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MONITORING PROGRAM

STRIPED MARLIN

Kajikia audax

2021 REPORT

PUERTO SAN CARLOS, MAGDALENA BAY, BAJA CALIFORNIA SUR

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INTRODUCTION

The Bahía Magdalena-Almejas lagoon complex (BMA) in Baja California Sur is an ecosystem with significant portions of its coastline covered by mangrove forests, the largest on the west coast of the Baja California Peninsula (20,527 ha in total). It is also part of the Pacific Islands Biosphere Reserve of the Baja California Peninsula. The communities in this region depend on marine resources for their survival, so understanding their relationship between fishing and tourism activities will help understand their impact on economic activities and the health of marine and coastal ecosystems (Cota-Nieto et al. 2016).

Bahía Magdalena-Almejas was designated as the priority marine region number 4 by the National Commission for the Knowledge and Use of Biodiversity (CONABIO) in 1998, and later in 1996-1997 it was designated as a bird conservation area. In December 2016, it became part of the Pacific Islands Biosphere Reserve of the Baja California Peninsula (DOF, 2016). Its diversity of habitats such as mangroves, dunes, sandy bars, islets, deepwater areas, seagrass meadows, and a network of channels make this site a priority for the protection, reproduction, and feeding of species such as the gray whale, sea turtles, birds and of course countless species of fish and invertebrates (Cota-Nieto et al. 2016). The great natural beauty of this region attracts many national and foreign visitors year-round, making it a central point for the development of recreational activities.

The striped marlin (Kajikia audax) is distributed in tropical, subtropical and temperate waters of the Pacific and Indian Oceans. In the Eastern Pacific Ocean, this species is found from southern California in the United States to Chile (Nakamura, 1985). For the community of San Carlos in Baja California Sur, swimming and free diving with striped marlin represents an economically important activity that has developed in the last 10 years. In 2020, we conducted an initial exercise using around 50 tourism trips to establish a baseline for the activity and, starting in 2021, we documented this activity with greater participation from tourism operators dedicated to this activity.

This document includes an estimate of the economic contribution generated by swimming and free diving with striped marlin to the community of Puerto San Carlos. This was achieved by adapting the activities of the Fisheries Monitoring Program, led by the Center for Marine Biodiversity and Conservation (CBMC), which has been operating in the area since 2012. The results obtained contribute to conservation and management efforts focused on this activity, aiming to preserve the integrity of the ecosystem, its species, and the community that depends on them.

BAHÍA MAGDALENA-ALMEJAS
LAGOON COMPLEX AND SURROUNDING AREA

The Bahía Magdalena-Almejas Lagoon Complex, located on the west coast of Baja California Sur (Figure 1), harbors a great diversity and abundance of species that support ecological processes, as well as commercial fishing and tourism activities (Rioja-Nieto et al. 2013). It has three distinct zones: the Channel Zone (137 km²) located to the northwest; Magdalena Bay (883 km²) in the central part of the complex; and Almejas Bay (370 km²) to the southeast. The climate in this area includes high temperatures, cool or cold winds, low humidity, scarce cloud cover and minimal precipitation. From December to February temperatures are low with morning fog; however, most of the year, a semi-desert climate prevails.

