Valuation of Ecosystem Services in the
MAGDALENA-ALMEJAS
LAGOON COMPLEX

B.C.S. MEXICO

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

GULF OF CALIFORNIA MARINE PROGRAM
of the INSTITUTE OF THE AMERICAS

CBMC
CENTRO PARA LA BIODIVERSIDAD MARINA Y LA CONSERVACIÓN; A.C.

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PREPARED BY:
Catalina López-Sagástegui
Gulf of California Marine Program
Institute of the Americas

Octavio Aburto Oropeza
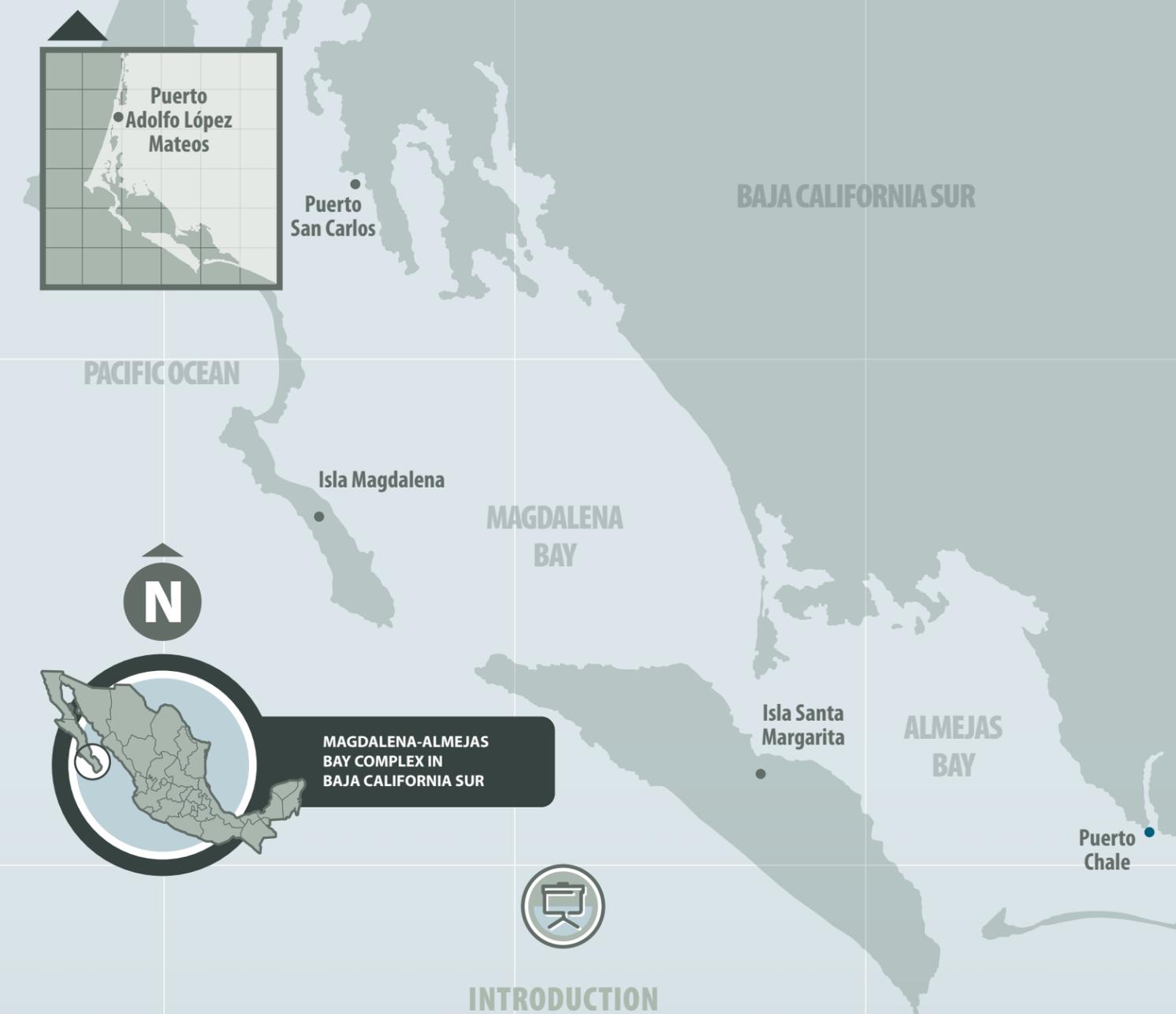Fabio Favoretto
Scripps Institution of Oceanography

Juan José Cota Nieto
Dayana Mendez
Centro para la Biodiversidad Marina y la Conservación A.C.

INTRODUCTION

The Magdalena-Almejas Lagoon Complex (BMA) is located on the west coast of Baja California Sur and hosts a great diversity and abundance of species that support important ecological processes, as well as commercial and tourist fishing activities (Rioja-Nieto et al., 2013). It has three distinct zones: the Channels Zone (137 km²) located in the northwest, Magdalena Bay (883 km²) in the central part of the complex, and Almejas Bay (370 km²) in the southeast. For most of the year, it experiences a semi-desert climate with high temperatures, cold winds, low humidity, scarce cloud cover, low pressure, and minimal precipitation.

BMA is considered one of the most important sites for Mexican industrial and coastal fishing. It has the largest mangrove forest on the Baja California Peninsula, providing refuge for species of high commercial and ecological value. Additionally, it is a highly productive site generating a large amount of food for other species (Hastings and Fisher, 2001). Revenues generated from tourism complement those from fishing. While gray whale watching has been developed for many years, activities such as hiking, bird watching and swimming with striped marlin in the open ocean have gained popularity.

The communities of the Magdalena-Almejas Lagoon Complex (BMA) depend on marine and coastal resources. Therefore, understanding the interaction between fishing and tourism, as well as their contribution to the local economy, will help comprehend the impact on ecosystem health and community well-being (Cota-Nieto et al., 2016). Monitoring fishing and tourism activities generates essential knowledge for natural resource management and ensures that social development is accompanied by strategies that guarantee the integrity and sustainability of the region's natural capital.

OBJECTIVE

To describe fishing and tourism activities, their dynamics, and their economic contribution to support efforts for responsible management in the Magdalena-Almejas Lagoon Complex, B.C.S., Mexico.

SPECIFIC OBJECTIVES
• Generate knowledge about the whale watching activities for gray whales (*Eschrichtius robustus*), and for activities related to swimming with striped marlin (*Kajikia audax*).

• Build a knowledge baseline for the responsible management of gray whale and striped marlin tourism activities.

• Describe coastal fishing dynamics to create a baseline for the economic contribution of each fishery in the region.

METHODOLOGY

We implemented a collaborative methodology that encourages the participation of scientists, service providers, resource users and community members in research programs. Monitoring work in BMA began with the fishing sector in 2012 (Cota-Nieto et al., 2017) and has been adapted to include gray whale and marlin tourism activities. The methodology incorporates traditional sampling and monitoring techniques with modern technology to streamline data analysis and collection.

