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Fishers' Local Ecological Knowledge recovers information about the recent-past existence of a Caribbean coastal shark and ray nursery area

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Abstract

Elasmobranchs have declined sharply due to overfishing and habitat destruction. Nursery-areas are crucial for the recruitment and sustainability of elasmobranch populations; however, they have been scarcely studied globally and in Mexico. We used fishers' Local Ecological Knowledge (LEK) to investigate whether Bahía de la Ascensión was an elasmobranch nursery-area 30 + years-ago, and for which species. Shark nursery-areas are defined by three criteria that we evaluated using semi-structured interviews covering 90% of the target population (local fishers aged 40+). Several elasmobranchs met all criteria, supporting that this bay served as a communal elasmobranch nursery-area 30 + years-ago for *Carcharhinus leucas*, *C. limbatus, Ginglymostoma cirratum*, *Negaprion brevirostris, Hypanus americanus* and *Styracura schmardae*. Additionally, fishers reported changes in early-offspring elasmobranch abundance –including declines and increases– between our study-period and the present. This is the first study showing that LEK can be used to reconstruct the former existence of elasmobranch nursery-areas, highlighting its value to rescue past information in data-poor contexts, in support of conservation. This approach can and should be widely-applied for similar purposes. Our study is part of a trans-disciplinary project examining past-and-present elasmobranch nurseries in the Mexican Caribbean, providing a baseline to evaluate changes while preventing misinterpretation based solely on present-day data.

INTRODUCTION

Chondrichthyans (sharks, batoids, and chimaeras) are one of the vertebrate taxa most susceptible to extinction globally, with more than 1/3 of species currently classified as threatened according to the IUCN (International Union for the Conservation of Nature) Red List of Threatened Species [1]. Human activity is the culprit: overfishing (both targeted and incidental) is the main cause of threat, followed by habitat loss and degradation [1].

The biological characteristics of most elasmobranchs (sharks and batoids) exacerbate their precarious situation. As archetypal K-strategists they have low reproductive potentials and therefore low capacities for population increase when compared to bony fishes [2–4]. As a result, elasmobranchs are particularly vulnerable to overfishing since their populations take long to recover from exploitation [4]. Still, sharks fulfil key ecological roles across diverse ecosystems through bottom-up and top-down processes, with the most pronounced top-down effects observed in macro-predatory sharks [3, 5].

The concept of elasmobranch nursery-areas has been widely recognized for a long time, yet until recently, there were no clear criteria to define an elasmobranch nursery-area. This ambiguity was addressed by establishing three criteria to declare a site as a shark nursery-area [6]: 1) the area is characterized by a higher density of individuals < 1 year-old (= early offspring) compared to the mean density of other areas; 2) early offspring exhibit an affinity to remain or return to the area for extended periods (weeks or months), indicating higher site-fidelity compared to other areas; and 3) the area is used repeatedly across years (recurrently, year-after-year) by early offspring. The same criteria apply also

for batoid nursery-areas [7]. In addition, the use of nursery-areas enhances the survival rates of individuals, leading to a greater contribution to the adult population [8, 9], such that identifying and protecting elasmobranch nursery-areas is critical for the effective conservation and management of this group [10].

Studying past ecological phenomena poses a significant challenge due to the absence of systematically-documented baseline scientific data from earlier periods. This is particularly acute in tropical regions, where coastal fisheries management has historically been hindered by a persistent lack of complete and continuous data [11]. As a result, researchers have increasingly turned to Local Ecological Knowledge (LEK) as a means to filling historical data gaps [12–14] LEK is defined as "the knowledge, practices, and beliefs regarding ecological relationships that are gained through extensive personal observation of and interaction with local ecosystems, and shared among local resource users" [15]. This type of knowledge has been utilized by humans since the early days of hunter-gatherer societies. Notably, in the 1980's, the term gained widespread usage and has since garnered growing recognition and acceptance across various scientific fields [16]. The valuable information gathered from LEK is applicable to conservation efforts across a range of environments and dimensions [17]. Indeed, recent efforts show a growing number of LEK studies supporting elasmobranch conservation, including among others, former presence and utilization of critically endangered sawfishes [18], reconstruction of elasmobranch abundance trends [19], assessment of elasmobranch conservation status [20] and detection of elasmobranch hotspot declines [21]. However, to date no one has used LEK to recover past or present information about elasmobranch nursery-areas.

Mexican shark and batoid fisheries are one of the largest in the Americas since the mid-1970s [22], and Mexico has remained a global leader in shark fishery production since then [23]. Between the 1970s and 1980s, Mexican elasmobranch catches rose from 5,000 tons per year to over 30,000 tons per year [22].