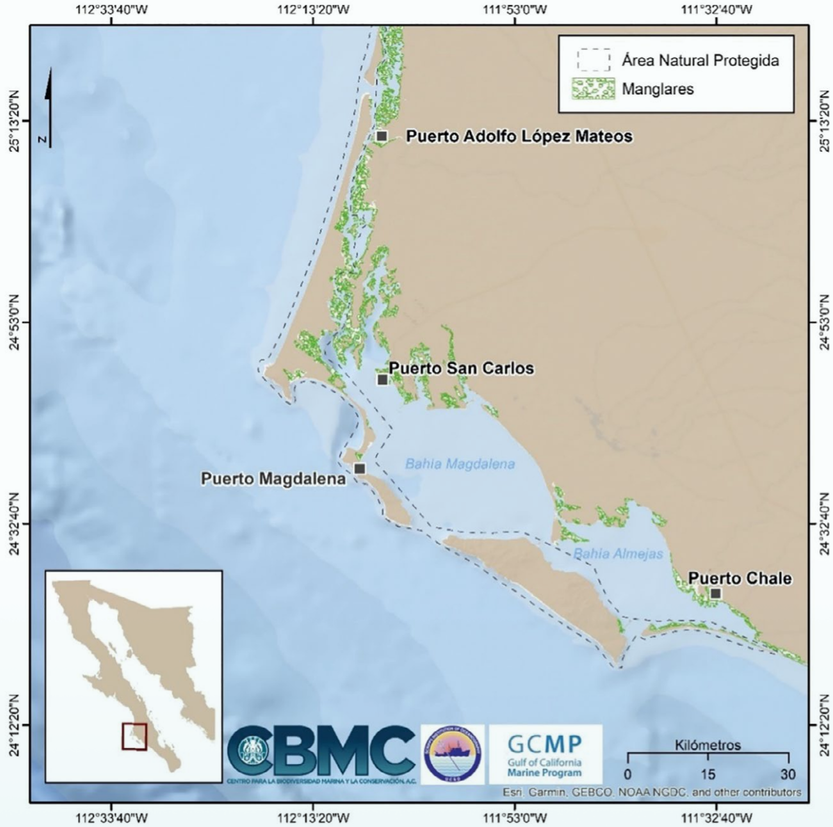

Figure 1. Magdalena-Almejas Lagoon Complex in Baja California Sur.

The prevailing winds in the region come from the Northwest which create conditions where high nutrient levels favor high concentrations of phytoplankton. In this region, the biotas with temperate-tropical affinity mix due to the dynamics of two marine currents flowing along the neritic zone adjacent to the bay: (i) the California Current predominantly flowing towards the equator, and (ii) a warm current heading towards the pole with wide variations in intensity throughout the year (Sánchez and Carriquiri, 2007). In the case of the presence of marlin, Ortega-García and collaborators (2015) used Generalized Additive Models to analyze sport fishing catch data in Cabo San Lucas and found that the highest catch rates occurred when temperatures were in the range of 26-28 ºC, along with high values of chlorophyll-a concentration (>1mg m-3).

DIVERSITY OF ACTIVITIES IN BMA

The Baja California Peninsula accounts for nearly 50% of the total national fishing production (Cisneros-Mata, 2010), and BMA is considered one of the most important sites for both industrial and artisanal fishing. It hosts the largest mangrove forest on the Baja California Peninsula, providing refuge to species of high commercial and ecological value while serving as a production site for a considerable amount of food for other species (Hastings and Fisher, 2001).

FISHERIES

Between 2001 and 2015, approximately 1.16 million tons of fishing products were caught in BMA, representing 47% of the total landings in Baja California Sur (2.5 million tons) (Cota-Nieto et al., 2015). Industrial fishing fleet landed 927,000 tons (79% of the total catch), generating an income of 1,574 million pesos, or 36% of the economic income of BMA. Sardines accounted for 92% of this production, while tunas and billfish accounted for the remaining 8% (Cota-Nieto et al., 2015).

During the same period, the artisanal fishing fleet produced 242,000 tons, equivalent to 21% of the total landings for BMA. Clams (138,000 tons) and shrimp (11,950 tons) were the largest catches. In terms of revenue, from 2001 to 2015, this sector generated 2,807 million pesos, corresponding to 64% of the economic income for BMA (Cota-Nieto et al., 2015). Although catch volumes are lower, the resources exploited by the artisanal sector are of high commercial value, and many of them are exported under strict marketing standards (Mascareñas-Osorio et al., 2022).

NATURE TOURISM IN PUERTO SAN CARLOS: STRIPED MARLIN

Following a global trend, interest in tourism activities in natural spaces has increased in BMA. This is especially relevant considering that tourism is the third most important economic activity globally due to the capital it generates and its potential for community development and improved living conditions (Ibáñez, 2015). Swimming and free diving with striped marlin in the BMA region has gained international fame as it is one of the most exotic wildlife spectacles on the Baja California Peninsula and this region is part of their migratory and feeding route. These aggregations are associated with increased primary productivity and the formation of baitballs.

The exceptional growth of tourism aimed at freediving with striped marlin over the last 10 years has raised concerns and interest regarding its potential impacts on the species and, consequently, on the local economy (Pers. Comm. Zarabia-Mendívil, 2021). This species is one of the most accessible for snorkeling and free diving, so tourism operators in Puerto San Carlos have made efforts to increase knowledge about its population dynamics and behavior.

In Mexico, observation and snorkeling with striped marlin in baitballs has seen increasing demand on the northwest coast, particularly in the area surrounding BMA, despite it being a relatively new activity. In 2011, the company Pelagic Life, along with local tourism operators, began exploring this activity with only a couple of trips per season (approximately 2 or 3) (Pers. Comm. Zarabia-Mendívil, 2021). From 2016 to 2021, the activity grew exponentially, going from just 10 trips in 2016 to around 300 trips in 2021 (Pers. Comm. Zarabia-Mendívil, 2022). Formal monitoring of this activity began in 2020 through the collaborative program between the CBMC and tourism operators in Puerto San Carlos.

