matter most to tourists. This allows conservation and economic outcomes to be coupled. We use the spatial distribution of economically important species to determine where NTZs would be of greatest benefit. Such an approach makes sense in the GMR because tourism revenue generated by the marine environment greatly exceeds fishery revenues, and so potential benefits greatly outweigh costs. Recognizing that NTZs incur a cost to fishers and that fisher compliance is essential for successful conservation, we recommend redistribution mechanisms to compensate fishery losses and improve fisher livelihoods as an integral part of marine conservation. Our holistic approach makes possible a triple bottom-line outcome where conservation goals and social outcomes are maximized while overall costs to stakeholders are minimized (Halpern et al. 2013).

The approach modeled by this study can help environmental managers all over the world design and determine the placement of NTZs, especially in areas where a sophisticated planning tool, such as MARXAN, is not a viable option; SeaSketch, an interactive spatial planning software designed to have a simple user interface, currently does not facilitate economic analyses of zoning designs. Importantly, our approach also includes an analysis of which ecological resources actually matter to tourists, which is often assumed or ignored in spatial planning processes.

Study Limitations

The results of our analyses were greatly influenced by the quality and availability of data. This does not undermine the overall conclusions drawn from the data given above. However, it does constrain how the data can be interpreted. Below we outline some of the major limitations of our data and what that means for those who want to use our results.

1. Tourism revenues, site revenues, and site visits are all estimates due to limitations in available data. The same assumptions were held constant across sites within each tour category and so while absolute numbers may be somewhat imprecise, the relative relationship among values should be preserved.
2. Fishery revenues were under-reported both because of lack of spatial coordinates (lobster and whitefish), and because whitefish catch is not fully reported by fishers. Thus, while the numbers in this report provide a good starting point for discussing compensation and assessing feasibility of NTZs, they should be interpreted as estimates only.
3. Regressions for tourism visits were only run using available ecology data that we were able to link spatially to tourism sites. There may be other ecological variables that are important to tourists that were not identified.
4. Ecology data are spatially biased. For example, shark tagging studies occur in areas where scientists expect to find sufficient sharks to tag and cetacean sightings are only recorded for places where tourism boats and other surveyors travel. Thus, there may be other areas with high levels of cetaceans that were not captured by our dataset.
5. Estimates of the costs of fisher development programs as well as monitoring and enforcement are largely based on other case studies and recommendations and can only be interpreted as rough estimates at the correct order of magnitude.

The Benefits of a NTZ Approach to Marine Conservation

Our arguments for expanding spatial marine conservation have so far been built conservatively on the assertion that marine protection is critical for the continued success of marine-based tourism. However, a sizeable body of evidence suggests that expanding NTZs could in fact increase tourists' willingness to pay (WTP) for marine-based tourism, and so could potentially increase the revenue generated by marine-based tourism in Galapagos. There are two mechanisms by which NTZs could increase tourists' WTP. First, a number of studies have demonstrated that users are willing to pay a premium to use marine areas protected from fishing (Parsons and Thur 2007; Arin and Kramer 2002; Lindsey and Holmes 2002); possible reasons given for why tourists are willing to pay more include a preference for privacy and seclusion, aesthetics, the perceived future benefits of conservation, and hazards posed by fishing activity to divers (Gill, Schuhmann, and Oxenford 2015).

Second, we hypothesize that implementing NTZs may increase visitors' WTP by improving the quality (e.g. abundance, biodiversity) of ecological resources they care about. While it is hard to find a single case study that demonstrates explicitly that the implementation of spatial protection led to ecological improvement that in turn led to an increase in visitors' WTP, there are studies that support each piece of this hypothesis. Many authors have shown that marine protected areas can improve a variety of ecological attributes, including fish abundance (Harmelin-vivien et al. 2008) and reef shark abundance (Bond et al. 2012; Robbins et al. 2006). A number of studies also provide analyses to support the prediction that visitors' WTP will increase when ecological resource abundances increase. For example, Gill et al. used a choice experiment to assess SCUBA divers' WTP as a function of the abundance and size of reef fishes in the Caribbean. They found that divers had a higher WTP for sites with higher fish abundance and larger fish, suggesting that an increase in fish abundance and fish size will likely increase divers' WTP (2015).

There are a number of ways that prohibiting fishing in the GMR may result in improved abundances of sharks and other species valued by tourists. First, there is some evidence that fishing in the Galapagos has caused a shift in trophic cascades due to overharvesting of large fish, which alters species richness and the abundance of apex predators, such as sharks (Schiller et al. 2014). Second, legal fishing can inadvertently capture sharks, turtles, and other fish as bycatch. Finally, implementing a NTZ in Darwin and Wolf, for example, will likely reduce the illegal fishing of sharks (Carr et al. 2013). The high density of sharks in Galapagos is a well-known fact to illegal fishers from Costa Rica and other countries in the region and attracts them to the GMR where they can harvest enough shark quickly and without being caught to make the journey worthwhile (personal correspondence, Wagner Quiros, March 4, 2016). Often, the small boats doing the illegal fishing in Darwin and Wolf have a mother ship that is parked outside the reserve boundary in waters where it is legal to harvest shark. Within the reserve boundaries it is difficult to differentiate a small fishing boat conducting legal harvesting from one conducting illegal harvesting; monitoring efforts also currently focus patrolling on the reserve boundary and so overlook vessels further inside the reserve. However, if a sizeable NTZ is implemented within the reserve, monitoring would become much easier as all fishing vessels are illegal and the patrol route can be modified to increase enforcement in areas most utilized by illegal shark fishers.

The ability of NTZs to increase tourists' WTP presents a means to sustain growth in tourism revenue that does not require an increase in the number of tourists. Tourism is known to impact the marine environment by initiating human contact with marine organisms and structures (Harriott et al., 1997), physically damaging benthic habitat due to anchoring (Milazzo et al. 2002), and introducing vessel noise to a previously quiet environment (Slabbekoorn et al. 2010). While direct impacts of tourism to the marine environment are thought to be minimal compared to other uses (Wachenfeld et al. 1997), such as fishing (Jennings and Kaiser 1998), there is a dearth of data on the long-term cumulative impacts of marine recreation. In addition, indirect impacts associated with an increase in the number of tourists, such as increased nutrient loading, destruction of habitat for development, and pollution, may have significant effects on the marine and terrestrial environment of Galapagos.

Capping the number of tourists has been recommended as key component of successful long-term environmental management in Galapagos (Stijn Schep et al. 2014). Not only does capping the number of visitors help protect the marine and terrestrial environment, but it also improves the tourist experience. Both in Galapagos (Stijn Schep et al. 2014) and other parts of the world (Mathieu, Langford, and Kenyon 2003), tourists have expressed a significantly higher WTP for tourism experiences with fewer visitors. Thus, implementing NTZs and decreasing the number of visitors to Galapagos both present strategies where win-win management outcomes are possible, that is, outcomes where both the environment and the economy benefit.

Looking Ahead

Our study demonstrates that NTZs could be implemented and should be implemented, but cannot answer the all-important question of whether they will be implemented, and more importantly, whether they will be implemented successfully. Historically, lack of compliance with zoning regulations and a trend of weak enforcement have undermined marine conservation efforts in the GMR. This suggests that additional steps that need to be taken to create the right incentives to ensure conservation success beyond modifying the zoning plan on paper. As long as fishers feel that complying with NTZs is disadvantageous to their livelihoods and enforcement lacks any real teeth, non-compliance will continue. By including ways to improve fisher livelihoods and mitigate short-term losses as an integral component of conservation, it becomes possible for NTZs to fulfill their mission: to ensure the sustainable use of the economically and ecologically important marine resources of the Galapagos Islands.

Bibliography

"Aquaculture." 2016. *Blue Ventures*. Accessed March 17. https://blueventures.org/conservation/aquaculture/.

Arin, Tijen and Randall A. Kramer. 2002. "Divers' Willingness to Pay to Visit Marine Sanctuaries: An Exploratory Study." *Ocean & Coastal Management* 45 (2–3): 171–83. doi:10.1016/S0964-5691(02)00049-2.

Balmford, Andrew, Pippa Gravestock, Neal Hockley, Colin J. McClean, and Callum M. Roberts. 2004. "The Worldwide Costs of Marine Protected Areas." *Proceedings of the National Academy of Sciences of the United States of America* 101 (26): 9694–97.

Ban, Natalie C., Vanessa Adams, Robert L. Pressey, and John Hicks. 2011. "Promise and Problems for Estimating Management Costs of Marine Protected Areas: Management Costs of Marine Protected Areas." *Conservation Letters* 4 (3): 241–52. doi:10.1111/j.1755-263X.2011.00171.x.

"Boletin Galapagos: Estadisticas de Demanda, Oferta Y Economia Del Turismo En Las Islas." 2015. Ministerio de Turismo del Ecuador.

Bond, Mark E., Elizabeth A. Babcock, Ellen K. Pikitch, Debra L. Abercrombie, Norlan F. Lamb, and Demian D. Chapman. 2012. "Reef Sharks Exhibit Site-Fidelity and Higher Relative Abundance in Marine Reserves on the Mesoamerican Barrier Reef." Edited by Vincent Laudet. *PLoS ONE* 7 (3): e32983. doi:10.1371/journal.pone.0032983.

Bucaram, Santiago J., J. Wilson White, James N. Sanchirico, and James E. Wilen. 2013. "Behavior of the Galapagos Fishing Fleet and Its Consequences for the Design of Spatial Management Alternatives for the Red Spiny Lobster Fishery." *Ocean & Coastal Management* 78 (June): 88–100. doi:10.1016/j.ocecoaman.2013.03.001.

Butler, Paul, Kevin Green, and Dale Galvin. 2013. *The Principles of Pride: The Science behind the Mascots*. Arlington, VA: Rare. Available online at http://www. rare. org/publications Cover photo: Jason Houston Back cover photo: AG Sano. https://www.rare.org/sites/default/files/Principles%2520of%2520Pride%25202013%2520lo%2520res.pdf.