Unfortunately, despite the importance of elasmobranchs to Mexican fisheries, there is limited research on life-history and stock-assessment for the majority of species occurring in Mexico [24]. The same applies to elasmobranch nursery-areas with only six previous studies devoted to this topic in Mexico [25–30]. The knowledge gap regarding elasmobranch nursery-areas in Mexico is particularly concerning given the significant threats these species face, particularly from overfishing. In the present study, we apply LEK to compile historical information to evaluate the role of the largest marine inlet in the Mexican Caribbean, Bahía de la Ascensión, as an elasmobranch nursery-area 30 + years ago, taking into account the 3 criteria already established [6]. Our study helps to alleviate the limited knowledge of elasmobranch nursery-areas in Mexico, and establishes a key baseline for future efforts focused on research, conservation and management of elasmobranchs in the region. In addition, to our knowledge, this is the first study worldwide to apply LEK in order to attempt the proper identification of elasmobranch nursery-areas in the present or back in time, based on currently accepted criteria [6, 7]. Rescuing information on elasmobranch nursery-areas is an important advancement in the evaluation of ecosystem services that some coastal areas can provide to humans, in this case as refugia that safeguard recruitment to the

adult populations sustaining fisheries, shark-diving operations, and ecosystem services such as ecosystem balance and ecological control [4, 5].

This study was conducted as part of a larger project in which LEK will provide a baseline to assess whether Bahía de la Ascensión functioned as an elasmobranch nursery-area 30 + years ago. We are currently conducting direct-sampling across the bay to assess which elasmobranch species currently meet the 3 nursery-area criteria in the present. Together, these paired approaches will allow us to assess change in the ecological services provided by this bay as an elasmobranch nursery-area, evaluate the potential drivers of such change, and devise needed management and conservation measures.

RESULTS

Occurrence of elasmobranchs' early offspring in the bay

We interviewed a total of 25 fishers aged 40–82 years (mean = 62.5 years, SD = 11.8 years), spanning 16–65 years of fishing experience (mean = 39.4 years, SD = 11.0 years; Fig. S4). Our results show a total of 23 elasmobranchs —12 sharks and 11 batoids— as present in Bahía de la Ascensión 30 + years ago, with 10 sharks and 8 batoids giving birth inside the bay (Table 1). The most frequently-reported (> = 50% of responses) sharks giving birth in the bay were *Carcharhinus leucas*, *C. limbatus*, *Ginglymostoma cirratum*, *Negaprion brevirostris*, and *Sphyrna tiburo*, whereas for batoids these were *Aetobatus narinari*, *Hypanus americanus*, and *Styracura schmardae*.

Table 1

Presence of species of sharks and batoids and their early offspring inside Bahía de la Ascensión 30 + years ago, according to the percentage of respondents (n = 25); species with > = 50% of respondents reporting early offspring are shown in bold.

Elasmobranch species			**Proportion of responses**	
Scientific name	**Common name**	**Red list categories[a]**	**Presence in the bay**	**Presence of early offspring in the bay**
Shark species			(%)	(%)
Carcharhinus acronotus	Blacknose shark	EN	16	4
Carcharhinus falciformis	Silky shark	VU	4	0
Carcharhinus leucas	**Bull shark**	VU	96	**72**
Carcharhinus limbatus	**Blacktip shark**	VU	100	**92**
Galeocerdo cuvier	Tiger shark	NT	76	12
Ginglymostoma cirratum	**Nurse shark**	VU	92	**88**
Mustelus canis	Dusky smooth-hound	NT	4	0
Negaprion brevirostris	**Lemon shark**	VU	100	**96**
Rhizoprionodon terraenovae	Atlantic sharpnose shark	LC	32	16
Sphyrna lewini	Scalloped hammerhead	CR	36	20
Sphyrna mokarran	Great hammerhead	CR	48	12
Sphyrna tiburo	**Bonnethead**	EN	80	**56**
Batoid species				
Aetobatus narinari	**Whitespotted eagle ray**	EN	100	**52**
Hypanus americanus	**Southern stingray**	NT	96	**80**

[a]According to the IUCN Red List [31]: NT (Near threatened), VU (Vulnerable), EN (Endangered), CR (Critically endangered).

Elasmobranch species			Proportion of responses	
Scientific name	**Common name**	**Red list categories[a]**	**Presence in the bay**	**Presence of early offspring in the bay**
Narcine bancroftii	Caribbean numbfish	LC	48	8
Pristis pectinata	Smalltooth sawfish	CR	36	8
Pristis pristis	Largetooth sawfish	CR	48	8
Pseudobatos lentiginosus	Freckled guitarfish	VU	12	0
Pseudobatos percellens	Chola guitarfish	EN	28	4
Pseudobatos sp.	guitarfish	----	28	0
Rhinoptera bonasus	American cownose ray	VU	4	0
Styracura schmardae	**Atlantic chupare**	EN	96	**84**
Torpedo andersoni	Caribbean torpedo	LC	4	0
Urobatis jamaicensis	Yellow round ray	LC	100	36

[a]According to the IUCN Red List [31]: NT (Near threatened), VU (Vulnerable), EN (Endangered), CR (Critically endangered).