OBJECTIVE OF THE MONITORING PROGRAM

Generate scientific knowledge and incorporate local knowledge related to the observation and free diving with striped marlin (Kajikia audax) to support responsible management efforts in the Magdalena-Almejas lagoon complex in Baja California Sur, Mexico.

SPECIFIC OBJECTIVES OF THE MONITORING PROGRAM

• Strengthen the collaborative network in BMA to include fishermen, tourism operators and scientists dedicated to monitoring and managing tourism around striped marlin.
• Describe the spatial and temporal dynamics of the activity and identify socio-economic and biophysical indicators linked to the observation of striped marlin:

- **Areas with the highest number of observations**
- **Average distance per trip (km)**
- **Average duration of trip (hr)**
- **Average number of tourists per trip**
- **Average gasoline consumption per trip (liters)**
- **Average sightings per trip**
- **Average earnings from the activity in BMA**
- **Average sea surface temperature in the study area**
- **Primary productivity (chlorophyll-a concentration [Chl-a]) in the study area**

METHODOLOGY

Due to the relevance and the economic importance of tourism for the region's inhabitants, CBMC, with support from the Gulf of California Marine Program, implements innovative tools to generate scientific information hand in hand with resource users, thus strengthening systematic research in the area (Cota-Nieto et al., 2017). Monitoring in BMA began with the artisanal fishing sector in 2012 (Cota-Nieto et al., 2017) and has been modified to include other activities such as the observation of gray and humpback whales, and now striped marlin. For the latter, we have collaborated with the tourism sector for the past two years (2020 and 2021).

I. DATA COLLECTION

Hand in hand with users, we generate and integrate two types of information: (a) geospatial, generated through GPS trackers on each participating vessel, and (b) details of each trip through logbook records (Annex I). All information is compiled into databases and jointly analyzed to describe the dynamics of tourism in each community in as much detail as possible.

II. SPATIAL DATA

i) Compilation.

We created a Geographic Information System (GIS) where we input all the information generated with GPS trackers. The information related to marlin observation activity consists of two main components: (a) spatial information containing coordinates (latitude, longitude), speed, and duration of each fishing trip, and (b) observation information consisting of file name (alphanumeric code), number of sightings, number of tourists, service charge (pesos), gasoline consumption (liters), start and end time of the trip.

ii) Digitization of sightings

With the experience gained from our fishing monitoring program, we have designed a technique to identify marlin observation areas using the speed of the boat and the maneuver it performs. According to interviews with service providers, sightings are characterized by placing the engine in neutral and letting the boat drift. The spatial information for each trip was downloaded using the CanWay software, which allows visualizing the route on Google Maps to discard incomplete or incorrect data. With this same program, the files were exported to '.csv' format, compatible with GIS programs, and imported using ArcGIS™ 10.8.1 software, with which the distance traveled on each trip was calculated. Observation information was related to its respective route using the file name (alphanumeric code). The areas where striped marlin was observed were identified when the vessel's speed was between 0-7 km/hr (Figure 2). Once identified, we cut to the route (lines) to calculate the distance traveled and the duration of the interaction and the sighting area was marked with a point, which will be the centroid of a line.

III) Spatial analysis

We were able to identify the observation areas using the Directional Distribution tool. In ArcGIS, we created an ellipse around the marlin observation sites and specified two standard deviations to cover a 95% confidence interval. We then created a polygon around the outer limits using the Aggregate Points tool and calculated the area of the polygon. Additionally, with spatial data, we conducted an intensity analysis to identify areas with the highest frequency of observations.

IV) Oceanographic factors and the presence of striped marlin

We used layers of trends in Sea Surface Temperatures (SST) and Chlorophyll-a (Chl-a) concentration in the area outside of BMA to explore possible relationships between environmental aspects and the presence of striped marlin. We analyzed SST and Chl-a data by separating the time series to obtain interannual trends for each and then evaluated the average and intra-annual variation range to assess the variation of both variables.