DATA COLLECTION
We generated and integrated two types of information. The first is geospatial data generated with GPS trackers (also known as data loggers), containing an alphanumeric code, coordinates (latitude, longitude), speed (km/h) and duration of each trip (h). For tourism activities, we also recorded the number of sightings (including the number of adults and calves), number of tourists, service fees (pesos), gasoline consumption (liters), initial and final trip times. For fishing trips, we noted the target species, total catch (kg), price per kilogram (pesos), fishing gear used and general characteristics of the boat (engine, boat length). The information is compiled into databases and analyzed to describe the dynamics of tourist activity in each community.

TOURISM

### DIGITIZATION OF SIGHTING AREAS
To identify gray whale and striped marlin sighting areas, we used the speed of the skiff and the maneuver performed by the captain. Spatial information was downloaded using the CanWay software to visualize the route on Google Maps and discard incomplete or erroneous data. With the same program, the files were exported to .csv format, compatible with GIS programs and imported using ArcGIS™ 10.8.1 software to calculate the total distance traveled on each trip.

Sighting areas for striped marlin were identified when the vessel's speed range was between 0-7 km/h. In the case of gray whale sightings, the vessel's speed range was between 0-5 km/h during the sighting. Additionally, we identified the areas of sighting visited most frequently.
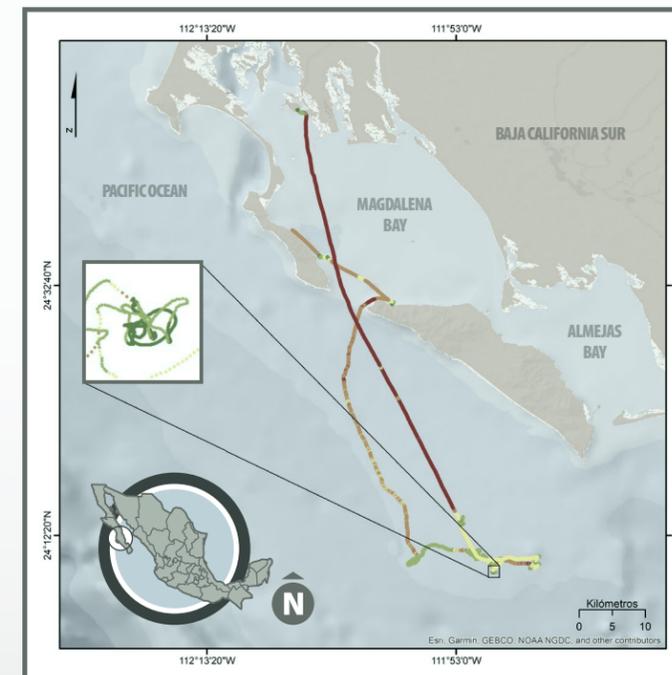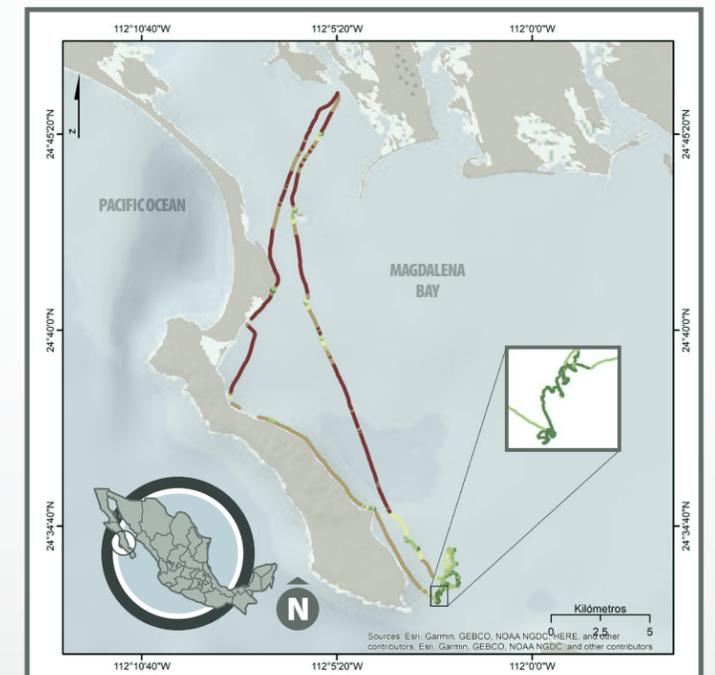
Whale watching and free diving trips for gray whale and striped marlin monitored with GPS loggers. The colors indicate the boat's speed.

ARTISANAL FISHERIES

DIGITIZATION OF TRIPS AND FISHING AREAS
Spatial information was downloaded using CanWay™ 1.1.12 software and exported to .csv format. Each file was edited using RStudio™ 1.4.1103 software for digitization and ArcGIS™ 10.8.1 to calculate the distances traveled on each fishing trip with the 'ModelBuilder' tool. Fishing areas were identified using the fishing maneuver pattern and vessel speed as references.

FISHING INTENSITY AND SEASONS
Fishing intensity is a way of measuring the fishing effort applied in specific areas, and we measured it based on the number of times a fisherman visited the same area. We used the 'Kernel Density' tool to categorize areas using the standard deviation classification method with a standard deviation interval size. The frequency of use was divided into high, medium, and low to represent it on the maps. The graph with the seasons with the best fishing catches (heat map) was created with Tableau 2022.1.7 and shows the cumulative catches (kg) each month during the study period (2012-2022).