Relative abundance of early offspring inside and outside the bay

Despite variations in the proportion of responses, overall, all the elasmobranchs that fishers identified as breeding in the study area, had a higher abundance of early offspring inside the bay than in nearby areas outside the bay (Fig. 2). For batoids, *Styracura schmardae* and *Hypanus americanus* had > = 50% of responses for higher abundance inside the bay, *Aetobatus narinari* and *Urobatis jamaicensis* had 44% and 31% of responses respectively, and the other species < = 10% of responses. An exception was *Narcine bancroftii*, which had an equal abundance inside and outside the bay.

For sharks, species with > = 50% of responses –indicating higher abundance of early offspring inside than outside the bay– included *Carcharhinus leucas, C. limbatus, Ginglymostoma cirratum* and *Negaprion brevirostri; Sphyrna tiburo* had 44% of responses, and the remaining species < = 20% of responses.

Seasonal occurrence of early offspring

The general pattern show by our data suggests that early offspring of most sharks and batoids remained in the area for prolonged periods of time 30–50 years ago, and were present mostly between April and December each year (Fig. 3). Species with >= 50% of responses suggesting prolonged permanence inside the bay included *Hypanus americanus* and *Styracura schmardae*, with *Aetobatus narinari* having about 30% of responses and the remaining batoids < = 20% of responses. For sharks, *Carcharhinus leucas, C. limbatus*, *Ginglymostoma cirratum* and *Negaprion brevirostris*, received >= 50% of responses for prolonged permanence inside the bay, *Sphyrna tiburo* had about 40% of responses, and the remaining species had < = 20% of responses, and therefore less reliable information about their prolonged permanence inside the bay.

Recurrent use by early offspring

Information about the recurrent use (year after year), of the bay by the early offspring of sharks and batoids shows >= 50% of responses for *Hypanus americanus*, *Styracura schmardae*, *Carcharhinus leucas*, *C. limbatus*, *Ginglymostoma cirratum*, *Negaprion brevirostris*, and *Sphyrna tiburo* (Fig. 4). *Aetobatus narinari* and *Urobatis jamaicensis* received 48% and 28% of responses for recurrent use, while the remaining species had <= 20% of responses for recurrent use. *Pristis pectinata* was the only species to have the same percentage of respondents (4%) for recurrent use and for non-recurrent use of the bay.

Changes in abundance and current presence of early offspring

Fishers' responses about changes in abundance of batoid early offspring between 30–50 years ago and the present varied by species (Fig. 5a): *Pristis pectinata*, *P. pristis*, and *Pseudobatos percellens* were only reported to have decreased in abundance (with < = 10% of responses). *Styracura schmardae* and *Aetobatus narinari* had slightly larger percentages of respondents for no-change in abundance, followed by increases in abundance. Responses for *Hypanus americanus* were evenly distributed between increased, decreased, and no-change in abundance. In contrast, *Urobatis jamaicensis* was the only species with a majority of responses for an increase in abundance.

For sharks, *C. limbatus* and *Negaprion brevirostris* had >= 50% of responses for increased abundance while *Carcharhinus acronotus* and *Galeocerdo cuvier* only received responses for increases in abundance (approx. 5%; Fig. 5b). *Carcharhinus leucas* and *Ginglymostoma cirratum* had slightly larger percentages of responses for no-change in abundance followed closely by >= 20% of responses for increased abundance. In contrast, *Sphyrna lewini* (8% of responses) and *S. tiburo* (40% of responses) had higher scores for a decrease in abundance. For *Rhizoprionodon terraenovae*, responses were evenly-split between decreased and no-change in abundance. *Sphyrna mokarran* had 8% of responses for no-change followed by decreased abundance.

Fishers reported the current presence in the bay of the early offspring of several species (Fig. 6): *Hypanus americanus, Styracura schmardae, Carcharhinus leucas, C. limbatus, Ginglymostoma cirratum*, and *Negaprion brevirosting* with >= 50% of responses, *Aetobatus narinari* and *Urobatis jamaicensis* with about 45% and 30% of responses, and the remaining species with < = 30% of responses. *Pristis pristis* was only reported as currently absent, while *P. pectinata* and *Sphyrna lewini* received equal proportions of responses for current presence and current absence in the bay (all < 10%).

DISCUSSION

Our results derived from fishers' LEK from Punta Allen indicates that Bahía de la Ascensión was a nursery-area for several sharks and batoids 30 + years ago. Five sharks (*Carcharhinus leucas, C. limbatus, Ginglymostoma cirratum, Negaprion brevirostris*, and *Sphyrna tiburo*) and three batoids (*Aetobatus narinari, Hypanus americanus*, and *Styracura schmardae*) had > = 50% of responses indicating the occurrence of early offspring inside the bay, suggesting they could have had a nursery-area there.

Due to the almost complete lack of studies focused on elasmobranchs in Bahía de la Ascensión, it is difficult to compare our results. The only previous study [32] reported a majority of early offspring of *Carcharhinus leucas, C. limbatus, C. perezi* and *Negaprion brevirostris* in fishery catches in Punta Allen in the mid-1990s compared to other life-stages, providing support to our results.