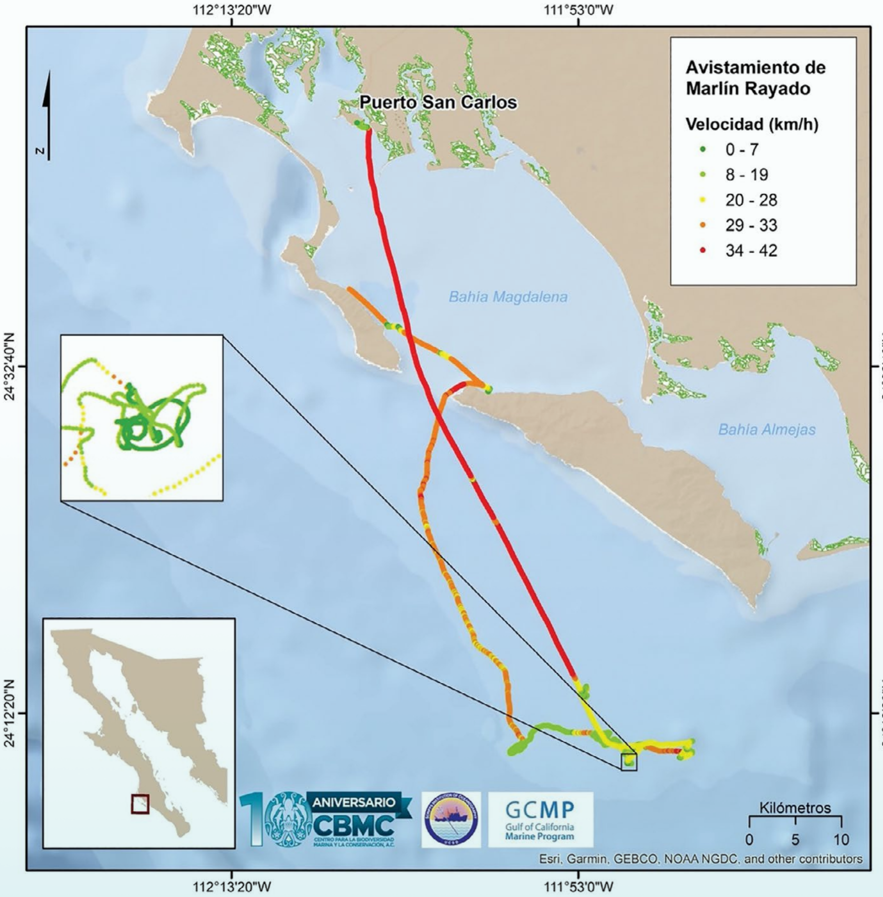

Figure 2. Example of a monitored trip using a GPS data logger. The colors indicate the boat's speed. Source: Gulf of California Marine Program (2022).

III. ECONOMIC ANALYSIS

Cost and profit calculations were performed using the data collected during the monitoring through the logbooks and interviews with tourism operators. To estimate the earnings per trip, we calculated the fuel cost and multiplied the average number of liters used by the average price per liter of gasoline for 2021. This value was subtracted from the Service Cost (trip price paid by tourists) to determine the percentage of cost and profit per trip.

RESULTS

This report includes information from the community of Puerto San Carlos, B.C.S., covering data from the 2020 and 2021 striped marlin seasons. A total of 168 trips with spatial data (GPS data loggers) and logbook information (sighting records) were monitored, with the months of October and November having the highest data collection (Table I). Routes for each of the trips were identified using the GPS records (Figure 3).

NUMBER OF TRIPS MONITORED

SEASON	OCTOBER	NOVEMBER	DECEMBER
2020	15	30	5
2021	49	45	24
TOTAL	64	75	29

Table I. Record of monitored days during the striped marlin season of 2020 and 2021 in Puerto San Carlos, B.C.S.