ESTIMATION OF THE ECONOMIC VALUE OF FISHERIES
We conducted surveys of fishermen in Isla Margarita, Puerto San Carlos, and Puerto Adolfo López Mateos to determine investment and maintenance costs, as well as indirect costs associated with fishing. The data generated with GPS trackers were used to calculate basic behavior statistics for a skiff and then extrapolate to the fishing population. We assumed that fishing activity in BMA behaves equitably.
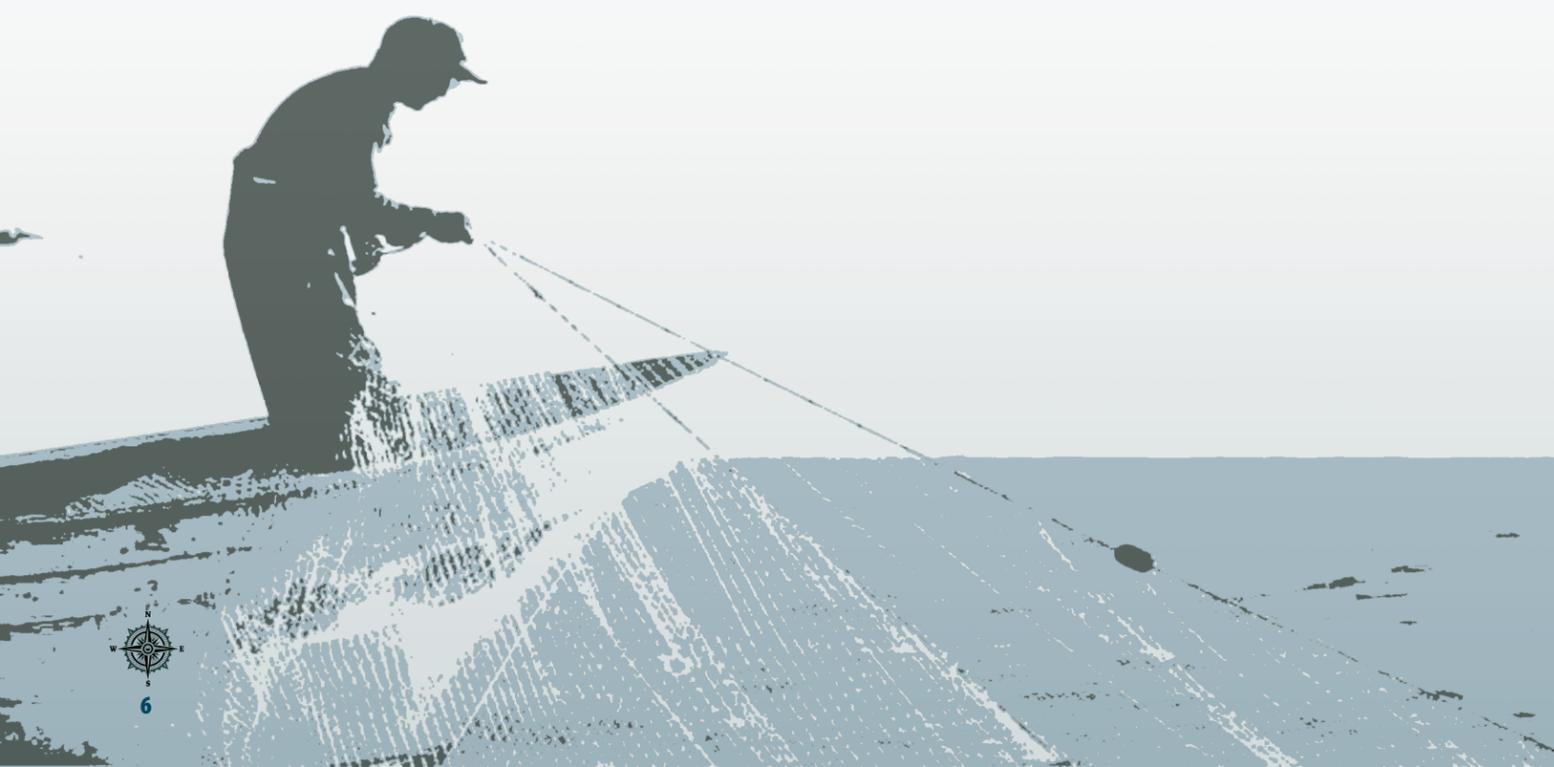
RESULTS

TOURISM
The data was generated by 35 tourism operators that offer trips focusing on striped marlin, gray whale, humpback whale, blue whale, diving tours, mangrove highking tours, birdwatching and sport fishing. Although the main objective of the trip is defined at the start of the trip, it is common for captains to record parallel sightings; for example, on a trip dedicated to striped marlin interactions, tourists may also get to see whales, mobulas (rays) or sharks.

Approximately 40% of the tourism fleet participates in three or more activities, while 60% participates in one or two at most. The difference in proportion is since, throughout the year, activities interchange between tourism and fishing, which has historically sustained the regional economy. Another factor may be that the boat owner or operator recently joined the tourism sector and is in the stage of familiarization and just gaining experience. Managing permits for some activities (e.g. gray whale, sport fishing, diving certification, etc.) is also a limitation since a significant economic investment is required and the bureaucratic process can be long.

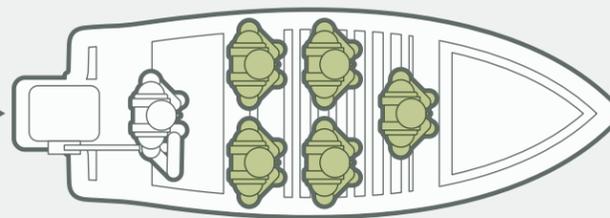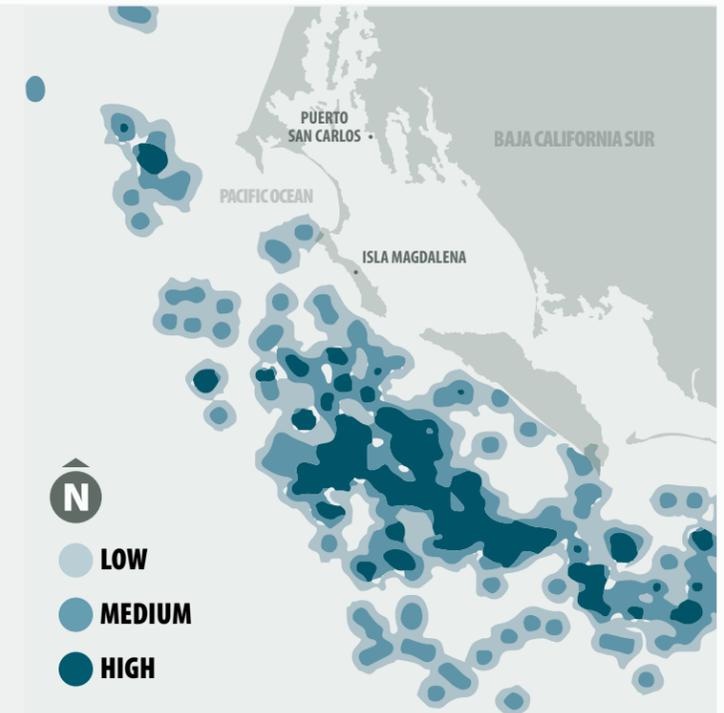Tourism activities during the 2020-2022 seasons in BMA.