Species matching current nursery-area criteria

Several elasmobranchs reported here as having early offspring inside Bahía de la Ascensión had large support in interviewees' responses for meeting all three criteria for the definition of an elasmobranch nursery-area. While many elasmobranchs are known to have coastal nursery-areas, studies on this topic are scarce with < 10% of the over 1,100 elasmobranch species properly studied in the context of nursery-areas [6, 10]. This is not surprising given the relatively recent definition of how to identify a nursery-area [6], however, this limits comparisons of our findings against other studies.

Sharks

Carcharhinus leucas, Carcharhinus limbatus, Ginglymostoma cirratum, and *Negaprion brevirostris* had large support in our LEK data for meeting the 3 criteria; this strongly suggests they had a nursery-area in Bahía de la Ascensión 30 + years ago. *Carcharhinus limbatus* has shallow coastal nursery-areas in the Gulf of Mexico [27, 33–34]. Similarly, *Negaprion brevirostris*, has shallow coastal nursery-areas in the Bahamas [35–36], the US Virgin Islands and Venezuela [37–38]. *Carcharhinus leucas* has nursery-areas on estuarine habitats, rivers and coastal bays [25, 39–40].

Whilst our results suggest that the nurse shark (*Ginglymostoma cirratum)* used this bay as a nursery-area in the past, and the term "nursery-area" has been used for this species based on the occurrence of offspring across multiple years [41–42], recent work indicates that early offspring of this species may

occur over broad geographic ranges without clear aggregation, suggesting that *G. cirratum* may not have discrete nursery-areas at all [43–44].

Our data provided medium-to-high support for *Sphyrna tiburo* using Bahía de la Ascensión as a nursery-area in the past, with only criterion 3 having > 50% of responses. This coincides with reports of *S. tiburo* having well-defined nurseries [45–46], although information on the nursery habitats of this species remains limited.

For *Sphyrna lewini* and *S. mokarran*, we found medium (10–49%) and low (< 10%) support in our LEK data for each of the 3 criteria. *Sphyrna lewini* is known to have coastal nursery-areas but in more open coastal waters close to shore, all typically characterized by turbid conditions [47–50]. However, information on nursery-areas for *S. mokarran* remains scarce. The absence of neonates in nearshore habitats suggests that this species does not rely on discrete coastal nursery-areas [46, 51]. Nonetheless, sporadic observations of neonates in shallow waters [52] and the recent report of a probable nursery-area in Biscayne Bay, FL. [53], meeting 2 of the 3 criteria, suggests that this species may use coastal nurseries more extensively than previously thought.

We found limited evidence for *Carcharhinus acronotus*, *Rhizoprionodon terraenovae* or *Galeocerdo cuvier* having a nursery-area in the Bahía de la Ascención in the past. *Rhizoprionodon terraenovae* had 10–49% and the other two species < 10% of respondents supporting the 3 criteria. In particular, workshop participants clarified that only older juvenile and adult tiger sharks occurred in the bay, and did not identify the bay as a nursery ground for any of these species. Both *Carcharhinus acronotus* and *Rhizoprionodon terraenovae* are not considered to utilize well-defined nursery-areas [6, 54] due to their relatively productive life-history strategies [55] allowing for greater tolerance to juvenile mortality, thereby diminishing the benefits of discrete nursery habitats [6]. Likewise, the large-bodied *Galeocerdo cuvier* is thought not to use discrete nursery-areas because it has large litters of fast-growing young, thus compensating for potentially high juvenile mortality in offshore less protected habitats [56–57]. However, a potential nursery-area for *G. cuvier* has been recently reported on the continental shelf between Florida and Georgia [58]. Information on tiger shark nursery grounds remains scarce, underscoring the need for further research to confirm and characterize additional nursery-areas for this species.

Batoids

The scientific literature on batoid nursery-areas is extremely limited for most of the species reported here, with a few exceptions [7, 10]. This underscores the value of LEK as an alternative tool to study nursery-areas in the present or in the recent past.

Our study suggests the past existence of a nursery-area in Bahía de la Ascensión for *Styracura schmardae* and *Hypanus americanus* with large support in our LEK results for them meeting the 3 criteria. *Styracura schmardae* is one of the few batoids for which a nursery-area meeting all 3 criteria has been rigorously documented in the Bahamas [59]. In contrast, the three nursery-area criteria have not yet been

evaluated for *H. americanus*. A secondary nursery for this species has been suggested based on the presence of older juveniles and gravid females in NE Brazil [60]. Other studies reported ontogenetic spatial segregation [61] and juvenile residency at some sites [62], however, to our knowledge, no study has fully met all 3 nursery-area criteria for this species.

We found medium-to-high support for *Aetobatus narinari* and moderate support for *Urobatis jamaicensis* having had a nursery-area in Bahía de la Ascensión in the past. There is limited research on the existence of discrete nursery-areas for both species, and none of it meets the 3-criteria used here [60, 63].