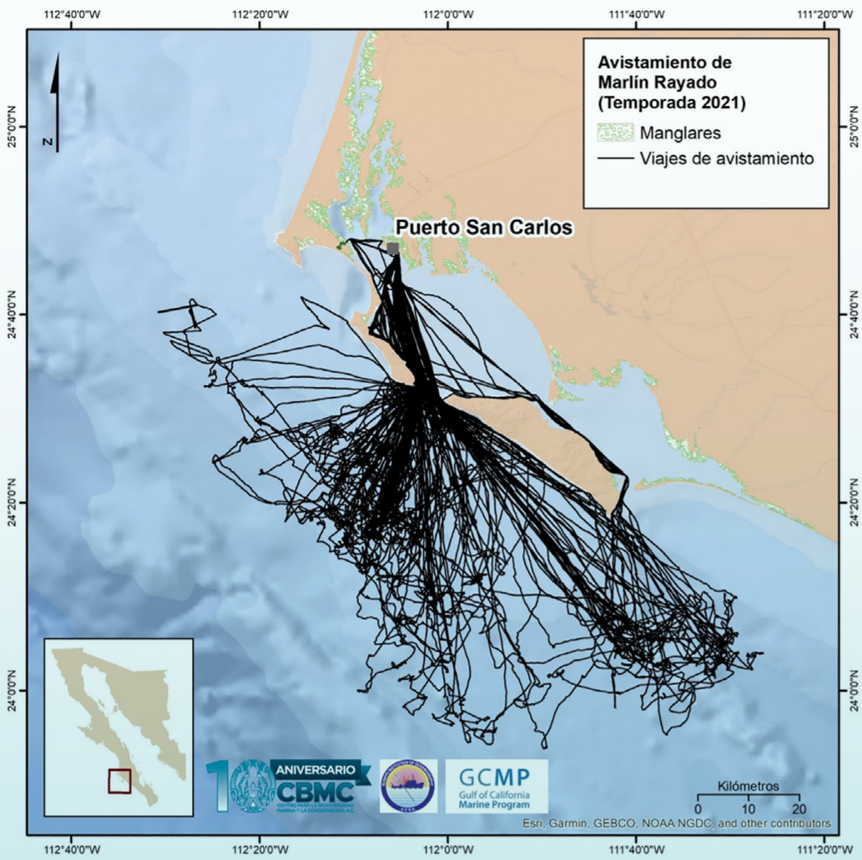

Figure 3. Example of striped marlin trips as recorded by the GPS data logger. Source: Gulf of California Marine Program (2022).

The main starting point for trips during both seasons was Puerto San Carlos, with an average of 4.5 tourists per trip. They covered an average distance of 183 km per trip with an average fuel consumption of 120 liters per trip (Table II). With the data collected from the GPS data loggers and the analyses conducted, we were able to identify the areas with the highest frequency of sightings (Figure 4).

Table II. Summary of data obtained from monitored striped marlin trips during the 2020 and 2021 seasons.

SEASON	Total number of tourists	Tourists per trip*	Sightings per trip*	Trip duration* (hr)	Distance travelled per trip* (km)	Gasoline used * (lt)
2020	257	4	2	10.5	177	104
2021	566	5	2	10	188	135

*Cifras son promedios

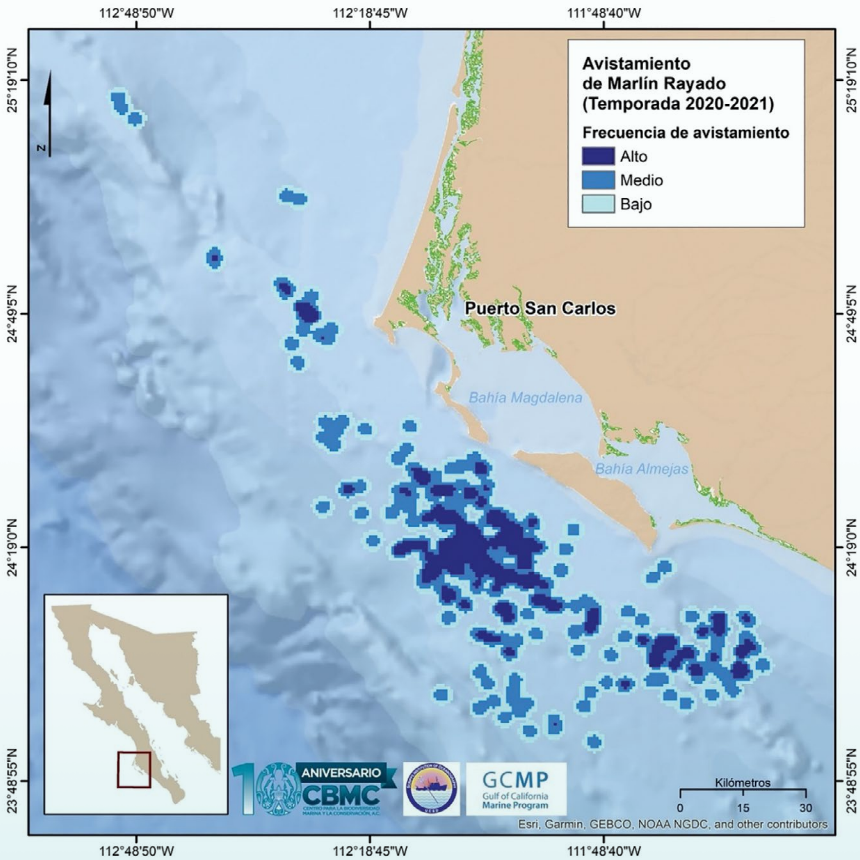

Figure 4. Areas with highest frequency of striped marlin sightings during the 202 and 2021 seasons. Source: Gulf of California Marine Program (2022).

Information was obtained through interviews with tourism service providers to estimate the economic contribution generated by this activity (Table III). While transportation costs from other cities in Mexico and/or countries to reach BMA are not included, our estimates indicate that the economic impact generated by this activity could easily exceed 10 million pesos each season.

