



<https://doi.org/10.15517/29wq2j10>

Habitat use of the Pacific eagle ray *Aetobatus laticeps* (Myliobatiformes: Aetobatidae) in a marine protected area of touristic importance, Banderas Bay, Mexico

Alejandra P. Castelo-Corona^{1,2*};  <https://orcid.org/0000-0003-3378-4297>

Adrián Maldonado-Gasca³;  <https://orcid.org/0000-0003-2067-7062>

Juan C. Pérez-Jiménez⁴;  <https://orcid.org/0000-0002-7258-1700>

Javier Tovar-Ávila⁵;  <https://orcid.org/0000-0001-9095-5801>

1. Aetos ID, Pacific Eagle Ray Investigation and Conservation Project, Jalisco, México; alejandrasteloc@gmail.com (Correspondence*)
2. Red de Observadores Ciudadanos, CP 23060, La Paz, Baja California Sur, México.
3. Tecnológico Nacional de México, Bahía de Banderas, Nayarit, México; adrian.mg@bahia.tecnm.mx
4. Laboratorio de Ecología Pesquera, El Colegio de la Frontera Sur. Campeche, México; jcperez@ecosur.mx
5. Instituto Mexicano de Investigación en Pesca y Acuicultura Sustentables, Centro Regional de Investigación Acuícola y Pesquera, Bahía de Banderas, Nayarit, México; javier.tovar@imipas.gob.mx

Received 01-III-2025. Corrected 19-IX-2025. Accepted 17-XI-2025.

ABSTRACT

Introduction: Aetobatids have low reproductive potential, with coastal and benthopelagic habits, which makes them vulnerable to anthropogenic activities. Despite this, the Pacific eagle ray *Aetobatus laticeps* is a poorly studied species, which makes it difficult to assess its populations to implement or improve conservation and management measures.

Objective: To determine the habitat use of the Pacific eagle ray in Los Arcos (LA), Banderas Bay, Central Mexican Pacific, a protected natural area of tourist importance.

Methods: From December 2015 to July 2017, 64 marine surveys were conducted to record the activity and size of eagle rays in three transects delimited by tourist use in LA. The variability in the seasonal presence of adults and juveniles, the trend in the space-time encounter rate, and its relationship with sea surface temperature (SST) were determined.

Results: The encounter rate was higher in April and May (2016 and 2017), decreasing to zero during July, August, and September of 2016 (with the warmest SST) and February 2017 (with the coldest SST). Displacement activity predominated, followed by feeding activity. Recorded sizes ranged from 50-130 cm disc width (DW) (mean = 89 ± 17 cm). The site with the highest encounter rate coincides with the area of greatest tourist activity.

Conclusions: This study provides evidence of the gregarious behaviour of juveniles and adults, their seasonal movements, and their relationship with SST at a limited spatial scale. Finally, it is essential to raise awareness among local communities in LA, as tourist activity may indirectly impact *A. laticeps*.

Key words: batoid; natural protected area; marine megafauna; conservation management; elasmobranch.



RESUMEN

Uso de hábitat de la raya águila del Pacífico, *Aetobatus laticeps* (Myliobatiformes: Aetobatidae) en un área marina protegida de importancia turística, Bahía de Banderas, México

Introducción: Los Aetobátidos tienen un bajo potencial reproductivo, con hábitos costeros y bentopelágicos, lo que los hace vulnerables a las actividades antropogénicas. A pesar de ello, la raya águila del pacífico *Aetobatus laticeps* es una especie poco estudiada, lo que dificulta la evaluación de las poblaciones para implementar o mejorar medidas de conservación y gestión.

Objetivo: Determinar el uso de hábitat de la especie en Los Arcos (LA), Bahía de Banderas, Pacífico central mexicano, un área natural protegida de importancia turística.

Métodos: Desde diciembre 2015 hasta julio 2017, se realizaron 64 censos marinos para registrar la actividad y el tamaño de las rayas águila en tres transectos delimitados por el uso turístico en LA. Se determinó la variabilidad en la presencia estacional de juveniles y adultos, la tendencia en la tasa de encuentro espacio-temporal y su relación con la temperatura superficial del mar (TSM).

Resultados: La tasa de encuentro fue mayor en abril y mayo (2016 y 2017), disminuyendo a cero durante julio, agosto y septiembre de 2016 (con la TSM más cálida) y febrero 2017 (con la TSM más fría). Predominó la actividad de desplazamiento, seguida de la actividad de alimentación. Las tallas registradas fueron de 50-130 cm de ancho de disco (promedio = 89 ± 17 cm). El lugar con la mayor tasa de encuentro coincide con la zona de mayor actividad turística.

Conclusiones: Este estudio aporta pruebas del comportamiento gregario de juveniles y adultos, sus movimientos estacionales y su relación con la TSM a una escala espacial limitada. Por último, es importante sensibilizar a las comunidades locales en LA, ya que la actividad turística puede afectar indirectamente a *A. laticeps*.

Palabras clave: batoideo; área natural protegida; megafauna marina; manejo para la conservación; elasmobranquio.