Our results show limited support (< 10% of respondents) for *Pseudobatos percellens* and *Narcine bancroftii* using the bay as a nursery-area in the past. There are no studies confirming the existence of nursery-areas for *Pseudobatos percellens* meeting the 3 criteria, only proposed primary and secondary nursery-areas in Brazil, based on high occurrence of neonates and gravid females [60]. For *Narcine bancroftii*, no nursery-areas have been documented.

We found only a low percentage of responses supporting that the 3 criteria were met for the sawfishes *Pristis pectinata* and *P. pristis* in Bahia de la Ascensión in the past. However, sawfishes deserve careful consideration since they are Critically Endangered in to the IUCN Red List [64–65], are very rare in Mexico [66], and suffered a strong decline in abundance throughout Mexico between the 1960s and 1980s [18, 67]. We argue that the majority of our interviewees did not witness the former existence of a nursery for sawfishes in the study site, and therefore our data is biased in this particular matter. Notably, the eldest workshop participant (76 years old) reported sawfish early offspring inside the bay in the past. He may be one of the last-living witnesses of the former use of the bay as a nursery-area by sawfishes. Likely, the downfall of sawfishes in the area (1960s-1980s) preceded the actual fishing experience of most of our interviewees (72% of respondents had < 46 years of experience fishing locally; Fig. S4). In addition, information collected by one of us (RB) in 2015 during a LEK study about sawfishes in Mexico [18], includes a witness providing testimony from the early 1970s of an impressive abundance of very small sawfishes in the shallow waters of the embayment behind Vigia Grande, in the southwest corner of the bay. *Pristis pectinata* is well-known to have nursery-areas in shallow euryhaline coastal habitats [68–71], and *P. pristis* has nursery-areas in rivers and estuaries [72].

Elasmobranch early-offspring abundance changes

Our results suggest strong declines in Bahía de la Ascensión –between 30 + years-ago and the present– in the abundance of early offspring of *Pristis pectinata*, *P. pristis*, *Pseudobatos percellens*, *Sphyrna tiburo*, and *Sphyrna lewini*. In contrast, the early offspring of *Urobatis jaimacensis, Carcharhinus limbatus*, and *Negaprion brevirostris* were predominantly reported to have increased during the same period, while the early offspring of *Aetobatus narinari, Styracura schmardae, Ginglymostoma cirratum, Carcharhinus leucas* and *Sphyrna mokarran* were mainly reported to have remained stable, with slightly less support for having increased in numbers.

The majority of participants in our study attributed the increase in shark and batoid early offspring to a general gillnet ban that came into effect after the establishment of the Sian Ka'an Biosphere Reserve in 1986 (Tab. S1), suggesting that this had an important positive impact on the conservation of elasmobranch populations in the bay.

The decline of many elasmobranch populations over the last 50 years is well documented [73–75]. Yet, scientific assessments often lack data from earlier periods hindering a full understanding of long-term trends. Our study helps fill this gap by integrating LEK to recover valuable past information on the ecosystem services provided by Bahía de la Ascensión 30 + years ago. LEK often unveils earlier declines not detected by short-term studies [76], underscoring the profound anthropogenic impacts on wild populations and ecosystems, and highlighting the need for more precautionary management and conservation strategies [77]. Similarly, fishers' perceptions have been used to identify population changes in marine organisms [78].

Our findings should be interpreted with consideration of their limitations. First, our relatively small sample-size was determined by the size of the target population, however, Punta Allen is the only human settlement with access to the bay and it has always been a small village. Additionally, the division of lobster fishing areas in *parcelas* may have biased the spatial perspective of interviewees' information about elasmobranch distribution inside the bay, since they generally used only specific areas of the bay. Finally, any study based on interviews may be affected by recall bias, particularly when referring to events that occurred several decades ago. Despite these limitations, LEK provides valuable information, especially regarding past ecosystem services and conditions.

Our study is the first to show that the thoughtful application of LEK can allow the reconstruction of the past-existence of an elasmobranch nursery-area –according to established criteria– providing a key baseline to evaluate ecological changes. Such insights are vital to guide current and future management decisions in the region, and demonstrate the importance of integrating accumulated local knowledge into conservation strategies for marine populations.

CONCLUSIONS

Bahía de la Ascensión functioned as a communal nursery-area for several shark and batoid species 30 + years-ago, chiefly: *Carcharhinus leucas*, *C. limbatus*, *Ginglymostoma cirratum*, *Negaprion brevirostris*, *Hypanus americanus*, and *Styracura schmardae.* It is possible that *Aetobatus narinari, Urobatis jamaicensis, Pristis pectinata, P. pristis* and *Sphyrna tiburo* also had nursery-areas inside the bay, but our data is not conclusive.

There have been strong population declines in the early offspring of *Pristis pectinata*, *P. pristis*, *Pseudobatos percellens*, *Sphyrna lewini*, and *S. tiburo*, concurrent with increases in the abundance of early offspring of *Carcharhinus limbatus*, *Negaprion brevirostris*, and *Styracura schmardae*. The abundance of early offspring of *Carcharhinus leucas*, *Ginglymostoma cirratum*, *S. mokarran*, *Urobatis jamaicensis*, and *A.*

narinari has remained stable. Increases and stability in abundance were largely attributed to the creation of the Sian Ka'an Biosphere Reserve and the concurrent ban on the use of gillnets.