STRIPED MARLIN ECOTOURISM ACTIVITIES

25
BOATS
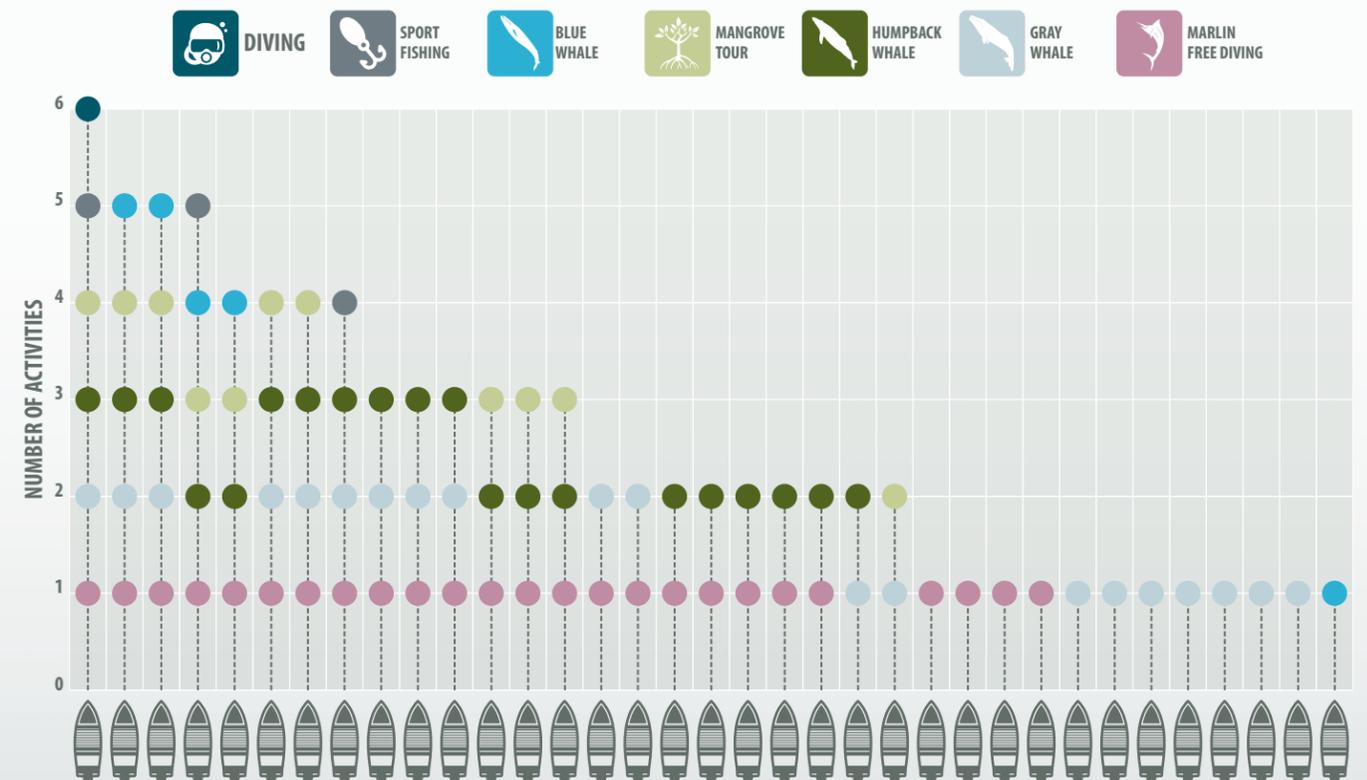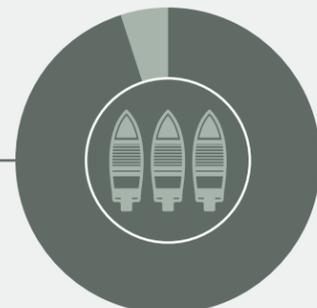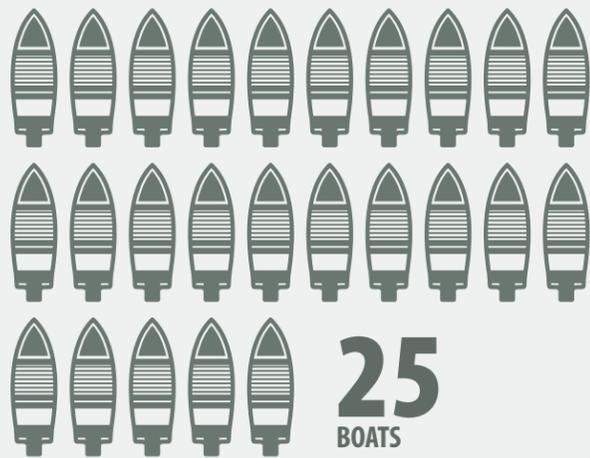
95%
OF THE FLEET
of the fleet focusing on this activity in Puerto San Carlos, B.C.S. during the 2020 - 2022 seasons.

258
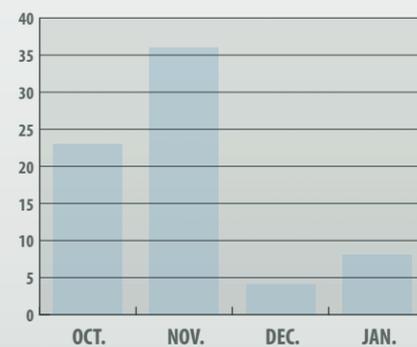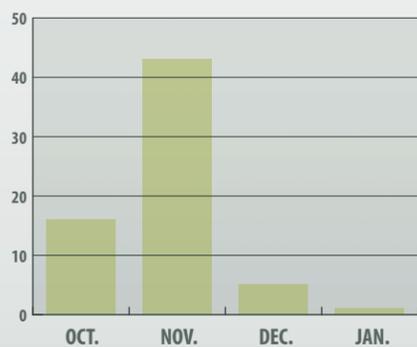**MONITORED TRIPS**

488
INTERACTION EVENTS

Boats launch from Puerto San Carlos, although some operate from Magdalena Island. Swimming with striped marlin is done along the underwater canyons that stretch along BMA's coast.

5 TOURISTS
ON AVERAGE PER TRIP

2 INTERACTION
EVENTS ON AVERAGE PER TRIP

185km
ON AVERAGE PER TRIP

115LITERS
OF GASOLINE ON AVERAGE PER TRIP

9.5HRS
ON AVERAGE PER TRIP

PUERTO SAN CARLOS · BAJA CALIFORNIA SUR
PACIFIC OCEAN · ISLA MAGDALENA

N

LOW
MEDIUM
HIGH

Areas where interactions with striped marlin occured during the 2020-2022 seasons.

Although striped marlin can be seen along the Baja California Sur coast between October and January, most of the trips were recorded during October and November.

TOTAL 2020: OCT., NOV., DEC., JAN.
TOTAL 2020: 65

OCT., NOV., DEC., JAN.
TOTAL 2021: 122

OCT., NOV., DEC., JAN.
TOTAL 2022: 71

Total number of monitored trips during the 2020 - 2022 seasons in Puerto San Carlos, B.C.S.

	TOTAL NUMBER OF TOURISTS	AVERAGE DURATION OF TRIP (HOURS)	AVERAGE DISTANCE COVERED PER TRIP (KM)	AVERAGE USE OF GASOLINE PER TRIP (LT)	AVERAGE PRICE OF TRIP (MXN PESOS)
2020 ▶	313	9	181	108	$9,853
2021 ▶	575	9.5	183	134	$13,406
2022 ▶	356	10	191	133	$14,822

Striped marlin ecotourism activities for the 2020-2022 seasons.

Source: Gulf of California Marine Program (2022).