INTRODUCTION

The pacific eagle ray *Aetobatus laticeps* (Gill, 1867) is a species classified as “Vulnerable” by the International Union for Conservation of Nature (IUCN); its populations are at risk of declining due to its low fecundity and the coincidence of its distribution with various fisheries (Pollom et al., 2021). Therefore, generating information is necessary as a tool for its conservation and management. This species was recently separated from *Aetobatus narinari* (Euphrasen, 1790) based on genetic evidence (Richards et al., 2009; Sales et al., 2019). It is considered to be poorly studied, and information from nearby species is relied upon to understand some biological and ecological aspects, such as habitat use. For instance, *A. narinari* is known for seasonal migrations, with sea temperature being the primary factor influencing its movements (Bassos-Hull et al., 2014; Cuevas-Zimbrón et al., 2011; Cuevas-Zimbrón et al., 2013). Likewise, patterns of site fidelity and return movements of *A. narinari* to

specific areas have been identified, such as permanent or seasonal residence (DeGroot et al., 2021; Flowers et al., 2017). The repeated use of specific sites suggests that these areas may play a critical role in the life cycle of these species, providing essential biotic and abiotic resources. As a result, human activities can exert heterogeneous impacts across their distribution range (Flowers et al., 2017). Hence, spatio-temporal research on habitat function is fundamental for assessing the interactions between elasmobranchs and anthropogenic activities (Becerril-García et al., 2022).

Banderas Bay (BB) is situated in the central Mexican Pacific (Fig. 1) and is recognized as an important shark and ray area (ISRA), functioning as both a breeding and feeding ground for *A. laticeps* (International Union for Conservation of Nature - Shark Specialist Group [IUCN SSC], 2023). This site includes the Flora and Fauna Refuge, Los Arcos (LA), an insular area located 105 m offshore, where pacific eagle rays aggregate. Furthermore, commercial and sport fishing is prohibited (Secretaría de Industria

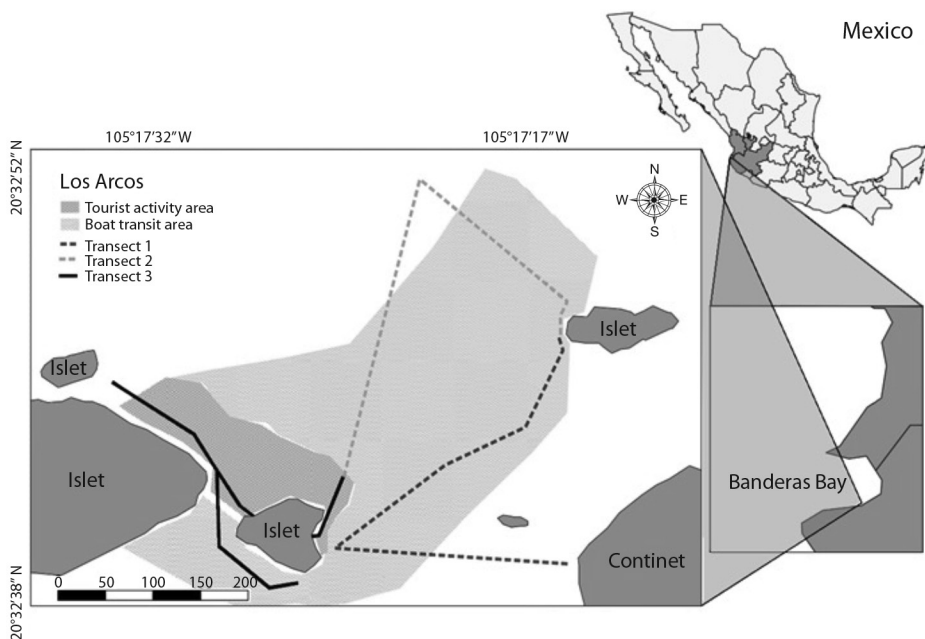


Fig. 1. Map of Los Arcos in Banderas Bay. On gray, tourist activity and boat transit zone. Lines indicate different transects.

y Comercio, 1975) in LA, with tourism being the main activity and an important source of income for local communities. However, there are currently no regulations in place to manage the number of tourists visiting the area in LA, this has resulted in modifications to the environment (Balzaretto-Merino et al., 2021; Medina-Rosas, 1997). Considering the gregarious and philopatric characteristics of aetobatids in certain areas, it can be inferred that these species may be vulnerable to changes in local environmental factors or the impact of human activities, such as fishing or unsustainable tourism practices. In this context, understanding the habitat use of *A. laticeps* in aggregation areas like LA is valuable for establishing management measures.

Direct observations can be used to assess habitat use in a non-invasive manner, providing accurate data on the activities of organisms *in situ*, at small spatial scales and over long periods of time (Carraro & Gladstone, 2006; Economakis & Lobel, 1998). This method yields information on the location and number

of organisms, as well as their behaviour and biological characteristics, such as size and associations with physical, biological factors or human disturbances (Simpfendorfer & Heupel, 2004). The aim of this study was to evaluate the habitat usage of *A. laticeps* in LA during peak tourist activity hours, considering their behaviour, individual size, and the number of sightings in relation to sea surface temperature, through direct observations.

MATERIALS AND METHODS

Study area: Los Arcos (LA) is comprised of five islets located between 105 and 497 m offshore, Southwest of Puerto Vallarta, Jalisco, Mexico (Fig. 1). The area is dominated by rocky reef and some patches of sand (Medina-Rosas & Cupul-Magaña, 2002). These islets are easily accessible, since they are close to the coast where there are several communities dedicated to tourism, and is one of the most frequently visited sites in BB for scuba diving, free diving, kayaking, paddle boarding and boat tours. The



sites where the pacific eagle ray surveys were conducted are shallow (3-12 m).