Our study demonstrates that the careful application of LEK, can be a formidable tool that can help fill important gaps in our knowledge about elasmobranch essential habitats and particularly the existence of shark and batoid nursery-areas in the recent past.

METHODS

Study area and human development

Bahía de la Ascensión (Fig. 1) is the largest shallow bay (720 km^2; maximum depth: 6 m) in the Mexican Caribbean, with a 12.5 km oceanic front [79]. It is part of the emblematic Sian Ka'an Biosphere Reserve, established January 20, 1986 [80]. The only human settlement is Punta Allen, a small fishing-village (393 inhabitants in 2020) [81] founded in 1968 by 49 people [82].

Finfish and spiny lobster (*Panulirus argus*) fisheries were the main activities in the early years [83]. However, economic activities have diversified over the decades with small-scale fisheries (lobster and finfish) and eco-tourism driving the local economy [82].

In Bahía de la Ascensión, lobster fishing-grounds are divided into exclusive areas (*parcelas*) regulated by the cooperative, which enforces strict access and use rules [84]. The fishery relies on recruitment-enhancing artificial habitats (*casitas*) providing refuge from predation while the capture of bony fish, sharks, and batoids, was done primarily with gillnets, trammel nets, handlines, and longlines [32]. However, following the establishment of the Biosphere Reserve of Sian Ka'an, the use of gillnets was prohibited [83]; currently, only one fisher continues shark-fishing in the area using longlines.

Data collection

We used semi-structured interviews to collect LEK information from fishers > = 40 years old from Punta Allen during 3 field-trips between June 2023 and February 2024. We used a snowball sampling approach [85] to find interviewees by asking initial participants to recommend other individuals with similar local fishing experience and age-range.

Our sample size (n = 25) was determined by the size of the local population and the limited number of fishers still alive but with sufficient age and local fishing experience to provide us information from a relatively distant past; only one person declined to participate in our surveys, and there were no-further fishers alive of the target age-or-experience range in Punta Allen.

We aimed at rescuing information from as far back-in-time as possible, but were constrained by the longevity, age and experience of the living population. Our period of study was roughly defined as 30 + years-ago considering the age-and-experience-ranges of interviewees (all older than 40 years old, meaning they all started fishing before 1995 if they started at age 10, which is a common practice in

communities where fishers incorporate their children into fishing at early ages; Fig. S4), that Punta Allen was founded in 1968, and also that the known changes in elasmobranch fishing activity in the region [86] and the resulting decline in some elasmobranch populations [18, 66] occurred in the 1970–2000 period.

Interviews were structured in two parts (Figures S1-S3): the first included interviewees' background information, a list of shark and batoid species that inhabited the bay, and which of them gave birth inside the bay (see Fig. 1 for delimitation). We used regional elasmobranch ID guides [87–88] and a custom-made visual guide featuring scientific drawings taken from the literature to aid accurate species identification by interviewees; the second part focused exclusively on those species identified by each interviewee as having early offspring in the bay, including questions about the relative abundance of early offspring of each species, their residency patterns, site fidelity, repeatability of use through the years, and using a map, we asked interviewees to point the specific locations inside the bay where each species occurred. Additional questions addressed interviewee's perception of temporal changes in the abundance of each species.

All our methodology was approved by the Research Ethics Committee of El Colegio de la Frontera Sur; all methods were performed in accordance with the relevant national guidelines and regulations. Prior written informed consent was obtained from all the participants involved in the study, and the objectives of the study were explained to each participant before the interview. Neither human or animal experiments were conducted, nor samples were collected for this study; we only obtained information from the memories of interviewees with their full consent.

Data refinement

Our data were validated and refined in a final workshop where we solved potential inconsistencies or contradictions in responses, and presented preliminary results to the interviewees and the community. In this workshop, the local reference sites used by fishers were verified using a map of the bay, and participants were asked about the reasons behind changes in the abundance of early offspring of elasmobranchs.

Data analysis

All data was entered into a Microsoft Access® database specifically designed to organize, manage, and analyze our data. Data were summarized and analyzed using descriptive statistics and figures were prepared using GraphPad Prism®.

When species identification by interviewees was uncertain, only the genus was recorded. This was the case for *Narcine sp.* and *Pseudobatos sp.* However, only *Narcine bancroftii* is known from Bahía de la Ascensión [89]; therefore, records initially classified as *Narcine sp.* were assigned to *N. bancroftii* during analysis. For *Pseudobatos*, two species are known from the Mexican Caribbean, *P. lentiginosus* and *P. percellens* [89–90]; when fishers were unable to differentiate between species, we conservatively recorded such information as *Pseudobatos sp*.