SEASON	Number of boats	Number of monitored trips	Cost per trip*	Gross profit*	Operating costs (35%)	Estimated earnings* (MXN)	Estimated earnings* (Dlls)
2020	22	300	12 mil	3.6 mdp	1.2 mdp	2.3 mdp	117,000
2021	25	750	15 mil	11.2 mdp	3.9 mdp	7.31 mdp	365,625

*Numbers are averages

Table III. Economic contribution estimates generated by swimming and free diving with striped marlin during the 2020 and 2021 seasons in Puerto San Carlos, B.C.S.

Other tourism activities like whale watching (gray and humpback whales) are also practiced, and tours through mangrove areas, bird watching, sport fishing, and diving have also become alternative activities to artisanal fishing, taking place both inside and outside the bay and generating significant economic income. Although artisanal fishing continues to be the main economic driver, low-impact tourism supports the community when fishery resources are scarce or during the closed season (Annex II).

The oceanographic conditions off Bahía Magdalena reflect the effect of the El Niño-Southern Oscillation (ENSO). This phenomenon is a disruption of the ocean-atmosphere system in the tropical Pacific with significant consequences for the planet's climate. The ENSO is a natural phenomenon, but its intensity is heightened by the effects of climate change (Thirumalai et al. 2017; Sanchez-Cabeza et al. 2022). El Niño phases are identified by peaks in average temperatures in historical temperature trends, while La Niña is characterized by low temperatures (Figure 6A).

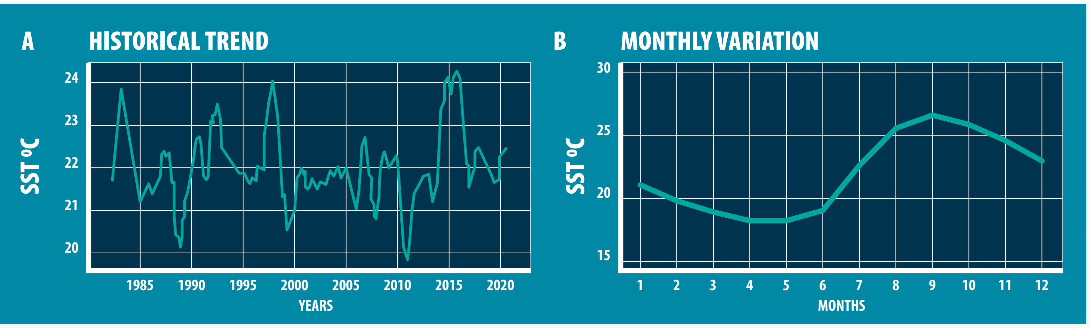

Figure 6. (A) Historical trend of the Sea Surface Temperature (SST) measured in degrees Celsius. (B) Monthly variation within the observation area.

The 2014 El Niño event was particularly intense, with impacts throughout the Mexican Pacific and the Gulf of California (Porter et al. 2022). As seen in Figure 6A, aside from the oscillations of ENSO, there is no overall increasing trend in average temperature (e.g., long-term effect of climate change), as observed in other areas such as the Gulf of California (Favoretto et al. 2022). One possible explanation for this is that the upwelling caused by the California Current is acting as a buffer against the general warming of the area around BMA. The significance of this is noteworthy, as it could serve as a natural refuge for various species during extreme temperature events.

However, the concentration of Chlorophyll-a (Chl-a) has been decreasing over the years, with its minimum averages during the latest, hotter phases (Figure 7A). Therefore, the effect of heatwaves and the last El Niño event has been relevant for the phytoplankton community (microalgae) of which Chl-a is an indicator. In seasonal terms, Chl-a and SST are inversely proportional; that is, high temperatures correspond to lower Chl-a concentrations and vice versa (Figure 6B and 7B). This phenomenon is noticeable and is caused by reduced oceanic circulation due to the formation of the thermocline (where temperature changes rapidly with depth) in the warmer months. Increased circulation during winter favors the input of nutrients and oxygen, leading to algal blooms which enhance Chl-a content.

When Chlor-a is higher, marine productivity is higher. The most productive months for the area are the months of April to July. This accumulation of primary productivity generates surplus biomass, which is used within the food web, transforming into secondary productivity (for example, sardines feed on plankton). The striped marlins benefit and take advantage of this increase in productivity and feed on the sardines that begin to accumulate in the area. It is important to note that peak striped marlin sightings occur during the months of October to December; That is, it has a difference with respect to the Chlor-a peak. This is probably because primary productivity takes time to be transferred to higher trophic levels.