Data collection: From December 2015 to July 2017, 64 surveys were conducted (one per week), by free diving during the hours of greatest tourist influx (08:00 to 15:00 h), in three transects that were previously delimited based on the characteristics of the area, such as depth, type of seabed, areas of boat traffic and tourist activity (Fig. 1). During the surveys, the number of eagle ray observations was recorded, and the disc width (DW) of each eagle ray was estimated at a distance of ~ 30 to 50 cm from the individuals, using a “T” ruler measuring 50 cm (horizontal) and 100 cm (vertical), with graduations every 10 cm (English et al., 1997). When rays were observed in groups (> 2 individuals), DW was visually estimated to avoid disturbing other organisms. From April 2016 to July 2017, the activity of eagle rays was documented following the classification by González-Pérez and Cubero-Pardo (2010), categorizing them as cleaning (symbiotic fishes associated with eagle rays, which remove parasites from their bodies, clean wounds, or feed on dead skin), swimming (when individuals move in a specific direction), foraging (individuals searching or feeding in the sand or among rocks in search of food), or reproduction (individuals observed during the mating or courtship process, according by Swider et al., 2017).

Data analysis: to standardize the number of eagle ray observations by sampling time, the encounter rate (ER) was calculated:

$$ER=n/t$$

Where: n is equal to the number of eagle ray observations per sample, and t is the total number of hours for each sampling.

In order to describe the activities of *A. laticeps* in each transect, the activity index (Karczmarski et al., 2000) was used:

$$AI=B/T$$

Where: B is the number of observations of eagle rays engaged in a particular activity, and T is the total number of observations. The activity index indicates dominance of an activity when it is close to one, and scarcity of the activity when it is close to zero.

The habitat preference index (Ajemian et al., 2012) was used to define temporal preference between transects:

$$Wi=O_i/\pi_i$$

Where: O_i is the proportion of the number of eagle rays observations per month in transect ‘x’ relative to the total number of rays from all transects per month, π_i is the proportion of the area of transect ‘x’ relative to the total area of all transects. This index indicates positive selection for an area when it is greater than one, and avoidance when it is less than one.

The Kruskal-Wallis test was used to determine whether there is a difference in length between months and in monthly ER. If significant differences were found, the Nemenyi post-hoc test was applied (Pohlert, 2014). A polynomial regression test was conducted to assess the relationship between ER and sea surface temperature (SST). The SST data were acquired from MODIS-Aqua (NASA OBPB, 2019) for the 2015-2017 period through the Environmental Research Division Data Access Program (ERDDAP) hosted by the NOAA Southwest Fisheries Science Center (National Oceanic and Atmospheric Administration [NOAA], 2023).

RESULTS

During the 64 marine surveys conducted, a total of 181 sightings of *A. laticeps* were recorded, with an overall average per survey of 2.82 ± 3.67 observations events. The average ER was 1.56 ± 2.18 , with the highest ER observed during April and May, whereas no eagle ray sightings were recorded in August and September (Fig. 2), with significant differences between May with August/September in 2016 ($p < 0.05$).

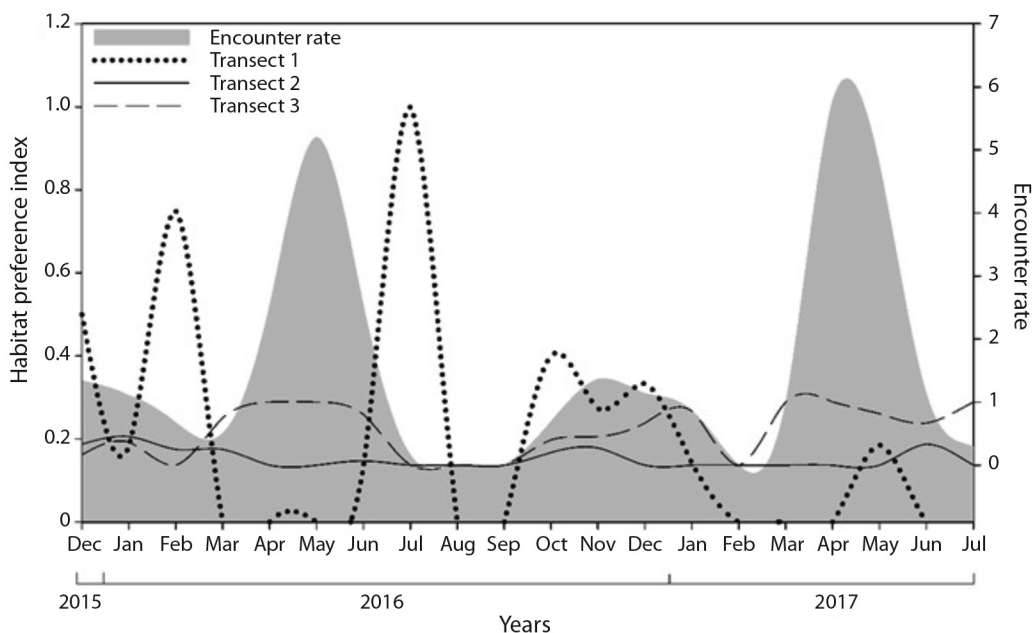


Fig. 2. Monthly encounter rate (shaded area) and habitat preference index for three transects surveyed from December 2015 to July 2017 in Los Arcos.

A total of 147 activity records of *A. laticeps* were obtained, where “swimming” was the activity most observed (87.07 %), followed by “foraging” (10.88 %), “cleaning” (1.36 %), and “breeding” (0.68 %) (Table 1). The habitat preference index was > 1 for transect three compared to transects one and two in most months (January, March-June, and October-December 2016, and January, March-July 2017), which coincided with the highest ER values (Fig. 2).

The recorded lengths of *A. laticeps* during the surveys ranged 50 to 130 cm DW (mean 88.83 ± 17 cm DW) approximately. For this study, individuals ≥ 90 cm DW were

considered adults based on previous length at maturity observations (Vázquez 2003 in Salomón-Aguilar, 2015), which also coincide with our records of some pregnant females with ≥ 90 cm DW in BB (Fig. 3). From the 181 sightings, 114 were classified as adults and 67 as juveniles (Fig. 4), with a ratio of 1:0.58. Additionally, there were differences in the total number of sightings between juveniles and adults ($\chi^2 = 12.2$, $p \leq 0.01$), but not among the sizes per month (Kruskall-Wallis, $p = 0.8195$, $\chi^2 = 10.835$, $df = 9$).