Carr, Lindsey A., Adrian C. Stier, Katharina Fietz, Ignacio Montero, Austin J. Gallagher, and John F. Bruno. 2013. "Illegal Shark Fishing in the Galápagos Marine Reserve." *Marine Policy* 39 (May): 317–21. doi:10.1016/j.marpol.2012.12.005.

Castrejon, Mauricio. 2012. "La Reforma Del Sistema de Licencias PARMA: El Primer Paso Para Eliminar La Carrera Por Pescar En La Reserva Marina de Galapagos." WWF Programa Galapagos.

Castrejón, Mauricio, and Anthony Charles. 2013. "Improving Fisheries Co-Management through Ecosystem-Based Spatial Management: The Galapagos Marine Reserve." *Marine Policy* 38 (March): 235–45. doi:10.1016/j.marpol.2012.05.040.

Caveen, Alex, Nick Polunin, Tim Gray, and Selina Marguerite Stead. 2015. *The Controversy over Marine Protected Areas*. SpringerBriefs in Environmental Science. Cham: Springer International Publishing. http://link.springer.com/10.1007/978-3-319-10957-2.

Debevec, Taylor, Norah Eddy, Laura Johnson, Jonathan Sim, and Katie Westfall. 2014. "Exploring Innovative Management for the Red Spiny Lobster Fishery in the Galápagos Islands."

Denkinger, Judith, and Luis Vinueza, eds. 2014. *The Galapagos Marine Reserve*. Social and Ecological Interactions in the Galapagos Islands. Springer International Publishing. http://link.springer.com/10.1007/978-3-319-02769-2.

Directorate of the Galapagos National Park. 2012. "Marine Visitor Sites."

Edgar, Graham J., Stuart Banks, Robert Bensted-Smith, Monica Calvopiña, Angel Chiriboga, Lauren E. Garske, Scott Henderson, Kathy Ann Miller, and Sandie Salazar. 2008. "Conservation of Threatened Species in the Galapagos Marine Reserve through Identification and Protection of Marine Key Biodiversity Areas." *Aquatic Conservation: Marine and Freshwater Ecosystems* 18 (6): 955–68. doi:10.1002/aqc.901.

Epler, Bruce. 2007. "Tourism, the Economy, Population Growth, and Conservation in Galapagos." *Charles Darwin Foundation*. http://cpps.dyndns.info/cpps-docs-web/planaccion/docs2011/oct/turismo_biodiv/Doc.15.Epler_Tourism_Report-en_5-08.pdf.

"Fasciculo Provincial Galapagos." 2010. Instituto nacional de estadistica y censos.

Forcada, A, C Valle, P Bonhomme, G Criquet, G Cadiou, P Lenfant, and Jl Sánchez-Lizaso. 2009. "Effects of Habitat on Spillover from Marine Protected Areas to Artisanal Fisheries." *Marine Ecology Progress Series* 379 (March): 197–211. doi:10.3354/meps07892.

Gill, David A., Peter W. Schuhmann, and Hazel A. Oxenford. 2015. "Recreational Diver Preferences for Reef Fish Attributes: Economic Implications of Future Change." *Ecological Economics* 111 (March): 48–57. doi:10.1016/j.ecolecon.2015.01.004.

Glynn, Peter W. 1994. "State of Coral Reefs in the Galápagos Islands: Natural vs Anthropogenic Impacts." *Marine Pollution Bulletin* 29 (1): 131–40. doi:10.1016/0025-326X(94)90437-5.

González, José A., Carlos Montes, José Rodríguez, Washington Tapia, and others. 2008. "Rethinking the Galapagos Islands as a Complex Social-Ecological System: Implications for Conservation and Management." *Ecology and Society* 13 (2): 13.

Halpern, Benjamin S., Carissa J. Klein, Christopher J. Brown, Maria Beger, Hedley S. Grantham, Sangeeta Mangubhai, Mary Ruckelshaus, et al. 2013. "Achieving the Triple Bottom Line in the Face of Inherent Trade-Offs among Social Equity, Economic Return, and Conservation." *Proceedings of the National Academy of Sciences* 110 (15): 6229–34. doi:10.1073/pnas.1217689110.

Harmelin-Vivien, Mireille, Laurence D. Ledireach, Just Bayle-Sempere, Eric Charbonnel, Jose Garcia-Charton, Denis Ody, Angel Perez-Ruzafa, Olga Renones, Pablo Sanchezjerez, and Carlos Valle. 2008. "Gradients of Abundance and Biomass across Reserve Boundaries in Six Mediterranean Marine Protected Areas: Evidence of Fish Spillover?" *Biological Conservation* 141 (7): 1829–39. doi:10.1016/j.biocon.2008.04.029.

Hearn, Alex, Juan Carlos Murillo, and Harry Reyes. 2007. "Declining Profitability of Fisheries in the Galapagos Marine Reserve." Galapagos Report 2006-2007.

Heylings, P., and M. Bravo. 2007. "Evaluating Governance: A Process for Understanding How Co-Management Is Functioning, and Why, in the Galapagos Marine Reserve." *Ocean & Coastal Management* 50 (3-4): 174–208. doi:10.1016/j.ocecoaman.2006.09.003.

Jennings, Simon, and Michel J. Kaiser. 1998. "The Effects of Fishing on Marine Ecosystems." In *Advances in Marine Biology*, edited by A. J. Southward and P. A. Tyler J.H.S. Blaxter, 34:201–352. Academic Press. http://www.sciencedirect.com/science/article/pii/S0065288108602126.

Lynham, Chris Costello, Steve Gaines, and Enric Sala. 2015. "Economic Valuation of Marine and Shark-Based Tourism in the Galapagos Islands."

Jones, Peter J.S. 2013. "A Governance Analysis of the Galápagos Marine Reserve." *Marine Policy* 41 (September): 65–71. doi:10.1016/j.marpol.2012.12.019.

Laurie, W. Andrew. 1990. "Effects of the 1982-83 El Niño-Southern Oscillation Event on Marine Iguana (Amblyrhynchus Cristatus) Populations on Galapagos." In *Elsevier Oceanography Series*, edited by P. W. Glynn, 52:361–80. Global Ecological Consequences of the 1982–83 El Nino—Southern Oscillation. Elsevier. http://www.sciencedirect.com/science/article/pii/S0422989408700412.

Leisher, Craig, Sangeeta Mangubhai, Sebastiaan Hess, Hesti Widodo, Tri Soekirman, Salomina Tjoe, Stevanus Wawiyai, et al. 2012. "Measuring the Benefits and Costs of Community Education and Outreach in Marine Protected Areas." *Marine Policy* 36 (5): 1005–11. doi:10.1016/j.marpol.2012.02.022.

Lindsey, Greg, and Ann Holmes. 2002. "Tourist Support for Marine Protection in Nha Trang, Viet Nam." *Journal of Environmental Planning and Management* 45 (4): 461–80. doi:10.1080/09640560220143503.

Mathieu, Laurence F., Ian H. Langford, and Wendy Kenyon. 2003. "Valuing Marine Parks in a Developing Country: A Case Study of the Seychelles." *Environment and Development Economics* 8 (2): 373–90. doi:10.1017/S1355770X0300196.

Mayol, Taylor. 2013. "Farming Sea Cucumbers in Madagascar…for Economic Hope and Conservation." *National Geographic (blogs)*. June 13. http://newswatch.nationalgeographic.com/2013/06/13/farming-sea-cucumbers-in-madagascar-for-economic-hope-and-conservation/.

Mercier, Annie, Roberto Hidalgo, and Jean-Francois Hamel. 2005. "Advances in Sea Cucumber Aquaculture and Management." *FAO Fisheries Technical Paper*, 347–58.

Micheli, Fiorenza, Andrea Saenz-Arroyo, Ashley Greenley, Leonardo Vazquez, Jose Antonio Espinoza Montes, Marisa Rossetto, and Giulio A. De Leo. 2012. "Evidence That Marine Reserves Enhance Resilience to Climatic Impacts." *PLOS ONE* 7 (7): e40832. doi:10.1371/journal.pone.0040832.

Milazzo, Marco, Renato Chemello, Fabio Badalamenti, Raffaele Camarda, and Silvano Riggio. 2002. "The Impact of Human Recreational Activities in Marine Protected Areas: What Lessons Should Be Learnt in the Mediterranean Sea?" *Marine Ecology* 23 (s1): 280–90. doi:10.1111/j.1439-0485.2002.tb00026.x.

Ocearch. 2014. "Banning Long-Lining in Galapagos Islands." *Globe Newswire News Room*. November 4. http://globenewswire.com/news-release/2014/11/04/679371/10106134/en/Banning-Long-lining-in-Galapagos-Islands.html.

Parsons, George R., and Steven M. Thur. 2007. "Valuing Changes in the Quality of Coral Reef Ecosystems: A Stated Preference Study of SCUBA Diving in the Bonaire National Marine Park." *Environmental and Resource Economics* 40 (4): 593–608. doi:10.1007/s10640-007-9171-y.

Penaherrera, Cesar, Yasmania Llerena, and Keith Inti. 2013. "Perceptions of the Economic Value of Sharks for Single-Day Dive Tourism and Commerce in Santa Cruz Island." Galapagos Report 2011-2012. Puerto Ayora, Galapagos, Ecuador: GNPS, GCREG, CDF, and GC.

http://www.galapagos.org/wp-content/uploads/2013/06/16.-TOUR-econ-value-sharks.penaherrera-llerena-keith.pdf.

Plaza, Martin, Jimmy Solis, and Salinas Gonzalez. 2014. “Producto 1: Diagnostico de La Situacion Actual de La Comercializacion de Los Productos de La Pesca Artesenal.” CORAMIR S.A.

Robbins, William D., Mizue Hisano, Sean R. Connolly, and J. Howard Choat. 2006. “Ongoing Collapse of Coral-Reef Shark Populations.” *Current Biology* 16 (23): 2314–19. doi:10.1016/j.cub.2006.09.044.

Sala, Enric, Christopher Costello, Dawn Dougherty, Geoffrey Heal, Kieran Kelleher, Jason H. Murray, Andrew A. Rosenberg, and Rashid Sumaila. 2013. “A General Business Model for Marine Reserves.” *PloS One* 8 (4): e58799.