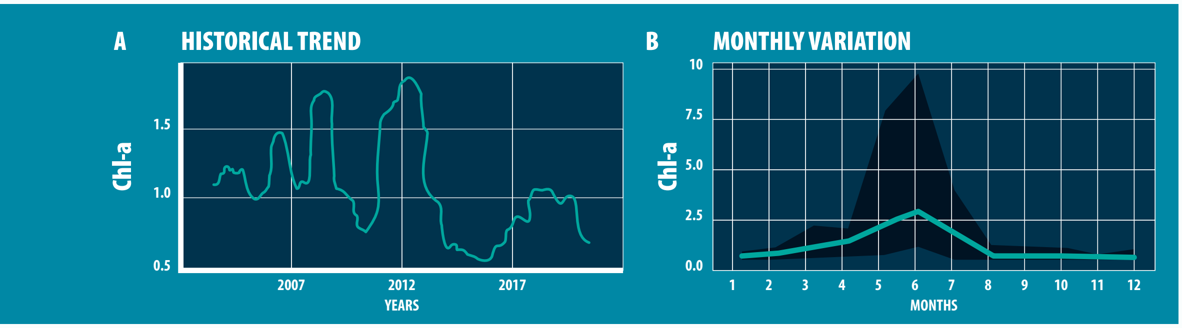

Figure 7. (A) Historical trend of chlorophyll-a (Chl-a) production in region in front of BMA. (B) Monthly variation showing the productivity peaks during the warm months.

CONCLUSIONS

The results included in this report contribute to the baseline of knowledge regarding the relationship between users and natural resources to ensure sustainable community development (artisanal fishing sector and low-impact ecological activities). The areas where the presence of striped marlin has been documented have oceanographic characteristics that enhance productivity. However, further studies and analyses related to the behavior of striped marlin and its relationship with other species present in the region during the same season are still required. Free diving with marlin is a new activity, and the importance of generating data has been crucial, so we have strengthened the connection with the community to continue monitoring economic activities in Bahía Magdalena-Almejas.

Fisheries productivity has declined in the last 10 years, impacting the profitability of the activity and, consequently, the local economy (Ojeda-Ruíz and Ramírez-Rodríguez, 2012). One way in which artisanal fishermen have adapted to this situation is by venturing into tourism activities, partially or definitively abandoning extractive activities. At the same time, changing economic activities helps reduce fishing effort in the region, benefiting the ecosystem and marine species in the short and long term. All the knowledge generated in collaboration with the community of Puerto San Carlos is important for designing strategies that ensure the sustainability of natural capital in the long term.

Tourism in Puerto San Carlos, as in other communities with this vocation, generates a positive impact due to the creation of employment opportunities and the economic benefit that encourages community development. During October through December, tourism services focus on the observation of striped marlin, which has generated significant economic benefits and represents direct income for those involved. Additionally, the indirect economic impact generated by tourists visiting the community is also significant (for example, in hotels or restaurants).

Globally, tourism has promoted growth and economic development in various countries. It is one of the most important industries, contributing up to 10% of the global GDP (Ibáñez, 2015). In Baja California Sur, nature tourism has positioned itself as a driver in the economic development of communities with natural attractions, as seen in Cabo Pulmo, B.C.S., for example. In this small National Park, ecotourism directly benefits the locals because they are the owners of tourism businesses, actively engage in management and conservation efforts with CONANP, and proactively participate in the development of their community (Ibáñez, 2015).

In 2021, it was estimated that visitors to Bahía Magdalena, particularly through striped marlin sighting, generated approximately $400,000 USD during the three-month season (Com. pers. Zarabia-Mendívil, 2022). Among the beneficiaries are tourism companies, restaurants, craft vendors, transportation services, and hotels (Com. pers. Zarabia-Mendívil, 2022).

Expanding monitoring efforts of this activity and maintaining engagement with all stakeholders (such as fishermen, hotel owners, restaurant owners, artisans, etc.) can help us understand more precisely the importance and dependence of each sector not only on striped marlin sighting but also on other tourism alternatives in the region. This becomes more relevant when considering that tourism serves as a significant economic supplement when fishing activity is limited by environmental factors or regulatory aspects. Data generated through monitoring will also facilitate a more reliable and detailed analysis, enabling us to anticipate anomalies and prepare strategies to minimize negative impacts on the community and species.

AKNOWLEDGEMENTS

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ANNEX I.

Logbook designed by the Centro para la Biodiversidad Marina y la Conservación A.C. used by the tourism operators to collect data related to their trips.