During the sampling period the SST ranged 23-30.5 °C. The correlation between the ER and

Table 1

Activity index (AI) of *Aetobatus laticeps* per transect at Los Arcos from December 2015 to July 2017.

Activity	AI transect 1	AI transect 2	AI transect 3	Total AI
Foraging	0.31 (5)	0.71 (5)	0.04 (6)	0.10
Breeding	0.00	0.00	0.008 (1)	0.006
Swimming	0.68 (11)	0.28 (2)	0.92 (115)	0.87
Cleaning	0.00	0.00	0.01 (2)	0.013

Number of observations events are in parenthesis.

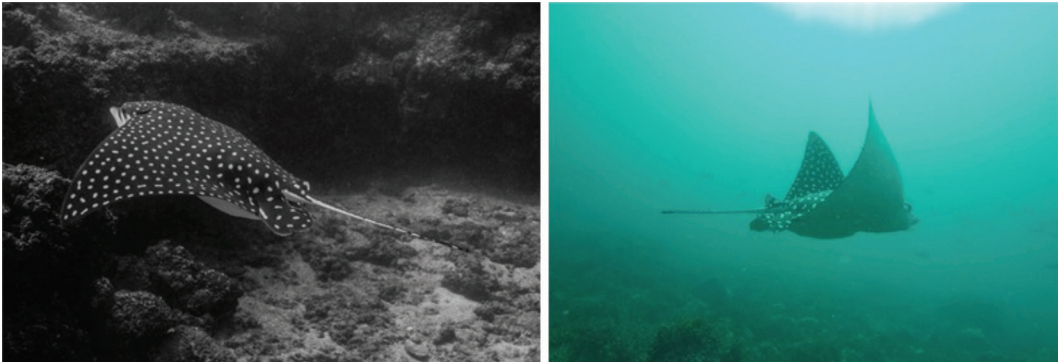


Fig. 3. Female pacific eagle rays visibly in gestation period, with approximately 90 cm DW.

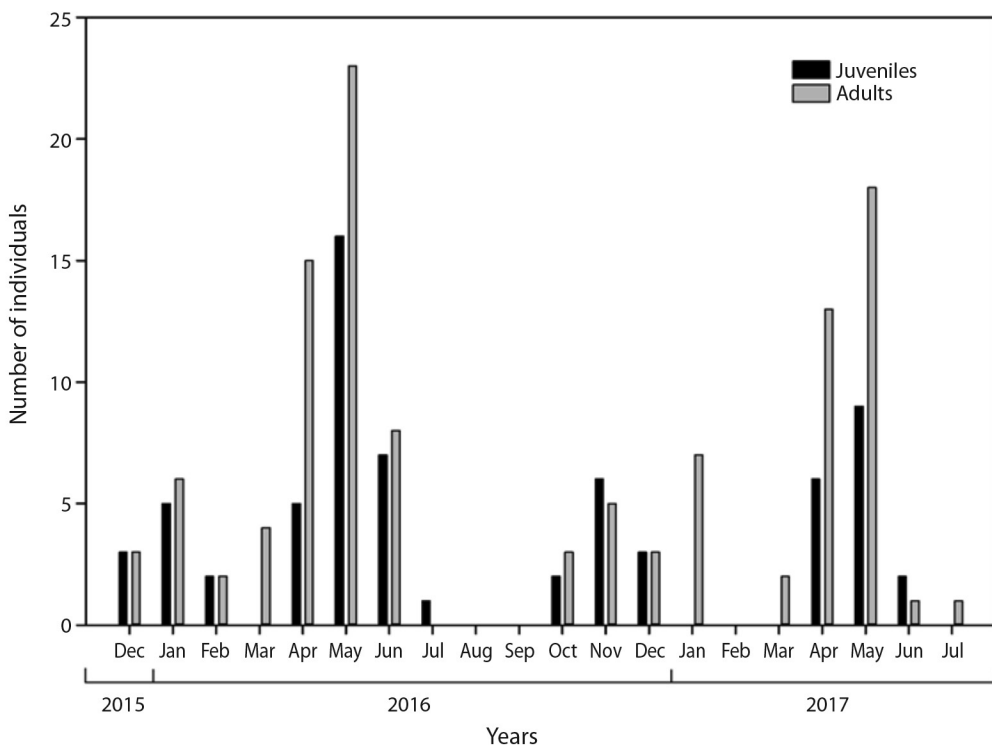


Fig. 4. Number of juveniles and adults of pacific eagle rays observed during the sampling period.

SST was low, but significant ($r = 0.2128$, $p < 0.001$), it is possible that there are other factors that influence ER, such as salinity, tidal flow, and dissolved oxygen. It is important mentioning that when the SST fluctuated between 25-27 °C, the highest ER occurred, whereas when the highest (30 °C) and lowest (23 °C)

SST occurred, eagle rays sightings decreased to zero (Fig. 5).