DECLARATIONS

Additional Information

Competing Interests Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Ramón Bonfil reports financial support was provided by Save Our Seas Foundation and El Colegio de la Frontera Sur.

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Author Contribution

ME: Conceptualization, data gathering and curation, formal analysis, investigation, methodology, validation, writing original draft and editing. JPS: Software, Writing-reviewing and editing. RB: Conceptualization, funding acquisition, data gathering, investigation, methodology, project administration, resources, supervision, validation, writing original draft, writing review & editing.

Acknowledgement

This study is based on the knowledge shared by the fishers of Punta Allen; we only translated and systematized their oral testimonies into written form. We thank each and every one of the fishers participating in our interviews and workshop; without their generous contributions this work would not have been possible. We thank Andres Navarro for his valuable help conducting interviews; Hugo Sánchez, Sarah Martinez and Roberto Herrera, assisted with some of the field work, and Paola Maldonado digitized the data. We also thank the Save Our Seas Foundation for financing most of this study. The first author thanks Juan Carlos Pérez and Alejandro Espinosa for their useful feedback and suggestions throughout the development of this study.

Data Availability

Due to the personal nature of the data (personal interviews) we are not at liberty to publicly distribute the data; data will be made available upon request. This study is based on the knowledge shared by the fishers of Punta Allen; we only translated and systematized their oral testimonies into written form. We thank each and every one of the fishers participating in our interviews and workshop; without their generous contributions this work would not have been possible. We thank Andres Navarro for his valuable help conducting interviews; Hugo Sánchez, Sarah Martinez and Roberto Herrera, assisted with

some of the field work, and Paola Maldonado digitized the data. We also thank the Save Our Seas Foundation for financing most of this study. The first author thanks Juan Carlos Pérez and Alejandro Espinosa for their useful feedback and suggestions throughout the development of this study.