Schiller, Laurenne, Juan José Alava, Jack Grove, Günther Reck, and Daniel Pauly. 2014. “The Demise of Darwin’s Fishes: Evidence of Fishing down and Illegal Shark Finning in the Galápagos Islands: The demise of Darwin’s fishes.” *Aquatic Conservation: Marine and Freshwater Ecosystems*, 25 (3), 431-446. doi:10.1002/aqc.2458.

Slabbekoorn, Hans, Niels Bouton, Ilse van Opzeeland, Aukje Coers, Carel ten Cate, and Arthur N. Popper. 2010. “A Noisy Spring: The Impact of Globally Rising Underwater Sound Levels on Fish.” *Trends in Ecology & Evolution* 25 (7): 419–27. doi:10.1016/j.tree.2010.04.005.

Snell, H.L., A. Tye, C.E. Causton, and Bensted-Smith. 2002. “Current Status of and Threats to the Terrestrial Biodiversity of Galapagos.” In *A Biodiversity Vision for the Galapagos Islands*. Puerto Ayora, Ecuador: Charles Darwin Foundation and World Wildlife Fund. www.darwinfoundation.org/files/library/pdf/bio_vision_galapagos_eng.pdf.

Sonnenholzner, Jorge, Lydia B. Ladah, and Kevin D. Lafferty. 2009. “Cascading Effects of Fishing on Galapagos Rocky Reef Communities: Reanalysis Using Corrected Data.” *Marine Ecology Progress Series* 375: 209–18. doi:10.3354/meps07890.

Schep, Stijn, Mirte Ruesen, Viviana Lujan Gallegos, Pieter van Beukering, and Wouter Botzen. 2014. “Does Tourism Growth on the Galapagos Islands Contribute to Sustainable Economic Development.” WWF Ecuador.

Tindall, Charlotte. 2012. “Fisheries in Transition: 50 Interviews with the Fishing Sector.” Prince’s Charities’ International Sustainability Unit.

Toral-Granda, Verónica. 2008. “Galapagos Islands: A Hotspot of Sea Cucumber Fisheries in Latin America and the Caribbean.” *Sea Cucumbers: A Global Review of Fisheries and Trade*, 231–53.

Valle, Carlos A., Felipe Cruz, Justine B. Cruz, Godfrey Merlen, and Malcolm C. Coulter. 1987. “The Impact of the 1982–1983 El Niño-Southern Oscillation on Seabirds in the Galapagos Islands, Ecuador.” *Journal of Geophysical Research: Oceans* 92 (C13): 14437–44. doi:10.1029/JC092iC13p14437.

Vargas, F. Hernán, Scott Harrison, Solanda Rea, and David W. Macdonald. 2006. “Biological Effects of El Niño on the Galápagos Penguin.” *Biological Conservation* 127 (1): 107–14. doi:10.1016/j.biocon.2005.08.001.

Vincent, Ida. 2016. “Madagascar – Sustainable Livelihoods | Reef Resilience.” Accessed March 17. http://www.reefresilience.org/case-studies/madagascar-sustainable-livelihoods/.

Viteri, Carlos. 2014. “Evaluacion de La Pesqueria de Langosta Espinosa (P. Penicillatus Y P. Gracilis) En La Reserva Marina de Galapagos.” DPNG- Comision Tecnica Pesqueria.

Viteri, César, and Carlos Chávez. 2007. "Legitimacy, Local Participation, and Compliance in the Galápagos Marine Reserve." *Ocean & Coastal Management* 50 (3-4): 253–74. doi:10.1016/j.ocecoaman.2006.05.002.

Wachenfeld, D, Jamie Oliver, Kim Davis, and Great Barrier Reef Marine Park Authority, eds. 1997. *State of the Great Barrier Reef World Heritage Area Workshop: Proceedings of a Technical Workshop Held in Townsville, Queensland, Australia, 27-29 November 1995*. Townsville, Queensland: Great Barrier Reef Marine Park Authority.

Watkins, Graham, and Felipe Cruz. 2007. "GALAPAGOS AT RISK." http://www.cometogalapagos.com/Galapagos_at_Risk.pdf.

APPENDIX

Table A1. *Results of multiple regression models for cruises.*

	Dependent variable:								
	Visits								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Price	49.0**	47.9**	-23.5	-19.0	-20.4	-22.0	-21.6	-34.6	-43.5
Distance	24.1	18.5	10.7	6.0	5.7	-1.0	5.5	20.8	14.3
Endemic_Richness	892.4	798.0	1,187.5	1,132.0	1,064.9	947.5	1,313.7	1,523.5	1,450.3
Sp_Richness	180.3***	187.7***	192.7	208.0**	217.5**	217.7**	217.8**	198.1	192.5
Cetaceans		65.1	51.2	53.5	53.3	59.5	54.8	21.7	25.3
Seabirds				8,017.0	8,743.9	8,232.1	9,831.1	14,281.2	14,677.2
Sea_Lion					-2,057.9	-4,773.8	-3,968.2	-3,676.7	-4,554.9
Iguana						4,888.0	3,371.3	2,643.5	3,006.5
Penguin							-5,202.9	3,817.6	3,034.6
Turtles								-26,654.1	-23,844.5
Sharks									-19,097.2
Intercept	-30,364.2***	-30,120.8***	-10,153.4	-12,996.3	-13,097.7	-11,390.7	-14,020.2	-9,943.1	-5,459.5
Observations	53	53	27	27	27	27	27	27	27
Adjusted R^2	0.20	0.21	0.15	0.15	0.11	0.10	0.07	0.15	0.11
Residual Std. Error	6,797.1 (df = 48)	6,777.1 (df = 47)	6,241.0(df = 21)	6,230.9 (df = 20)	6,374.9 (df = 19)	6,417.0 (df = 18)	6,509.5 (df = 17)	6,243.2 (df = 16)	6,370.4 (df = 15)
F Statistic	4.4*** (df = 4; 48)	3.8*** (df = 5; 47)	1.9 (df = 5; 21)	1.7 (df = 6; 20)	1.4 (df = 7; 19)	1.3 (df = 8; 18)	1.2 (df = 9; 17)	1.4 (df = 10; 16)	1.3(df = 11; 15)

Note: $^{**}p<0.05$; $^{***}p<0.01$

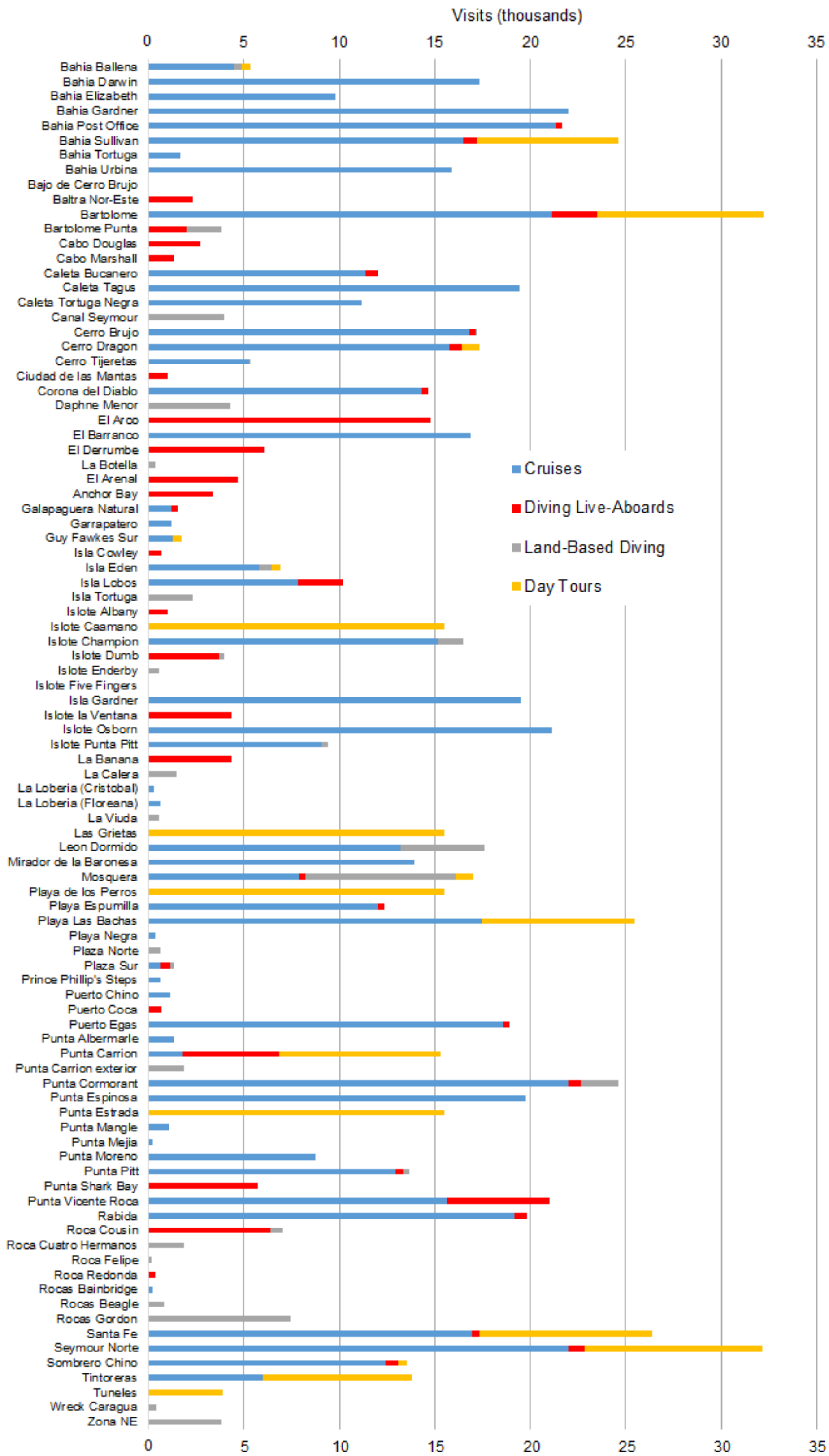


Figure A1. *Annual number of visits (thousands) to each marine tourism site in the GMR by category.*