DISCUSSION

This study presents novel information on the habitat use of *A. laticeps* obtained through

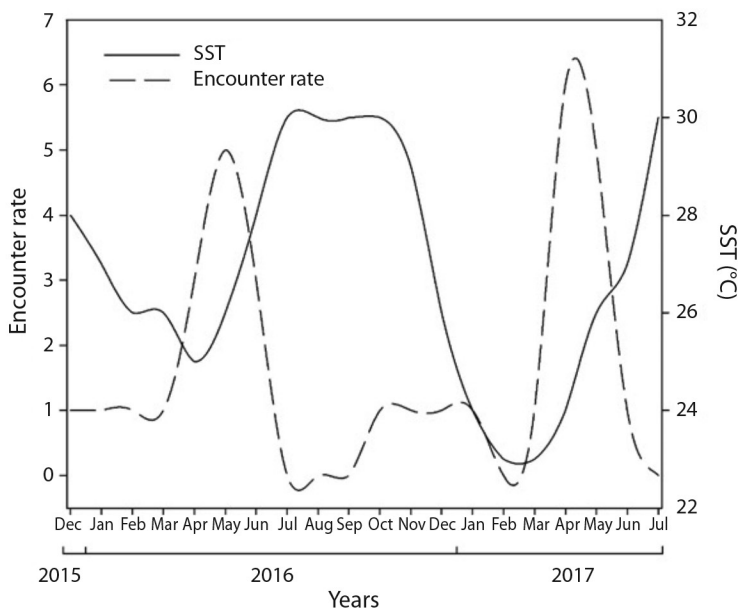


Fig. 5. Encounter rate variability of *Aetobatus laticeps* in Los Arcos in relation to sea surface temperature (SST).

direct observations in a tourist area in the Mexican Pacific. Los Arcos harbors a high diversity and abundance of mollusks in Banderas Bay (Ríos-Jara et al., 2001), which are an important part of the diet of pelagic eagle rays (Ajemian et al., 2012; Schluessel et al., 2010; Serrano-Flores et al., 2018). This area is one of the well-known spots for divers in the BB where *A. laticeps* forms aggregations (Balzaretto-Merino et al., 2021). Considering the observations of individuals feeding, it is likely that eagle rays frequent LA due to the high availability of prey, as is the case of *A. narinari* in Bermuda and the Southern Gulf of Mexico (Ajemian et al., 2012; Serrano-Flores et al., 2018).

The area where eagle rays showed habitat preference was specifically located between two islets where strong currents form and vary in direction and intensity throughout the day. This could benefit the rheotaxis of *Aetobatus laticeps* by facilitating water flow through its gills. Aquatic activities are common in this area, with high boat traffic. Occasionally, eagle rays have been observed quickly fleeing when boats pass nearby, similar to the behaviour described

by Berthe and Lecchini (2016) for *Aetobatus ocellatus*. However, in more recent years, an eagle ray with fresh propeller-inflicted wounds was recorded in LA, although the frequency of such incidents is still uncertain (Castelo-Corona & Arnés-Urgellés, 2025). Furthermore, the long-term effects of interrupting their activities, such as cleaning or feeding in an aggregation area like LA, remain unknown.

During most of the sampling period, both adult and juvenile individuals were observed in LA, with adults being more prevalent (62 % of the sightings). Their primary recorded activities were swimming and feeding. Previous studies have shown that habitat preference can vary during ontogeny in species of the family Aetobatidae (Bassos-Hull et al., 2014; Cuevas-Zimbrón et al., 2011; Degroot et al., 2021), as well as in several elasmobranch species (Hoyos-Padilla et al., 2014; Yamaguchi & Taniuchi, 2000). This has mainly been attributed to variations in food requirements, differences in the distribution and abundance of prey, and the ability to evade predators (Palacios et al., 2021). In Southern BB, the continental shelf is narrow



and drops steeply to over 1 400 m (Plata & Filonov, 2007). Given the shallow-water preference of aetobatids waters (Ajemian et al., 2012; Ajemian & Powers, 2014), both juveniles and adults likely remain nearshore. This represents a lower energy expenditure as they make shorter vertical foraging trips.

The classification of individuals ≥ 90 cm DW as adults in this study is supported by the only available reference on the species' size at sexual maturity (Vázquez, 2003 in Salomón-Aguilar, 2015), although this corresponds to unpublished gray literature and is not easily accessible. Nevertheless, this criterion is further supported by our direct observations ($n = 16$) of pregnant females ≥ 90 cm DW recorded during and after the study period. This agreement reinforces the reliability of using the 90 cm DW threshold to distinguish adults from juveniles, despite the limited published information on the reproductive biology of *A. laticeps*.

In other areas, temperature has been demonstrated as one of the main factors influencing the movement of pelagic eagle rays (Bassos-Hull et al., 2014; Bernal et al., 2012; Cuevas-Zimbrón et al., 2013). This aligns with the absence of *Aetobatus laticeps* sightings in LA during periods of either the warmest or coldest temperatures. This variability in temperature preference may reflect *A. laticeps* affinity for intermediate temperatures to optimize metabolic processes, potentially due to physiological constraints (Gleiss et al., 2022). For example, in the case of *A. narinari*, higher catches were recorded in Campeche when sea surface temperature (SST) was 23.9 °C (Cuevas-Zimbrón et al., 2013), and observations in Florida occurred primarily within the 23-31 °C range (Bassos-Hull et al., 2014). Similarly, *A. flagellum* was captured in Ariake Sound when SST exceeded 15 °C. Temperature has been consistently identified as a key factor driving elasmobranch movements (Bernal et al., 2012). However, other seasonally variable factors, such as dissolved oxygen, salinity, and pH, can also influence elasmobranch behaviour (Schlaff et al., 2014), but were not considered in this study, leaving the effects of these factors on the movement of *A. laticeps* in

the area unknown. Future studies should incorporate these environmental variables to better understand their impact on the habitat use of this species.