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BITÁCORA DE NADO CON MARLÍN

FECHA: DD / MM / AA ___ / ___ / ___

CAPITÁN: ______________________

PANGA: ___________
MOTOR: ___________
TIEMPOS (2-4): ________

NÚMERO TRACKER: ______________

HORA DE SALIDA

HORA DE REGRESO

NÚMERO DE TURISTAS EN LA PANGA:

COBRO DEL SERVICIO (PESOS):

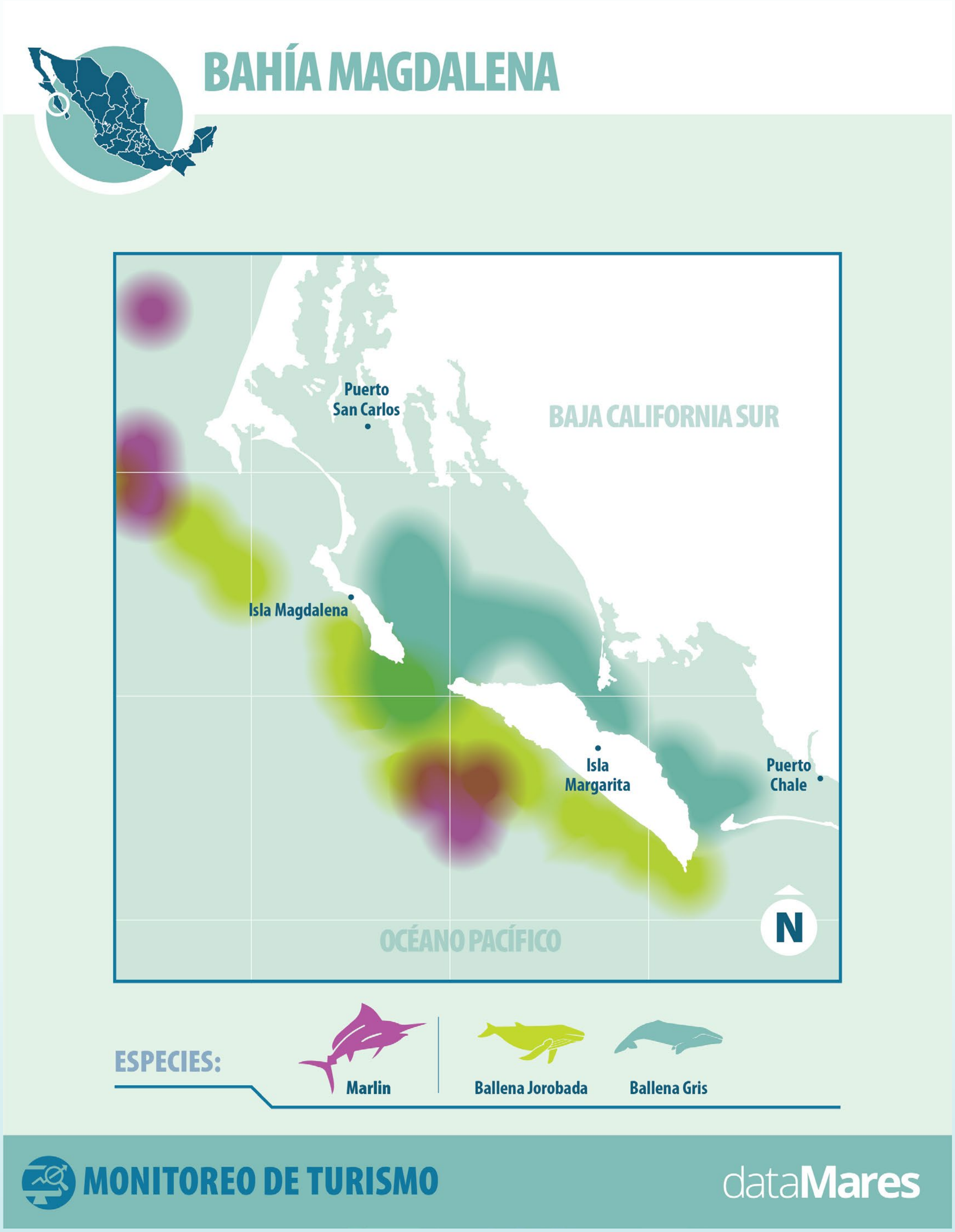
CONSUMO DE GASOLINA (LITROS):

ESTADO DEL TIEMPO (NUBOSIDAD, VIENTO, ETC.):

No. de bola	Especie(s):	Tipo de bola (estática, movimiento):	Tipo de alimento (sardina, macarela, etc.):	Profundidad / Temperatura	Coordenadas (formato abierto) LAT / LONG
1				/	/
2				/	/
3				/	/
4				/	/

ANNEX II.

ETourism operators in the Magdalena-Almejas Lagoon Complex offer whale watching trips for gray and humpback whales and free diving and swimming with striped marlin. In collaboration with dataMares, the CBMC created maps showing the areas where these activities tend to take place.



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dataMares

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