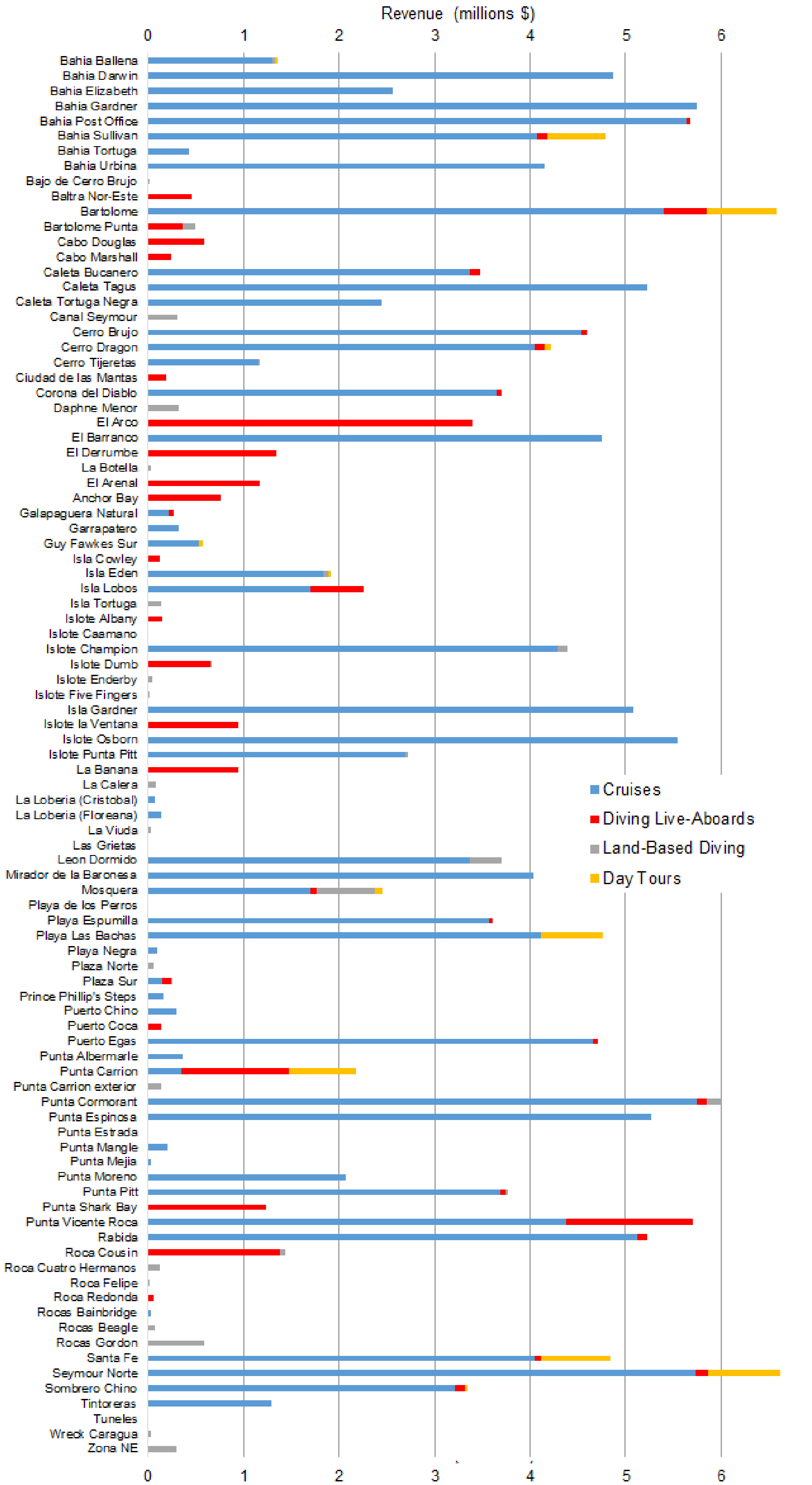


Figure A2. *Annual marine revenue (millions $) from each tourism site in the GMR by category.*

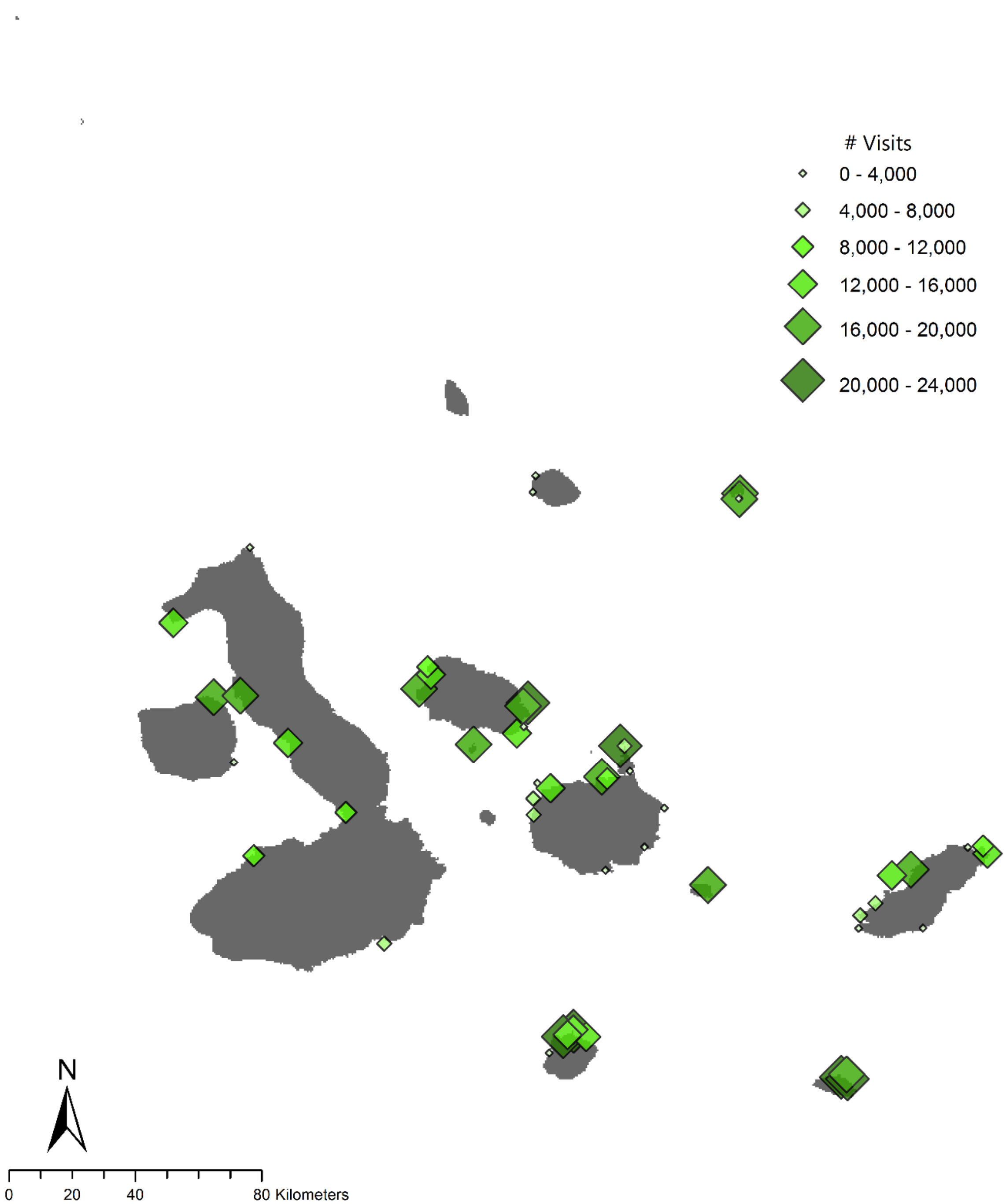


Figure A3. *Spatial distribution of annual number of visits to marine tourism sites in the GMR.*