According to the results of this study, LA represents an aggregation area for *Aetobatus laticeps*, where juvenile and adult individuals primarily engage in feeding activities. Additionally, recent information indicates that the area is an important area for the reproduction of the species (IUCN SSC, 2023). At the same time, this species holds significant importance for recreational tourism activities in the area (Balzaretto-Merino et al., 2021). Despite LA being a 3 km² protected natural area since 1975, there is no constant surveillance at the site, and illegal fishing continues to occur (Stokes et al., 2019). Furthermore, the area lacks regulations to manage tourism activities. Nearly three decades ago, (1997) noted that boating, snorkeling, scuba diving, and fishing in LA already caused coral damage, invertebrate extraction, pollution, and sedimentation from anchoring. He suggested implementing conservation measures to regulate these tourism activities. Additionally, considering the benthos as the physical environment that provides the food source for *Aetobatus laticeps*, it is likely that these activities also impact the area as a feeding zone for this species.

Considering the surface habits of *Aetobatus laticeps*, it is likely to be affected by collisions with boats, as recently recorded in Banderas Bay with this species (Castelo-Corona & Arnés-Urgellés, 2025). Similar incidents have been documented with other megafauna species, such as whales and giant manta rays in Banderas Bay (Dominguez-Sanchez et al., 2024; Ransome et al., 2021). Therefore, regulating boat traffic and speed in this and surrounding areas is necessary to protect megafauna with epipelagic habits, ensuring that the movements of these animals are not disrupted.

Medina-Rosas (1997) estimated a daily visitation of 2 000 to 3 000 people in LA. Currently, considering that tourism demand in Puerto Vallarta has increased significantly over the last decade (Secretaría de Turismo de Gobierno del

Estado de Jalisco, 2024), it is likely that visitation in LA has also risen due to its easy access. Therefore, in addition to establishing a tourism management program, it is imperative to raise awareness among local residents with continuous influence in the area. This would aim to encourage local tourism service providers and fishers to adopt environmentally respectful behaviours, fostering a better balance between social equity, economic growth, and environmental protection in LA and surrounding communities over the long term.

Ethical statement: The authors declare that they all agree with this publication and made significant contributions; that there is no conflict of interest of any kind; and that we followed all pertinent ethical and legal procedures and requirements. All financial sources are fully and clearly stated in the acknowledgments section. A signed document has been filed in the journal archives.

ACKNOWLEDGMENTS

We thank all the volunteers from Aetos ID who participated in the fieldwork at Los Arcos, and the members of the fisheries laboratory at ECOSUR-Campeche for their support in structuring the project.

REFERENCES

- Ajemian, M. J., & Powers, S. P. (2014). Towed-float satellite telemetry tracks large-scale movement and habitat connectivity of myliobatid stingrays. *Environmental Biology of Fishes*, 97(9), 1067–1081. <https://doi.org/10.1007/s10641-014-0296-x>
- Ajemian, M. J., Powers, S. P., & Murdoch, T. J. T. (2012). Estimating the potential impacts of large mesopredators on benthic resources: Integrative assessment of spotted eagle ray foraging ecology in Bermuda. *PLOS ONE*, 7(7), 1–17. <https://doi.org/10.1371/journal.pone.0040227>
- Balzaretti-Merino, N., Bravo-Olivas, M. L., Chávez-Dagostino, R. M., & Medina-Rosas, P. (2021). Impacts of recreational scuba diving on a natural area in Puerto Vallarta, México. *Sustainability*, 13(11), 1–17. <https://doi.org/10.3390/su13116249>
- Bassos-Hull, K., Wilkinson, K. A., Hull, P. T., Dougherty, D. A., Omori, K. L., Ailloud, L. E., Morris, J. J., & Hueter, R. E. (2014). Life history and seasonal occurrence of the spotted eagle ray, *Aetobatus narinari*, in the eastern Gulf of Mexico. *Environmental Biology of Fishes*, 97, 1039–1056. <https://doi.org/10.1007/s10641-014-0294-z>
- Becerril-García, E. E., Arauz, R., Arellano-Martínez, M., Bonfil, R., Ayala-Bocos, A., Castillo-Géniz, J. L., Carrera-Fernández, M., Charvet, P., Chiamonte, G., Cisneros-Montemayor, A. M., Concha, F., Espinoza, M., Ehemann, N. R., Estupiñán-Montaño, C., Fuentes, K., Galván-Magaña, F., Graham, R., Hacohen-Domené, A., Hazin, F., ... Godard-Codding, C. A. (2022). Research priorities for the conservation of chondrichthyans in Latin America. *Biological Conservation*, 269, 109535.
- Bernal, D., Carlson, J. K., Goldman, K. J., & Lowe, C. G. (2012). Energetics, metabolism and endothermy in sharks and rays. In J. C. Carrier, J. A. Musick, & M. R. Heithaus (Eds.), *Biology of Sharks and Their Relatives* (2nd Ed., pp. 57–95). CRC Press. <https://doi.org/10.1201/b11867-10>
- Berthe, C., & Lecchini, D. (2016). Influence of boat noises on escape behaviour of white-spotted eagle ray *Aetobatus ocellatus* at Moorea Island (French Polynesia). *Comptes Rendus - Biologies*, 339(2), 99–103. <https://doi.org/10.1016/j.crv.2016.01.001>
- Carraro, R., & Gladstone, W. (2006). Habitat preferences and site fidelity of the ornate wobbegong shark (*Orectolobus ornatus*) on rocky reefs of New South Wales. *Pacific Science*, 60, 207–223.
- Castelo-Corona, A. P., & Arnés-Urgellés, C. (2025). Healing response in a pacific eagle ray (*Aetobatus laticeps*) after a vessel strike in Banderas Bay, Mexico. *Journal of Fish Biology*, 1–5. <https://doi.org/10.1111/jfb.70141>
- Cuevas-Zimbrón, E., Pérez-Jiménez, J. C., & Méndez-Loeza, I. (2011). Spatial and seasonal variation in a target fishery for spotted eagle ray *Aetobatus narinari* in the southern Gulf of Mexico. *Fisheries Science*, 77(5), 723–730. <https://doi.org/10.1007/s12562-011-0389-9>
- Cuevas-Zimbrón, E., Pérez, J. C., & Méndez, I. (2013). Efecto de factores ambientales y la asignación del esfuerzo pesquero sobre las capturas de la raya *Aetobatus narinari* (rajiformes: Myliobatidae) en el sur del golfo de México. *Revista de Biología Tropical*, 61(3), 1341–1349. <https://doi.org/10.15517/rbt.v61i3.11963>
- DeGroot, B. C., Bassos, K., Wilkinson, K. A., Barbieri, S. L., Poulakis, G. R., & Ajemian, M. J. (2021). Variable migration patterns of whitespotted eagle rays *Aetobatus narinari* along Florida's coastlines. *Marine Biology*, 168, 1–21. <https://doi.org/10.1007/s00227-021-03821-2>
- Dominguez-Sanchez, P. S., Zavala-Jimenez, A., Fonseca-Ponce, I., Kumli, K. R., Rubin, R. D., & Stewart, J. D.