WHALE WATCHING - GRAY WHALE

20 BOATS

167 TRIPS MONITORED

157 INCLUDE SPATIAL AND SURVEY DATA
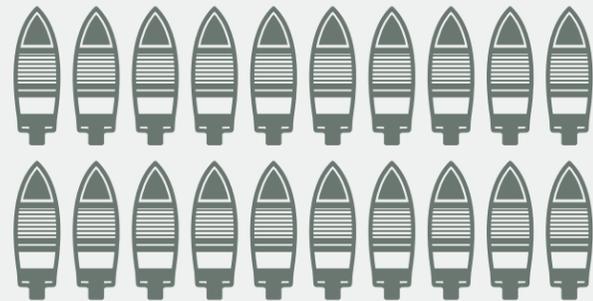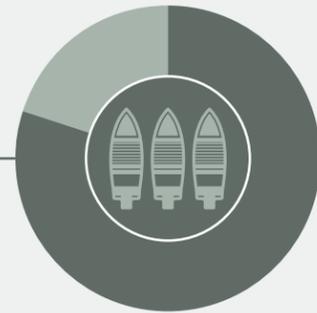
80% **OF THE FLEET** in Puerto San Carlos was dedicated to this activity during the 2020-2022 seasons.

Boats launch from Puerto San Carlos and they usually head towards the bays' entrances and the narrow connection between Magdalena Bay and Almejas Bay.
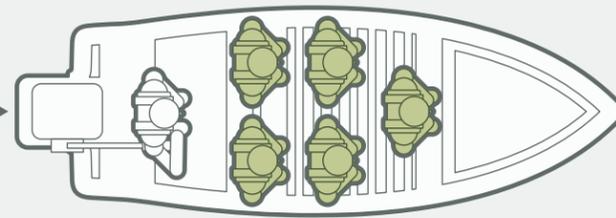
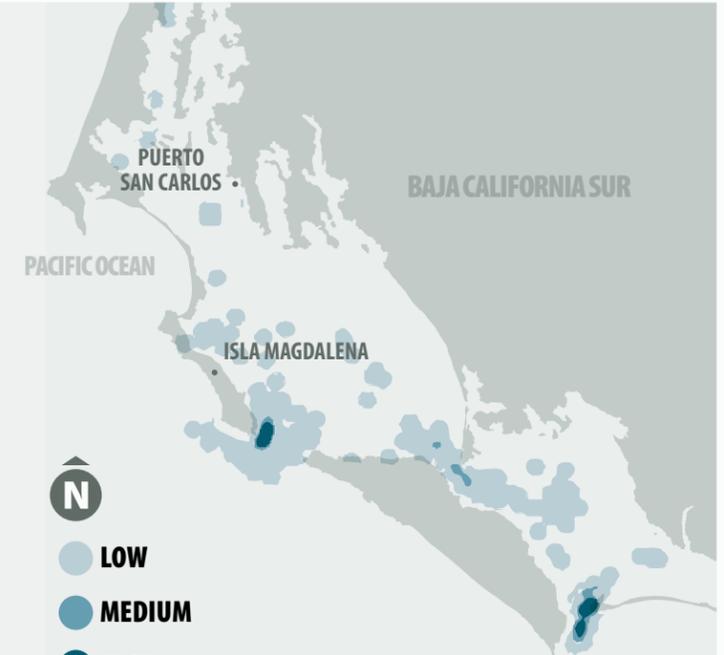**5** TOURISTS ON AVERAGE PER TRIP

5 SIGHTINGS ON AVERAGE PER TRIP

110 km ON AVERAGE PER TRIP

73 LITERS OF GASOLINE ON AVERAGE PER TRIP

7.5 HRS ON AVERAGE PER TRIP

PUERTO SAN CARLOS

BAJA CALIFORNIA SUR

PACIFIC OCEAN

ISLA MAGDALENA

N

LOW
MEDIUM
HIGH

Areas where whale watching activities took place during the 2020-2022 seasons.

While solitary whales can be seen as soon as December, most sightings were recorded between February and March.
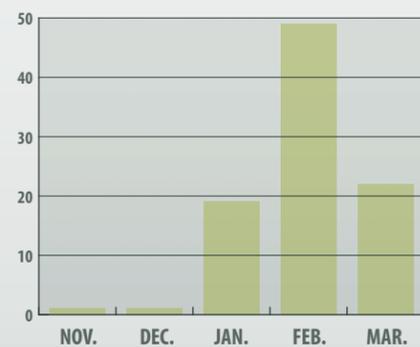
TOTAL 2020: 92
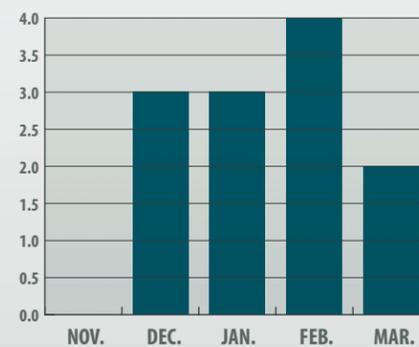
TOTAL 2021: 12
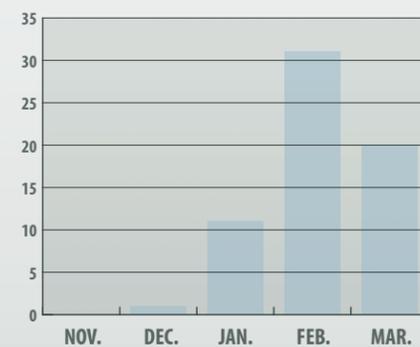
TOTAL 2022: 63

Number of monitored trips during the 2020-2022 seasons in Puerto San Carlos, B.C.S.

	TOTAL NUMBER OF TOURISTS	AVERAGE DURATION OF TRIP (HOURS)	AVERAGE DISTANCE COVERED PER TRIP (KM)	AVERAGE USE OF GASOLINE PER TRIP (LT)	AVERAGE PRICE OF TRIP (MXN PESOS)
2020 ▶	372	8	108	73	$6,152
2021 ▶	53	8.5	129	73	$5,693
2022 ▶	315	7	112	–	$6,780

Whale watching for gray whale 2020-2022 seasons.

Source: Gulf of California Marine Program (2022).

ECONOMIC CONTRIBUTION OF WHALE WATCHING AND FREE DIVING WITH STRIPED MARLIN

Recreational tourism has become a significant activity contributing to the region's economy and complementing artisanal fishing. The number of trips each boat can make during a season varies depending on different factors such as the size of the customer network each service provider has built, the investment capacity of each boat owner, whether the boat is alternating with fishing, whether the permit specifies where the activity can be carried out, and, of course, the weather.

In the specific case of free diving with marlin, we conducted 20 interviews with service providers at the beginning of the research to obtain information that helps contextualize our analysis and interpret the results better. To estimate the economic contribution of tourism focused on marlin and gray whale to the families' economy in BMA, we assume that the operational cost represents approximately 35% of the price (what they charge) of each trip.