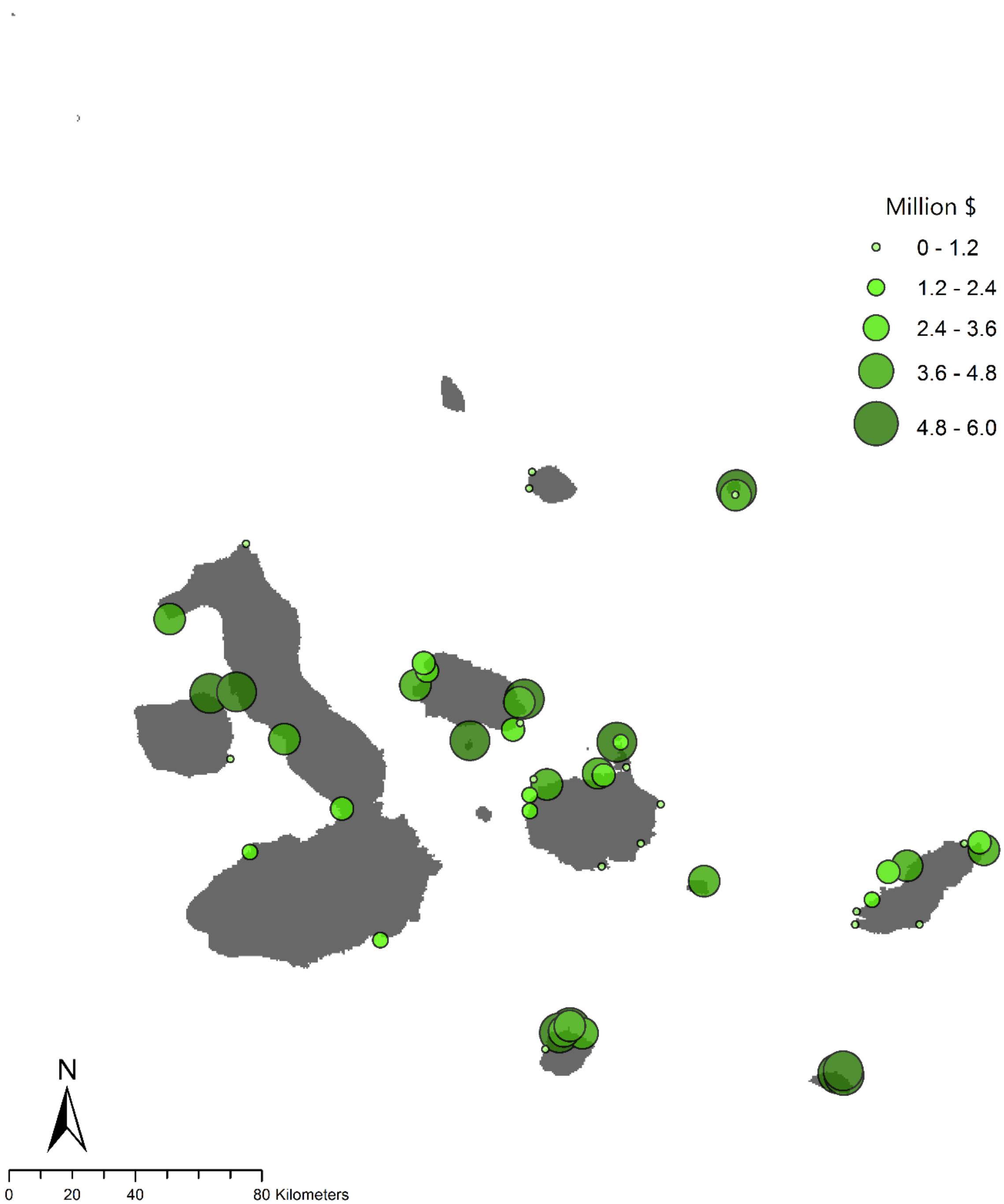


Figure A4. *Spatial distribution of annual cruise revenue (millions $) from marine tourism sites in the GMR.*

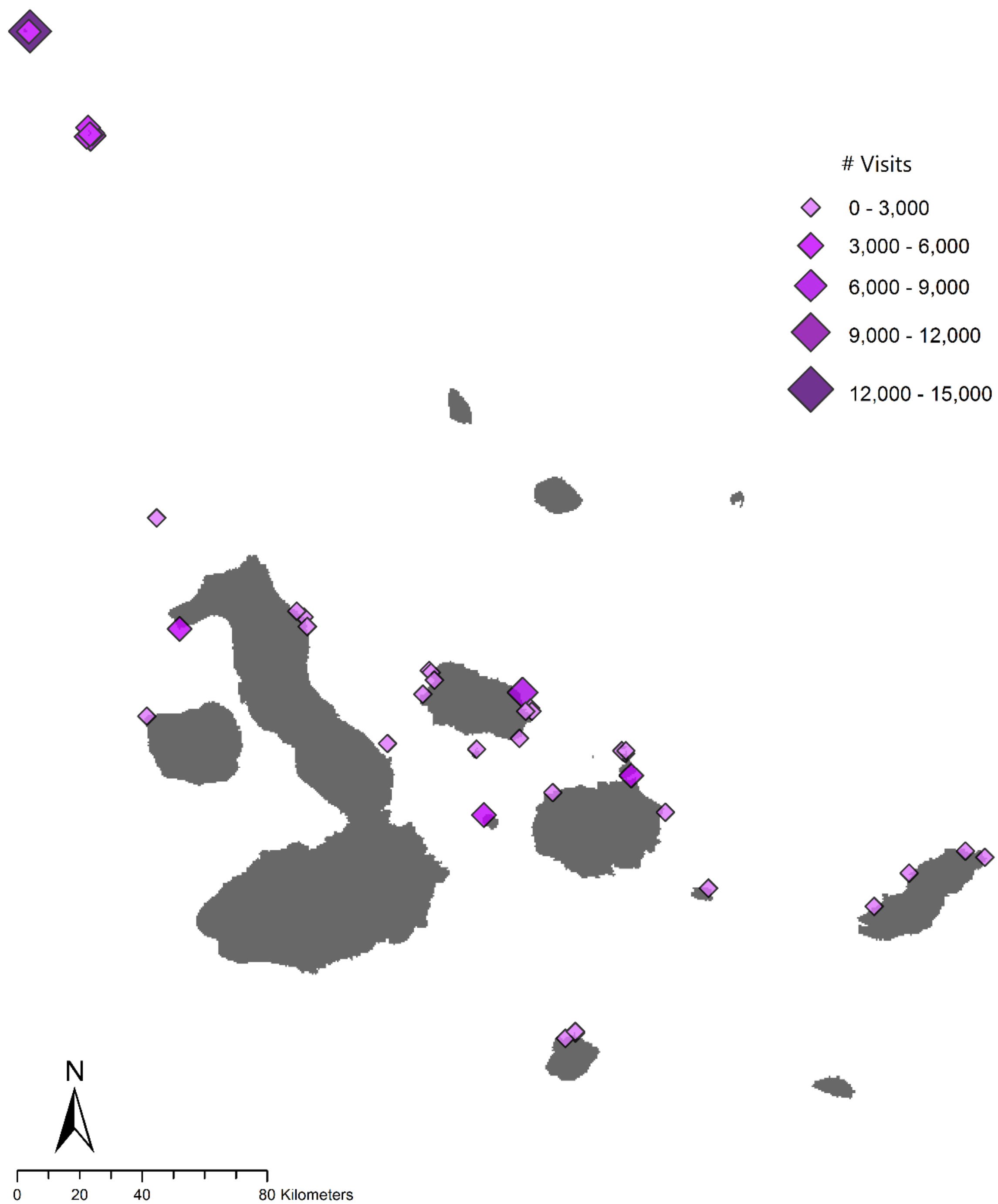


Figure A5. *Spatial distribution of annual number of diving live-aboard visits to marine tourism sites in the GMR.*

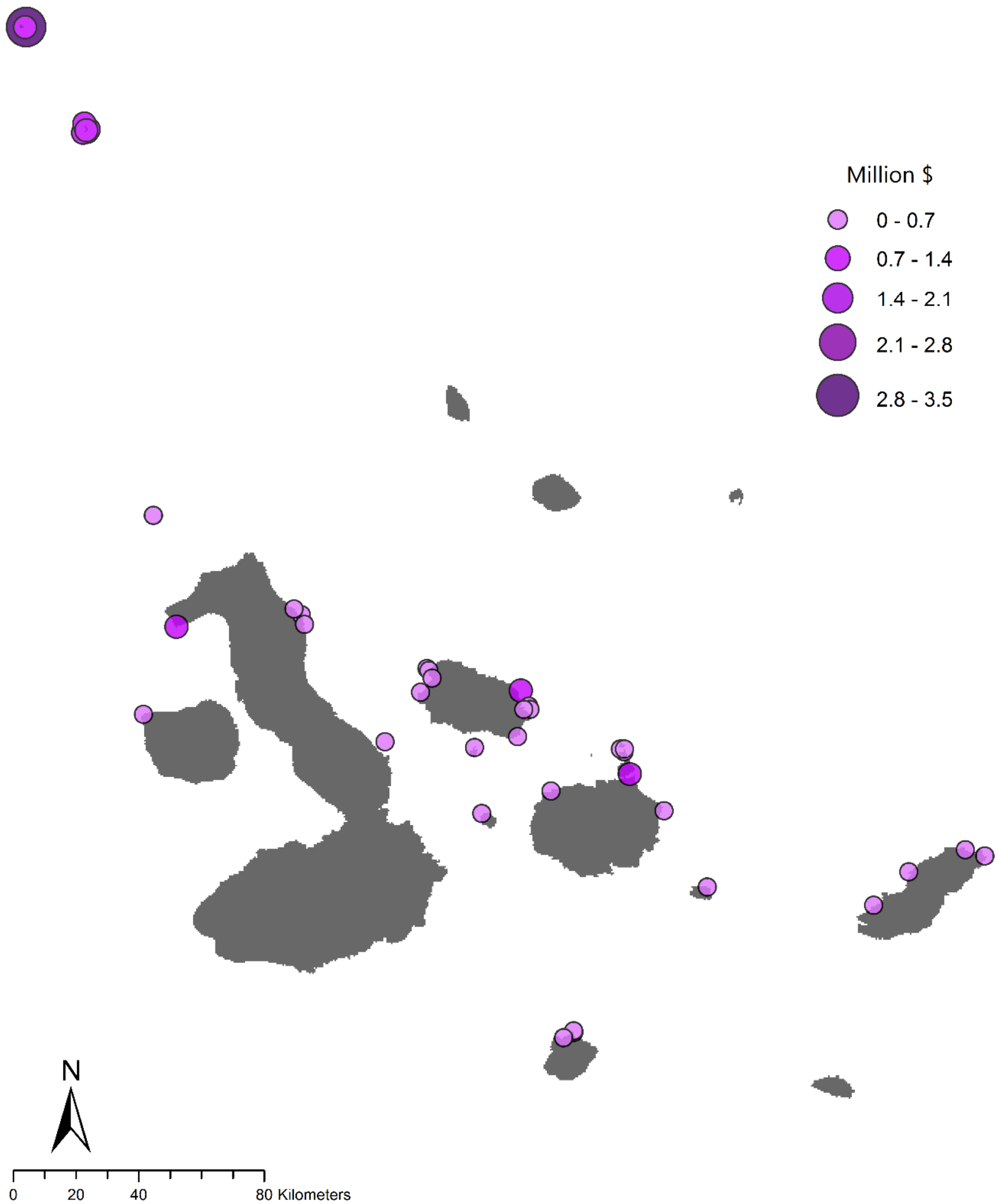


Figure A6. *Spatial distribution of annual diving live-aboard revenue (millions $) from marine tourism sites in the GMR.*