- (2024). Oceanic manta rays aggregating near a major population center have far higher injury rates than at an offshore protected area. *Endangered Species Research*, 55, 37–42. <https://doi.org/10.3354/esr01358>
- Flowers, K. I., Henderson, A. C., Lupton, J. L., & Chapman, D. D. (2017). Site affinity of whitespotted eagle rays *Aetobatus narinari* assessed using photographic identification. *Journal of Fish Biology*, 91(5), 1337–1349. <https://doi.org/10.1111/jfb.13452>
- Economakis, A. E., & Lobel, P. S. (1998). Aggregation behavior of the grey reef shark, *Carcharhinus amblyrhynchos*, at Johnston Atoll, Central Pacific Ocean. *Environmental Biology of Fishes*, 51(2), 129–139.
- English, S., Wilkinson, C., & Baker, V. (1997). *Survey manual for tropical marine resources*. Australian Institute of Marine Science.
- Gleiss, A. C., Treberg, J. R., Byrnes, E. E., & Lear, K. O. (2022). Physiological and applied energetics of elasmobranch fishes. In J. C. Carrier, C. A. Simpfendorfer, M. R. Heithaus, & K. Yopak (Eds.), *Biology of sharks and their relatives* (Third edition, pp. 289–322). CRC press. <https://doi.org/10.1201/9781003262190>.
- González-Pérez, F., & Cubero-Pardo, P. (2010). Efecto de actividades turísticas sobre el comportamiento de fauna representativa de las Islas Galápagos, Ecuador. *Latin American Journal of Aquatic Research*, 38(3), 493–500. <https://doi.org/10.3856/vol38-issue3-fulltext-13>
- Hoyos-Padilla, E. M., Ketchum, J. T., Klimley, A. P., & Galván-Magaña, F. (2014). Ontogenetic migration of a female scalloped hammerhead shark *Sphyrna lewini* in the Gulf of California. *Animal Biotelemetry*, 2, 1–9. <https://doi.org/10.1186/2050-3385-2-17>
- International Union for Conservation of Nature - Shark Specialist Group. (2023). *Banderas Bay ISRA Factsheet*. ISRA Importar Shark and Ray Areas (ISRA). <https://sharkrayareas.org/portfolio-item/banderas-bay-isra/>
- Karczmarski, L., Cockcroft, V. G., & Mclachlan, A. (2000). Habitat use and preferences of Indo-Pacific humpback dolphins *Sousa chinensis* in Algoa Bay, South Africa. *Marine Mammal Science*, 16(1), 65–79. <https://doi.org/10.1111/j.1748-7692.2000.tb00904.x>
- Medina-Rosas, P. (1997). *El efecto de las actividades turísticas sobre corales pétreos (Cnidaria, Anthozoa, Scleractinia) de los Arcos, Jalisco, México* [Tesis de Bachillerato]. Centro Universitario de Ciencias Biológicas y Agropecuarias, Universidad de Guadalajara.
- Medina-Rosas, P., & Cupul-Magaña, A. (2002). Los corales del área protegida Los Arcos: sobrevivir a impactos humanos y naturales. *Mexicoa*, 3(1-2), 86–91.
- NASA OBPG. (2019). *MODISA Level 3 Daily Mapped 4km Sea Surface Temperature (SST), Science Quality* (Version R2019.0). Greenbelt, MD, USA: NASA Ocean Biology DAAC. <https://doi.org/10.5067/MODSA-1D4D9>
- National Oceanic and Atmospheric Administration. (2023). *The NOAA GEO-IDE UAF ERDDAP: Easier access to scientific data* (Version 2.28.1) [Database]. NOAA Fisheries - Southwest Fisheries Science Center. <https://coastwatch.pfeg.noaa.gov/erddap/index.html>
- Palacios, M. D., Hoyos-Padilla, E. M., Trejo-Ramírez, A., Croll, D. A., Galván-Magaña, F., Zilliachus, K. M., O'Sullivan, J. B., Ketchum, J. T., & González-Armas, R. (2021). Description of first nursery area for a pygmy devil ray species (*Mobula munkiana*) in the Gulf of California, Mexico. *Scientific Reports*, 11(1), 132. <https://doi.org/10.1038/s41598-020-80506-8>
- Plata, L. J., & Filonov, A. (2007). Internal tide in the northwestern part of Banderas Bay, Mexico. *Ciencias Marinas*, 33(2), 197–215. <https://doi.org/10.7773/cm.v33i2.1013>
- Pohlert, T. (2014). *The pairwise multiple comparison of mean ranks package (PMCMR)* [R package]. CRAN. <https://cran.r-project.org/web/packages/PMCMR/index.html>
- Pollom, R., Avalos, C., Bizzarro, J., Burgos-Vázquez, M. I., Cevallos, A., Espinoza, M., González, A., Herman, K., Mejía-Falla, P. A., Morales-Saldaña, J. M., Navia, A. F., & Pérez-Jiménez, J. C. (2021). *Pacific Eagle Ray: Aetobatus laticeps*. The IUCN Red List of Threatened Species. <https://dx.doi.org/10.2305/IUCN.UK.2021-1.RLTS.T104021731A104021771.en>
- Ransome, N., Loneragan, N. R., Medrano-González, L., Félix, F., & Smith, J. N. (2021). Vessel strikes of large whales in the eastern tropical pacific: A case study of regional underreporting. *Frontiers in Marine Science*, 8, 1–15. <https://doi.org/10.3389/fmars.2021.675245>
- Ríos-Jara, E., Pérez-Peña, M., Juárez-Carrillo, E., López-Urriarte, E., Enciso-Padilla, L., & Robles-Jarero, E. G. (2001). *Moluscos macrobénticos del intermareal y plataforma continental de Jalisco y Colima* [Informe Final SNIB-CONABIO Proyecto No.S110. México, D.F.]. Universidad de Guadalajara, Centro Universitario de Ciencias Biológicas y Agropecuarias.
- Sales, L., Negra, C., Sampaio, I., Oliveira, C., Cruz, V. P., & Fernando, L. (2019). Phylogeography of eagle rays of the genus *Aetobatus*: *Aetobatus narinari* is restricted to the continental western Atlantic Ocean. *Hydrobiologia*, 836, 169–183. <https://doi.org/10.1007/s10750-019-3949-0>
- Salomón-Aguilar, C. A. (2015). Zonas prioritarias de conservación de rayas y mantarrayas en el noroeste del Pacífico mexicano. *Ciencia Pesquera*, 23(2), 77–99.
- Schlaff, A. M., Heupel, M. R., & Simpfendorfer, C. A. (2014). Influence of environmental factors on shark and ray movement, behaviour and habitat use: a review. *Reviews in Fish Biology and*