The popularity of free diving with striped marlin has increased rapidly in the last 5 years and, while gray whale whale-watching in Puerto San Carlos has been practiced for a longer time, it is affected by the increase in service providers in Puerto Chale in Bahía Almejas.

Estimated economic value of whale watching during the 2020-2022 seasons in Puerto San Carlos, B.C.S.

Estimated economic value of free diving with striped marlin during the 2020-2022 seasons in Puerto San Carlos, B.C.S.

GREY WHALE

56 TRIPS PER BOAT

1,120 TRIPS PER SEASON

PRICE PER TRIP: $8,112

OPERATING COST OF BOAT/SEASON	$158,995
OPERATING COAST OF FLEET/SEASON	$3,179,904
GROSS INCOME OF BOAT/SEASON	$454,272
GROSS INCOME OF FLEET/SEASON	$9,085,440
NET INCOME OF BOAT/SEASON	$295,277
NET INCOME OF FLEET/SEASON	$5,905,536
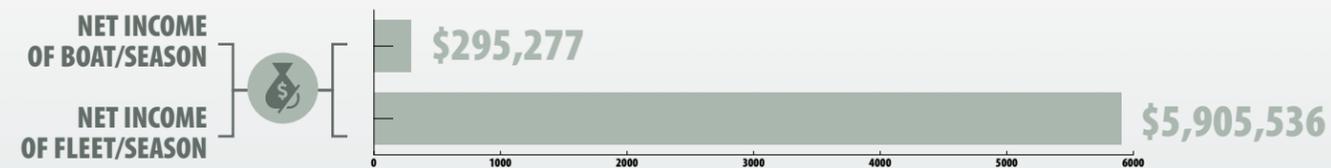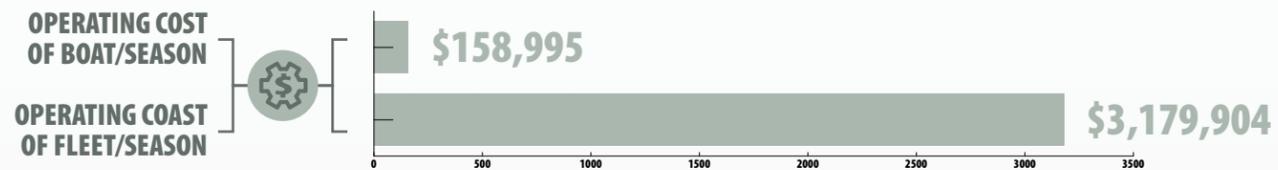
$295,000 PESOS — AVERAGE INCOME OF A BOAT PER SEASON

STRIPED MARLIN

86 TRIPS PER BOAT

2,150 TRIPS PER SEASON

PRICE PER TRIP: $12,758

OPERATING COST OF BOAT/SEASON	$384,016
OPERATING COAST OF FLEET/SEASON	$9,600,395
GROSS INCOME OF BOAT/SEASON	$1,097,88
GROSS INCOME OF FLEET/SEASON	$27,429,700
NET INCOME OF BOAT/SEASON	$713,172
NET INCOME OF FLEET/SEASON	$17,829,305
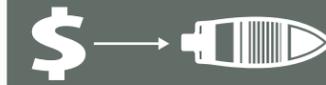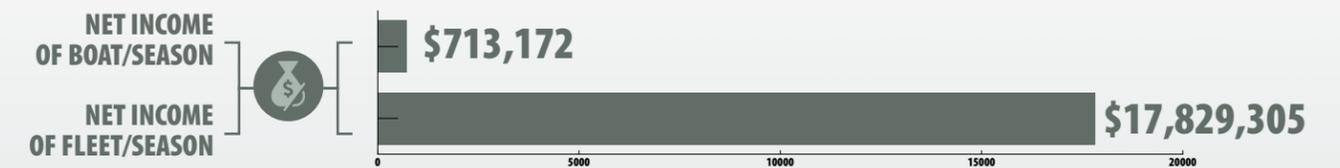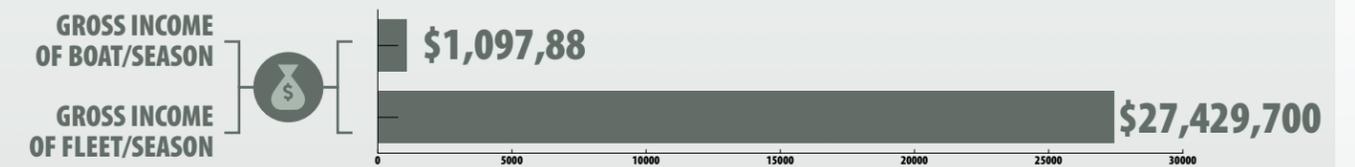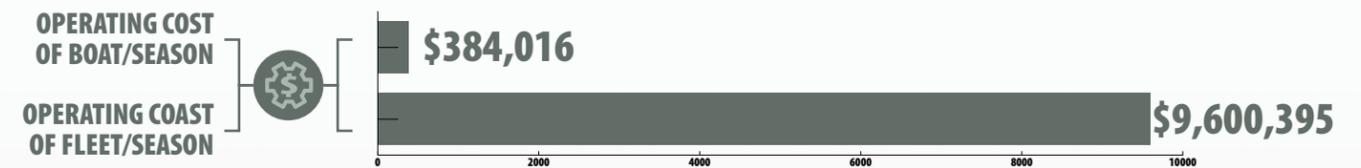
$713,172 PESOS — AVERAGE INCOME OF A BOAT PER SEASON

ARTISANAL FISHERIES

Through the Artisanal Fishing Monitoring Program in BMA, we have monitored 7,737 fishing trips from October 2012 to August 2022; 4,323 of these trips have spatial information. The information has been generated by 166 different vessels, and there are just over 12,300 records in the database (Mascareñas-Osorio et al., 2017).

Monitored fishing trips in BMA from 2012-20202.