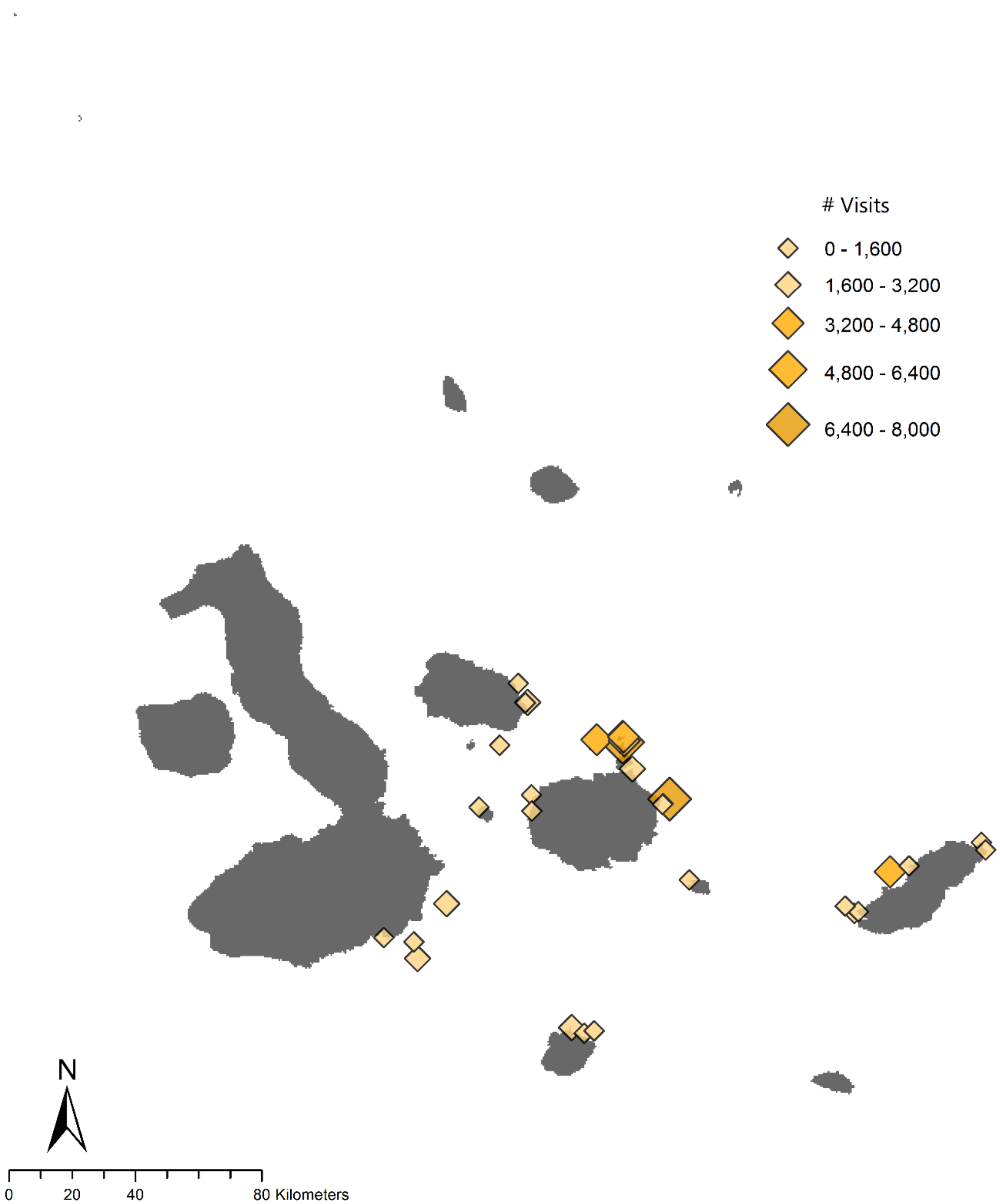


Figure A7. *Spatial distribution of annual number of land-based diving visits to marine tourism sites in the GMR.*

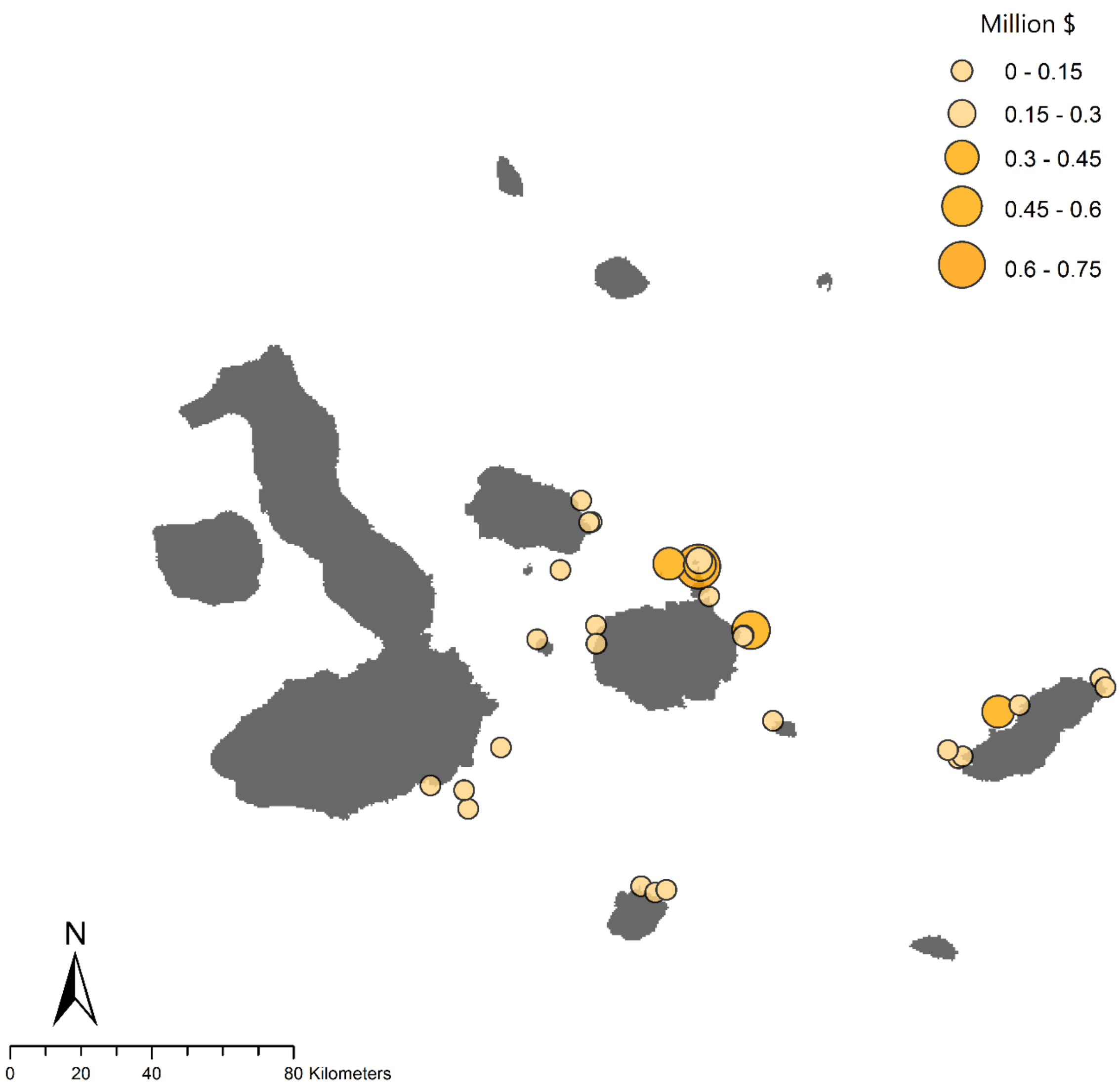


Figure A8. *Spatial distribution of annual land-based diving revenue (millions $) from marine tourism sites in the GMR.*

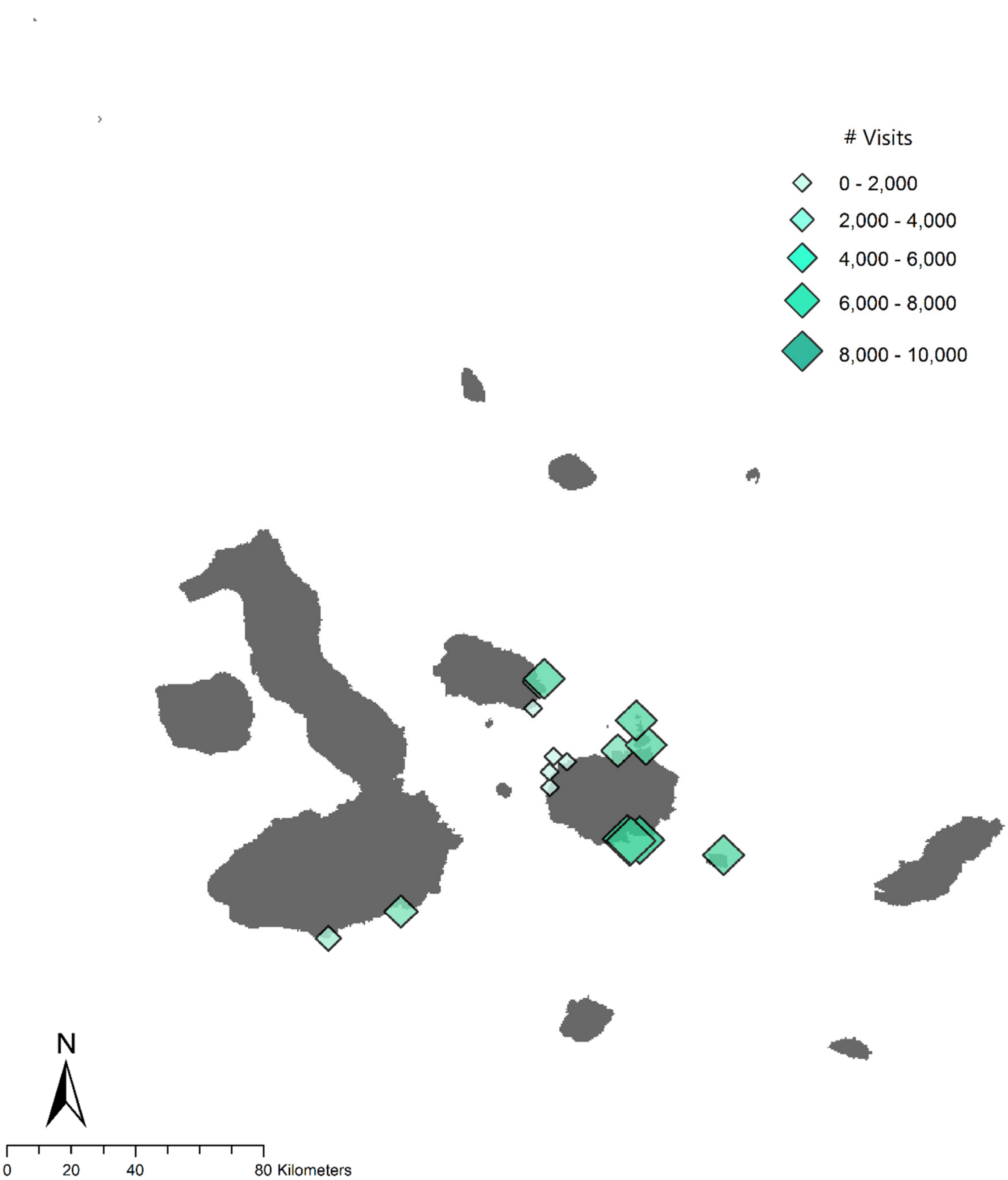


Figure A9. *Spatial distribution of annual number of day tour visits to marine tourism sites in the GMR.*