- Fisheries*, 24(4), 1089–1103. <https://doi.org/10.1007/s11160-014-9364-8>
- Schluessel, V., Bennett, M. B., & Collin, S. P. (2010). Diet and reproduction in the white-spotted eagle ray *Aetobatus narinari* from Queensland, Australia and the Penghu Islands, Taiwan. *Marine and Freshwater Research*, 61(11), 1278–1289. <https://doi.org/10.1071/MF09261>
- Secretaría de Industria y Comercio. (1975, 28 de Julio). *Acuerdo que establece como zona de refugio para la protección de la flora y fauna marinas, las aguas comprendidas en “Los Arcos”, Jalisco*. Diario Oficial de la Federación. https://www.dof.gob.mx/nota_to_imagen_fs.php?codnota=4785822&fecha=28/07/1975&od_diario=206044
- Serrano-Flores, F., Pérez-Jiménez, J. C., Méndez-Loeza, I., Bassos-Hull, K., & Ajemian, M. J. (2018). Comparison between the feeding habits of spotted eagle ray (*Aetobatus narinari*) and their potential prey in the southern Gulf of Mexico. *Journal of the Marine Biological Association of the United Kingdom*, 99(3), 661–672. <https://doi.org/10.1017/S0025315418000450>
- Secretaría de Turismo de Gobierno del Estado de Jalisco. (2024). *Estadísticas en el sector turístico*. SERTURJAL. <https://secturjal.jalisco.gob.mx/invierte-en-jalisco/estadisticas-en-el-sector-turistico>
- Simpfendorfer, C. A., & Heupel, M. R. (2004). Assessing habitat use and movement. In J. C. Carrier, J. A. Musick, & M. R. Heithaus (Eds.), *Biology of sharks and their relatives* (pp. 553–572). CRC Press.
- Stokes, K., Scammon, K., Double, D., Toon, K., Hendricks, S., Alfonso, A., Jimenez, Z., Pena, K. D., & Santos, K. C. (2019). Management of a Marine Park: analysis of recreational and illegal fishing pressures on the reef fish assemblage at Los Arcos Reserve in Jalisco, Mexico. *Journal of Fisheries and Life Sciences*, 4(1), 24–28.
- Swider, D. A., Corwin, A. L., Kamerman, T. Y., Zimmerman, S. L., Violetta, G. C., Davis, J., & Janse, M. (2017). Reproduction of spotted eagle rays, *Aetobatus narinari*, in aquaria. In M. Smith, D. Warmolts, D. Thoney, R. Hueter, M. Murray, & J. Ezcurra (Eds.), *The Elasmobranch Husbandry Manual II: Recent Advances in the Care of Sharks, Rays and their Relatives* (pp. 433–442). Ohio Biological Survey.
- Richards, V. P., Henning, M., Witzell, W., & Shivji, M. S. (2009). Species delineation and evolutionary history of the globally distributed spotted eagle ray (*Aetobatus narinari*). *Journal of Heredity*, 100(3), 273–283. <https://doi.org/10.1093/jhered/esp005>
- Yamaguchi, A., & Taniuchi, T. (2000). Food variations and ontogenetic dietary shift of the star-spotted dogfish *Mustelus manazo* at five locations in Japan and Taiwan. *Fisheries Science*, 66(6), 1039–1048. <https://doi.org/10.1046/j.1444-2906.2000.00166.x>