ISLA MARGARITA
- 2,464 — MONITORED TRIPS
- 666 — TRIPS WITH SPATIAL DATA

PUERTO SAN CARLOS
- 4,181 — MONITORED TRIPS
- 2,795 — TRIPS WITH SPATIAL DATA

PUERTO ADOLFO LÓPEZ MATEOS
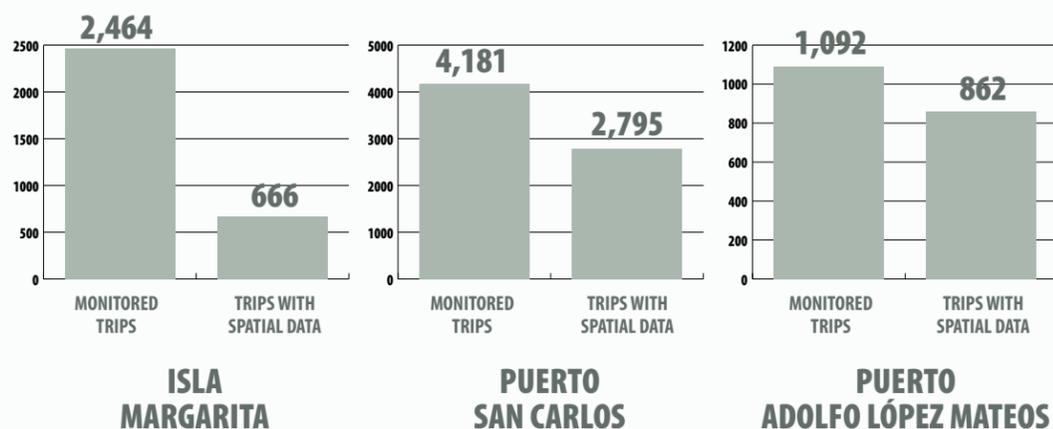- 1,092 — MONITORED TRIPS
- 862 — TRIPS WITH SPATIAL DATA

There are approximately 90 species targeted through various types of fishing permits in BMA. Source: Gulf of California Marine Program (2022).

- SHRIMP **51.83%**
- FINFISH **51.22%**
- SHARKS AND RAYS **29.88%**
- PACIFIC GEODUCK **20.12%**
- BLUE CRAB **19.51%**
- BAIT FISH **7.93%**
- MULLET **4.27%**
- CHOCOLATA CLAM **1.83%**
- ROÑOSA CLAM **1.22%**
- SNAIL **1.22%**
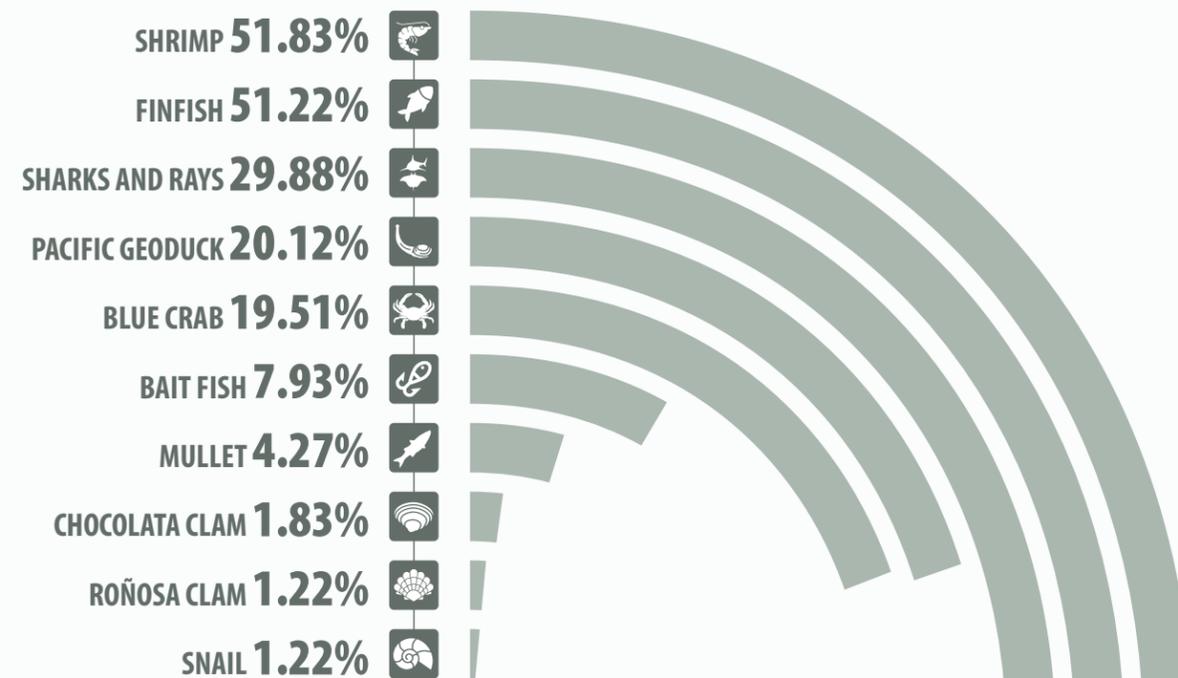
Each community depends on different species, so the fishing dynamics vary. Although the best catches are recorded in the warmer months, fishing in BMA occurs throughout the year. Changes in target species are related to biological and ecological processes that affect their presence and abundance.

Target species and the production seasonality in BMA. Soruce: Gulf of California Marine Program (2022).
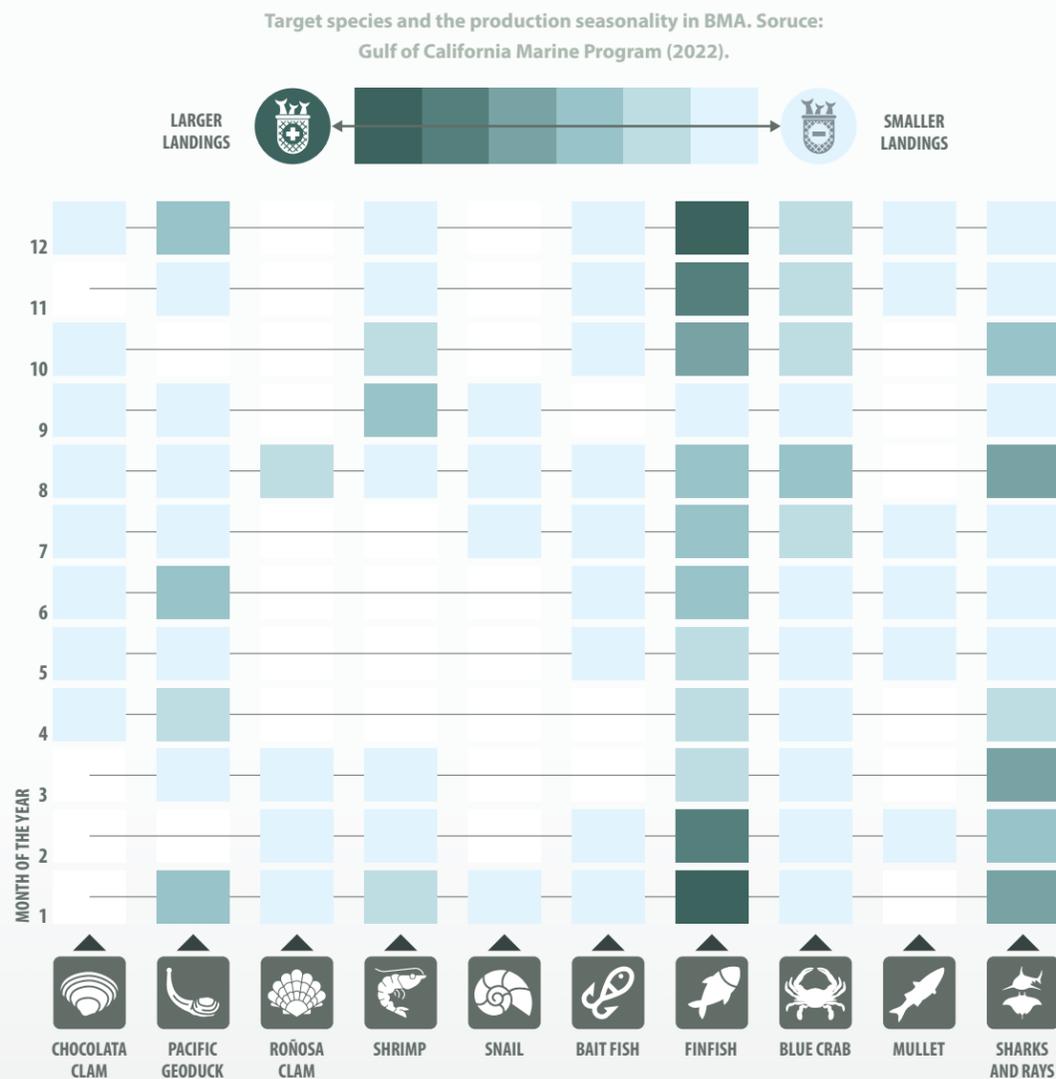
There are other factors that fishermen consider when planning their activities. Perhaps the most important is weather and meteorological conditions (such as hurricanes, tides, wind, etc.), as crew safety is a priority. Regulatory aspects such as bans, quotas, or the validity of fishing permits also influence decision-making. Those with permits to participate in tourism activities must also, during certain seasons, decide between both activities.