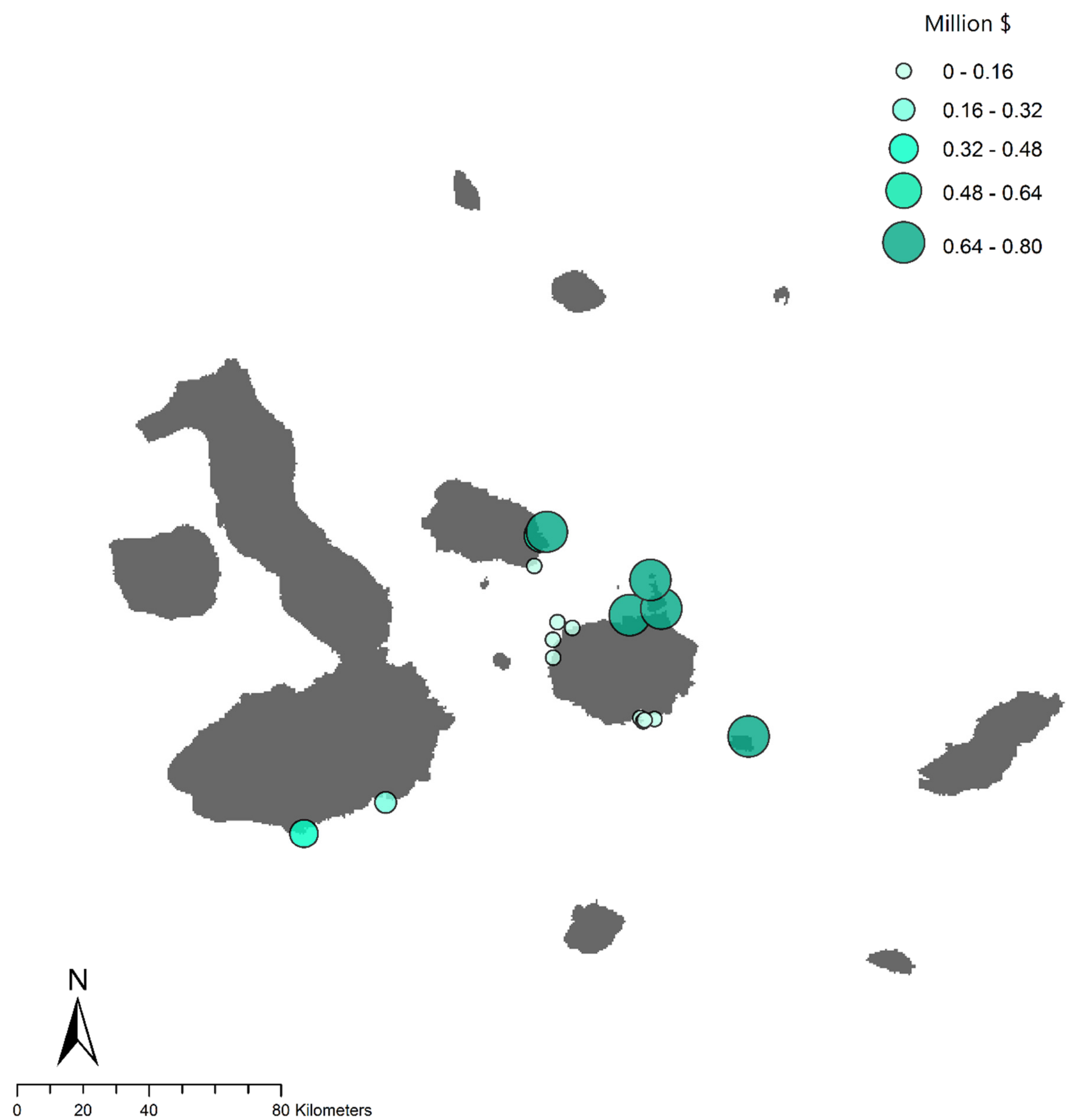


Figure A10. *Spatial distribution of annual day tour revenue (millions $) from marine tourism sites in the GMR.*

Table A2. *Annual visits by GMR site and tour category.*

Site Name	Cruise Visits	Land-Based Diving Visits	Live-aboard Diving Visits	Day Tour Visits	TOTAL Visits
Bahia Ballena	4,507	389	-	443	5,340
Bahia Darwin	17,326	-	-	-	17,326
Bahia Elizabeth	9,797	-	-	-	9,797
Bahia Gardner	21,995	-	-	-	21,995
Bahia Post Office	21,348	-	336	-	21,684
Bahia Sullivan	16,517	-	672	7,428	24,617
Bahia Tortuga	1,646	-	-	-	1,646
Bahia Urbina	15,869	-	-	-	15,869
Bajo de Cerro Brujo	-	41	-	-	41
Baltra Nor-Este	-	-	2,353	-	2,353
Bartolome	21,132	-	2,353	8,758	32,243
Bartolome Punta	-	1,850	2,017	-	3,866
Cabo Douglas	-	-	2,689	-	2,689
Cabo Marshall	-	-	1,345	-	1,345
Caleta Bucanero	11,389	-	672	-	12,061
Caleta Tagus	19,431	-	-	-	19,431
Caleta Tortuga Negra	11,173	-	-	-	11,173
Canal Seymour	-	3,942	-	-	3,942
Cerro Brujo	16,787	37	336	-	17,160
Cerro Dragon	15,761	-	672	887	17,320
Cerro Tijeretas	5,290	27	-	-	5,317
Ciudad de las Mantas	-	-	1,008	-	1,008
Corona del Diablo	14,331	-	336	-	14,667
Daphne Menor	-	4,283	-	-	4,283
El Arco	-	-	14,790	-	14,790
El Barranco	16,894	-	-	-	16,894
El Derrumbe	-	-	6,050	-	6,050
La Botella	-	389	-	-	389
El Arenal	-	-	4,706	-	4,706
Anchor Bay	-	-	3,361	-	3,361
Galapaguera Natural	1,187	-	336	-	1,524

Garrapatero	1,214	-	-	-	1,214
Guy Fawkes Sur	1,295	-	-	443	1,739
Isla Cowley	-	-	672	-	672
Isla Eden	5,802	681	-	443	6,927
Isla Lobos	7,827	-	2,353	-	10,179
Isla Tortuga	-	2,336	-	-	2,336
Islote Albany	-	-	1,008	-	1,008
Islote Caamano	-	-	-	15,521	15,521
Islote Champion	15,194	1,314	-	-	16,508
Islote Dumb	-	243	3,697	-	3,941
Islote Enderby	-	535	-	-	535
Islote Five Fingers	-	26	-	-	26
Isla Gardner	19,539	-	-	-	19,539
Islote la Ventana	-	-	4,370	-	4,370
Islote Osborn	21,132	-	-	-	21,132
Islote Punta Pitt	9,068	354	-	-	9,422
La Banana	-	-	4,370	-	4,370
La Calera	-	1,460	-	-	1,460
La Loberia (Cristobal)	270	-	-	-	270
La Loberia (Floreana)	648	-	-	-	648
La Viuda	-	584	-	-	584
Las Grietas	-	-	-	15,521	15,521
Leon Dormido	13,197	4,382	-	-	17,579
Mirador de la Baronesa	13,953	-	-	-	13,953
Mosquera	7,880	7,885	336	887	16,988
Playa de los Perros	-	-	-	15,521	15,521
Playa Espumilla	12,037	-	336	-	12,373
Playa Las Bachas	17,461	-	-	7,982	25,443
Playa Negra	378	-	-	-	378
Plaza Norte	-	633	-	-	633
Plaza Sur	648	195	504	-	1,347
Prince Phillip's Steps	648	-	-	-	648
Puerto Chino	1,133	-	-	-	1,133
Puerto Coca	-	-	672	-	672

Puerto Egas	18,595	-	336	-	18,931
Punta Albermarle	1,322	-	-	-	1,322
Punta Carrion	1,835	-	5,042	8,426	15,303
Punta Carrion exterior	-	1,850	-	-	1,850
Punta Cormorant	21,995	1,947	672	-	24,614
Punta Espinosa	19,782	-	-	-	19,782
Punta Estrada	-	-	-	15,521	15,521
Punta Mangle	1,080	-	-	-	1,080
Punta Mejia	216	-	-	-	216
Punta Moreno	8,771	-	-	-	8,771
Punta Pitt	12,981	324	336	-	13,641
Punta Shark Bay	-	-	5,714	-	5,714
Punta Vicente Roca	15,626	-	5,378	-	21,004
Rabida	19,188	-	672	-	19,861
Roca Cousin	-	681	6,386	-	7,068
Roca Cuatro Hermanos	-	1,850	-	-	1,850
Roca Felipe	-	195	-	-	195
Roca Redonda	-	-	336	-	336
Rocas Bainbridge	243	-	-	-	243
Rocas Beagle	-	827	-	-	827
Rocas Gordon	-	7,447	-	-	7,447
Santa Fe	16,975	-	336	9,091	26,402
Seymour Norte	21,995	-	840	9,313	32,148
Sombrero Chino	12,414	-	672	443	13,530
Tintoreras	6,018	-	-	7,760	13,779
Tuneles	-	-	-	5,038	3,880
Wreck Caragua	-	417	-	-	417
Zona NE	-	3,845	-	-	3,845

Table A3. *Annual revenue ($) by GMR site and tour category.*

Site Name	Cruise Revenue ($)	Land-Based Diving Revenue ($)	Live-aboard Diving Revenue ($)	Day Tour Revenue ($)	TOTAL Revenue ($)
Bahia Ballena	1,297,433	30,455	-	31,042	1,358,930
Bahia Darwin	4,876,195	-	-	-	4,876,195
Bahia Elizabeth	2,565,429	-	-	-	2,565,429
Bahia Gardner	5,748,837	-	-	-	5,748,837
Bahia Post Office	5,638,276	-	46,610	-	5,684,885
Bahia Sullivan	4,078,669	-	105,227	610,223	4,794,119
Bahia Tortuga	421,172	-	-	-	421,172
Bahia Urbina	4,152,791	-	-	-	4,152,791
Bajo de Cerro Brujo	-	3,181	-	-	3,181
Baltra Nor-Este	-	-	451,635	-	451,635
Bartolome	5,395,148	-	454,226	726,852	6,576,226
Bartolome Punta	-	143,471	355,763	-	499,234
Cabo Douglas	-	-	591,047	-	591,047
Cabo Marshall	-	-	245,935	-	245,935
Caleta Bucanero	3,365,523	-	105,227	-	3,470,750
Caleta Tagus	5,227,805	-	-	-	5,227,805
Caleta Tortuga Negra	2,439,210	-	-	-	2,439,210
Canal Seymour	-	310,167	-	-	310,167
Cerro Brujo	4,538,914	2,910	46,610	-	4,588,434
Cerro Dragon	4,041,700	-	105,227	67,122	4,214,048
Cerro Tijeretas	1,153,776	2,121	-	-	1,155,897
Ciudad de las Mantas	-	-	187,318	-	187,318
Corona del Diablo	3,648,090	-	58,617	-	3,706,707
Daphne Menor	-	326,270	-	-	326,270
El Arco	-	-	3,391,619	-	3,391,619
El Barranco	4,756,217	-	-	-	4,756,217
El Derrumbe	-	-	1,344,158	-	1,344,158
La Botella	-	29,203	-	-	29,203
El Arenal	-	-	1,164,871	-	1,164,871
Anchor Bay	-	-	763,677	-	763,677
Galapaguera Natural	217,475	-	46,610	-	264,085

Garrapatero	325,138	-	-	-	325,138
Guy Fawkes Sur	538,146	-	-	36,080	574,226
Isla Cowley	-	-	117,235	-	117,235
Isla Eden	1,835,580	50,167	-	31,042	1,916,789
Isla Lobos	1,703,173	-	559,435	-	2,262,608
Isla Tortuga	-	131,414	-	-	131,414
Islote Albany	-	-	151,837	-	151,837
Islote Caamano	-	-	-	155,210	155,210
Islote Champion	4,285,250	107,454	-	-	4,392,705
Islote Dumb	-	19,469	647,294	-	666,763
Islote Enderby	-	45,022	-	-	45,022
Islote Five Fingers	-	2,031	-	-	2,031
Isla Gardner	5,085,374	-	-	-	5,085,374
Islote la Ventana	-	-	945,345	-	945,345
Islote Osborn	5,543,805	-	-	-	5,543,805
Islote Punta Pitt	2,695,742	27,572	-	-	2,723,315
La Banana	-	-	945,345	-	945,345
La Calera	-	82,134	-	-	82,134
La Loberia (Cristobal)	73,340	-	-	-	73,340
La Loberia (Floreana)	131,744	-	-	-	131,744
La Viuda	-	32,854	-	-	32,854
Las Grietas	-	-	-	155,210	155,210
Leon Dormido	3,366,728	341,144	-	-	3,707,872
Mirador de la Baronesa	4,033,794	-	-	-	4,033,794
Mosquera	1,706,444	611,858	58,617	73,718	2,450,637
Playa de los Perros	-	-	-	155,210	155,210
Playa Espumilla	3,566,770	-	46,610	-	3,613,379
Playa Las Bachas	4,116,869	-	-	652,906	4,769,775
Playa Negra	95,316	-	-	-	95,316
Plaza Norte	-	49,229	-	-	49,229
Plaza Sur	152,848	14,880	85,355	-	253,083
Prince Phillip's Steps	160,679	-	-	-	160,679
Puerto Chino	291,357	-	-	-	291,357
Puerto Coca	-	-	128,700	-	128,700

Puerto Egas	4,655,848	-	58,617	-	4,714,466
Punta Albermarle	355,969	-	-	-	355,969
Punta Carrion	350,209	-	1,126,973	695,582	2,172,763
Punta Carrion exterior	-	133,536	-	-	133,536
Punta Cormorant	5,748,837	146,392	105,227	-	6,000,456
Punta Espinosa	5,263,007	-	-	-	5,263,007
Punta Estrada	-	-	-	155,210	155,210
Punta Mangle	205,880	-	-	-	205,880
Punta Mejia	29,250	-	-	-	29,250
Punta Moreno	2,070,999	-	-	-	2,070,999
Punta Pitt	3,691,044	25,224	46,610	-	3,762,877
Punta Shark Bay	-	-	1,240,868	-	1,240,868
Punta Vicente Roca	4,378,016	-	1,328,019	-	5,706,035
Rabida	5,120,178	-	105,227	-	5,225,405
Roca Cousin	-	53,296	1,383,902	-	1,437,198
Roca Cuatro Hermanos	-	115,874	-	-	115,874
Roca Felipe	-	14,602	-	-	14,602
Roca Redonda	-	-	53,475	-	53,475
Rocas Bainbridge	23,751	-	-	-	23,751
Rocas Beagle	-	70,428	-	-	70,428
Rocas Gordon	-	580,186	-	-	580,186
Santa Fe	4,051,399	-	58,617	739,626	4,849,642
Seymour Norte	5,728,596	-	131,965	757,666	6,618,226
Sombrero Chino	3,212,466	-	105,227	31,042	3,348,736
Tintoreras	1,283,078	-	-	310,419	1,593,497
Tuneles	-	-	-	349,222	349,222
Wreck Caragua	-	32,490	-	-	32,490
Zona NE	-	294,425	-	-	294,425

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Tourism data

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Ecological data

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Data	Source
Critical habitat of cormorants and penguins	Banda-Cruz, G.& G. Jiménez-Uzcátegui (eds.) 2015. Informe técnico de recopilación de datos espaciales de las especies: pingüino de Galápagos (Spheniscus mendiculus), cormorán no volador (Phalacrocorax harrisi), albatros de Galápagos (Phoebastria irrorata), flamenco rojo (Phoenicopterus ruber) y cucuve de Floreana (Mimus trifasciatus). Fundación Charles Darwin, Galápagos.
Ocurrence of cetaceans	Alarcón, D. (2012). Análisis de la abundancia relativa y distribución de cetáceos en el Canal Bolívar (Isabel), Galápagos. Galágos. s/d
	Denkinger, D. Salazar, S. Krutwa A., Merlen G. Murillo J. (2009) Proyecto CETACEA, Distribución y abundancia de cetáceos den la Reserva Marina Galápagos. Informe 2009. s/d.
	Denkinger, J. (s/d) From Whaling to Whale Watching: Cetacean Presence and Species Diversity in the Galapagos Marine Reserve
	Dirección del Parque Nacional Galápagos. (s/d) Informes y reportes técnicos de Campo de la DPNG
	Reserva Marina Galápagos. Línea Base de la Biodiversidad. Palacios, D. & Salazar, S. (2002) Capítulo 16. Cetáceos. Puerto Ayora. Galápagos
Critical habitat of fur seals	Villegas Amtmann S, Jeglinski JWE, Costa DP, Robinson PW, Trillmich F. (2013). Individual Foraging Strategies Reveal Nich Overlap between Endangered Galapagos Pinnipeds. University of Californi
	GAIA-Universidad San Francisco de Quito. (2014) Informe técnico Censo Poblacional de Lobos marinos 2014
Whale shark telemetry data	Hearn et al (2012). Marcaje de tiburón ballena, reporte final 2011.
	Acuña-Marrero D, Jiménez J, Smith F, Doherty PF Jr, Hearn A, et al. (2014) Whale Shark (Rhincodon typus) Seasonal Presence, Residence Time and Habitat Use at Darwin Island, Galapagos Marine Reserve. PLoS ONE 9(12): e115946.doi:10.1371/journal.pone.0115946
Galapagos shark telemetry data	Alex Hearn (USFQ)
Blacktip reef shark telemetry data	Alex Hearn (USFQ)
Hammerhead shark telemetry data	Alex Hearn (USFQ)
	Hearn, A., Ketchum, ,. J., Kimbley, P., Espinoza, E., & Peñaherrera, C. (2010). Hotspots within hotspots? Hammerhead shark movements around Wolf Island, Galapagos Marine Reserve. s/d: Springer.
	Ketchum, J., Hearn, A., Kimley, P., Peñaherrera, C., Espinoza, E., Bessudo, S., Arauz, R. (2014). Inter-island movements of scalloped hammerhead sharks (Sphyrna lewini) and seasonal connectivity in a marine protected area of the eastern tropical Pacific. s/d. Springer
	Ketchum, J. (2011). Movement Patterns and Habitat Use of Scalloped Hammerhead Sharks (Sphyrna lewini) in the Galapagos Islands: Implications for the Design of Marine Reserves. Estados Unidos: UMI.
Silky shark telemetry data	Alex Hearn (USFQ)