The coastal fleet uses the entire bay and the surrounding area outside, but the intensity of use varies depending on the season and the species being targeted. Fishing intensity helps measure the effort directed at a specific area or a specific resource. Monitoring it will help understand where and how much fishing is taking place so that fishermen and authorities can design fishing strategies that address the needs of the community without threatening the health of the resources' population.

As in tourism, fishing is carried out in different places depending on the target species. For example, fishermen who have permits to catch sharks and finfish often go out to the Pacific to work in open waters.

These trips are usually long, so some of the fishermen have a camp on Margarita Island from where they operate. Manta fishing is carried out in the northern area of Bahía Magdalena and in front of Puerto Adolfo López Mateos. Within the bay and in the canal area, scale fish are also fished, although the majority are boatfish and croaker. Shrimp, crab, and clam fisheries are also developed within the bay.

BAJA CALIFORNIA SUR

Puerto
San Carlos

MAGDALENA
BAY

ALMEJAS
BAY

OCEAN PACIFIC

N

GROUPER   **SNAPPERS**   **PUFFERFISH**   **JACKS**   **CORVINA**

**OCEAN
WHITEFISH**   **RED SNAPPER**

BAJA CALIFORNIA SUR

Puerto
San Carlos

MAGDALENA
BAY

ALMEJAS
BAY

PACIFIC OCEAN

N

BLUE SHRIMP   **BROWN SHRIMP**   **PACIFIC GEODUCK**   **BLUE CRAB**
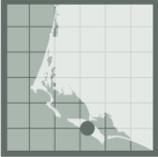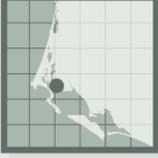
ECONOMIC VALUE OF COASTAL FISHERIES

Of the three communities analyzed, Puerto San Carlos has the highest diversity of fisheries (six); however, if we consider the number of resources (species) included in those fisheries, Puerto Adolfo López Mateos takes advantage of a greater diversity (53). Fishermen operating from Isla Margarita fish 44 species grouped into the categories of "sharks and rays" and "finfish." In Puerto San Carlos, 20 species are landed, including clams, shrimp, crabs, scale, and sharks.

Information collected through the artisanal fisheries monitoring program in BMA from 2012-2020.

	MONITORED TRIPS	NUMBER OF FISHERIES ANALYZED	NUMBER OF TARGET SPECIES
PUERTO ADOLFO LÓPEZ MATEOS	2,619	2	53
ISLA MARGARITA	5,035	2	44
PUERTO SAN CARLOS	4,610	6	20

Each species had a different price in the market; however, we also recorded differences between communities. This can be due to various factors, including the quality of the product at the time of delivery, the buyer's preference operating in each community, or the origin of the buyer. The values presented here are averages that include different species. For example, within the finfish category, the pufferfish has a higher price than the oceanic whitefish; the same occurs within the Clams category, where the chocolata clam has a better price than the roñosa.

Estimated value of fisheries landings in BMA in an average year.

	TOTAL NUMBER OF BOATS	AVERAGE CATCH OF A BOAT/TRIP (KG)	NUMBER OF TRIPS PER BOAT	RANGE IN ANNUAL EARNINGS PER BOAT	RANGE IN ANNUAL EARNINGS OF FLEET
PUERTO ADOLFO LÓPEZ MATEOS	141	17-103	200	$69,000 ▼ $426,600	$9,720,000 ▼ $60,155,600
ISLA MARGARITA	9	5-7	150	$10,700 ▼ $16,000	$96,100 ▼ $144,500
PUERTO SAN CARLOS	350	2-33	200	$16,200 ▼ $349,300	$6,666,000 ▼ $122,244,300

CONCLUSIONS

The Bahía Magdalena-Almejas lagoon complex sustains the well-being of communities due to its economic dynamism. Both, tourism and fishing, support the region's economy and strengthen the social fabric of Puerto Adolfo López Mateos and Puerto San Carlos. Given that the same families engage in both fishing and tourism, and because the same area is used for these activities, collaborative work between sectors becomes even more crucial. Striking a balance between both activities is required to ensure that the sustainable use of the region's natural capital continues to develop.

During certain times of the year, fishing and tourism occur simultaneously and the two activities even coincide in some areas. Fishing not only generates employment but also produces food for the region, the state and even the country, making it a priority productive activity. Fishers recognize the challenges they face due to phenomena like climate change and overfishing, and they are already experiencing the impacts these factors have on the ecosystems and species they rely on. However, given the economic, cultural, and social value of target species, families are seeking sustainable alternatives for utilization. Tourism has become an important activity when fishing is limited by environmental or regulatory factors. While whale watching has had a significant economic impact on the region historically, during the past several years free diving with striped marlin has gained popularity and generates a significant economic impact that further encourages community development.

It is essential for the scientific sector to continue collaborating with communities to generate information that comprehensively details the dynamics of productive activities so we can improve our understanding of how they interact and how they can balance each other. Through collective learning, we can contribute to the development of strategies for sustainable use and conservation of priority species and ecosystems without compromising the wellbeing of local communities.

ACKNOWLEDGMENTS

We would like to aknowledge the fishermen and tourist service providers of Bahía Magdalena and we are thankful for their support and participation in this collaborative monitoring program. We appreciate the time they have dedicated and all the knowledge they have shared with our team.

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