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Figures

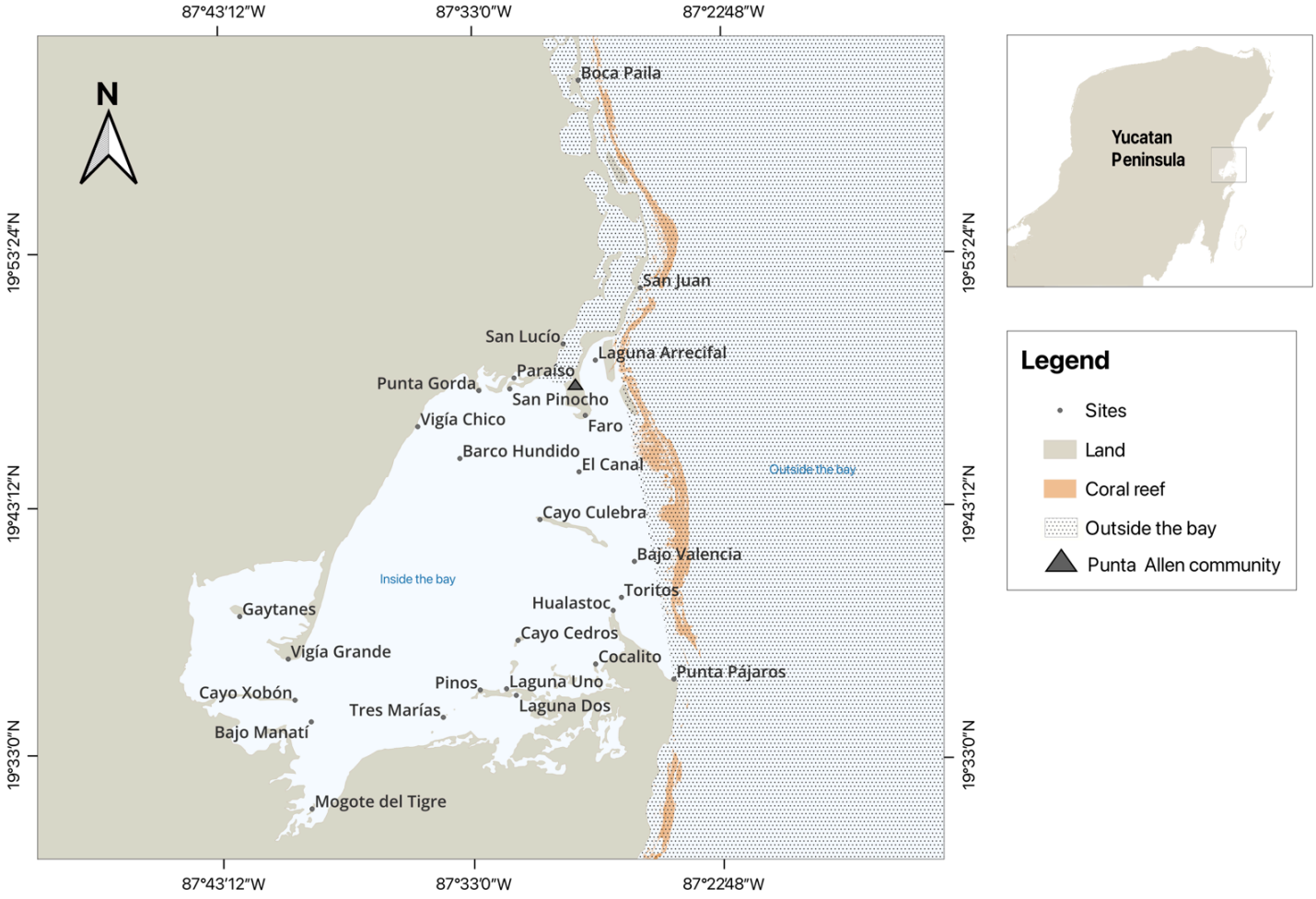


Figure 1

Study area (Bahía de la Ascensión) with site-names based on local references: well-known features such as shoals, keys, and points used by fishers to navigate and find fishing spots. The shaded area shows the definition of areas considered as “outside” the bay in this study.

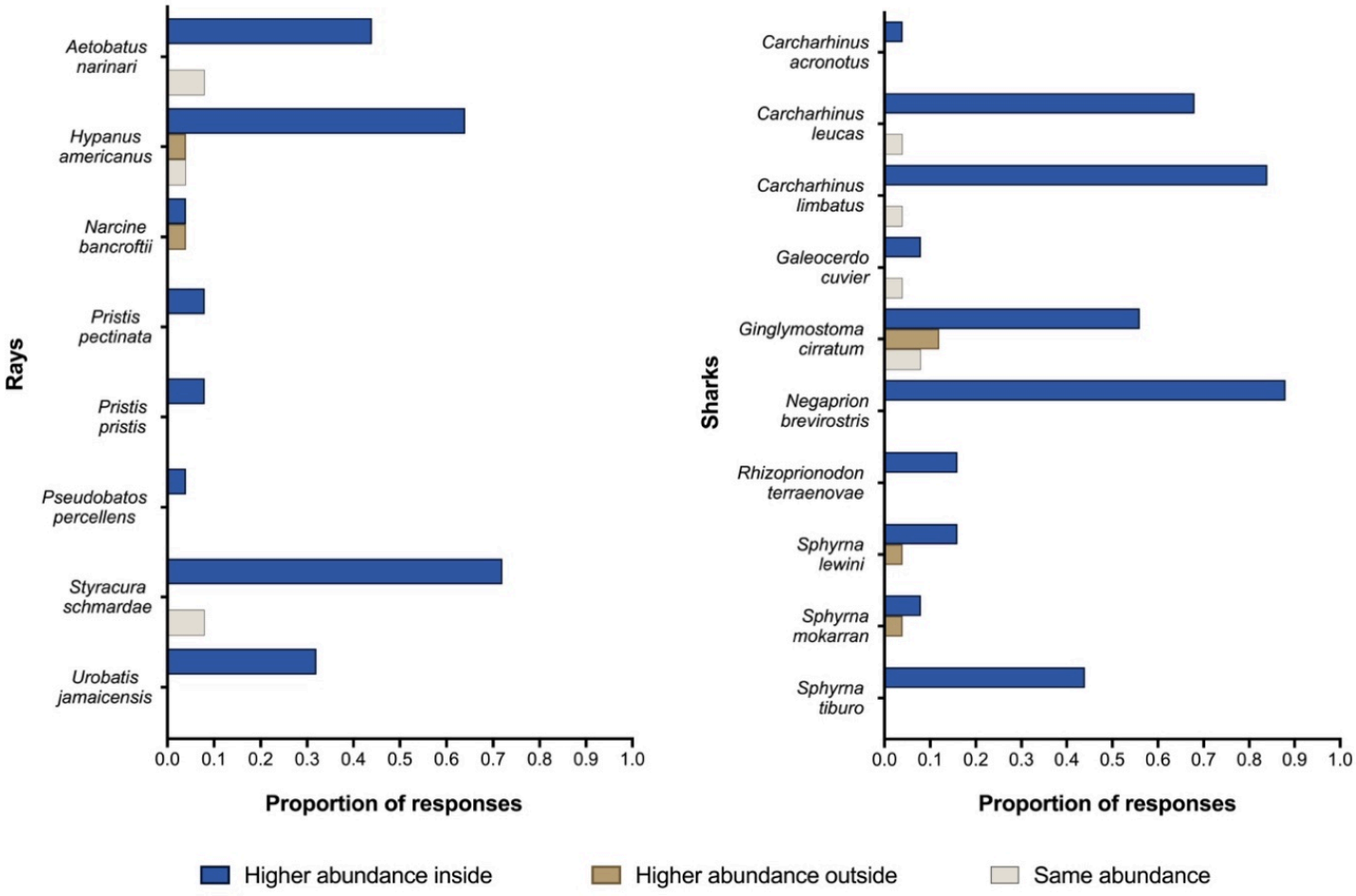


Figure 2

Relative abundance of early offspring of elasmobranchs inside and outside the bay, according to interviewees' responses (n=25).

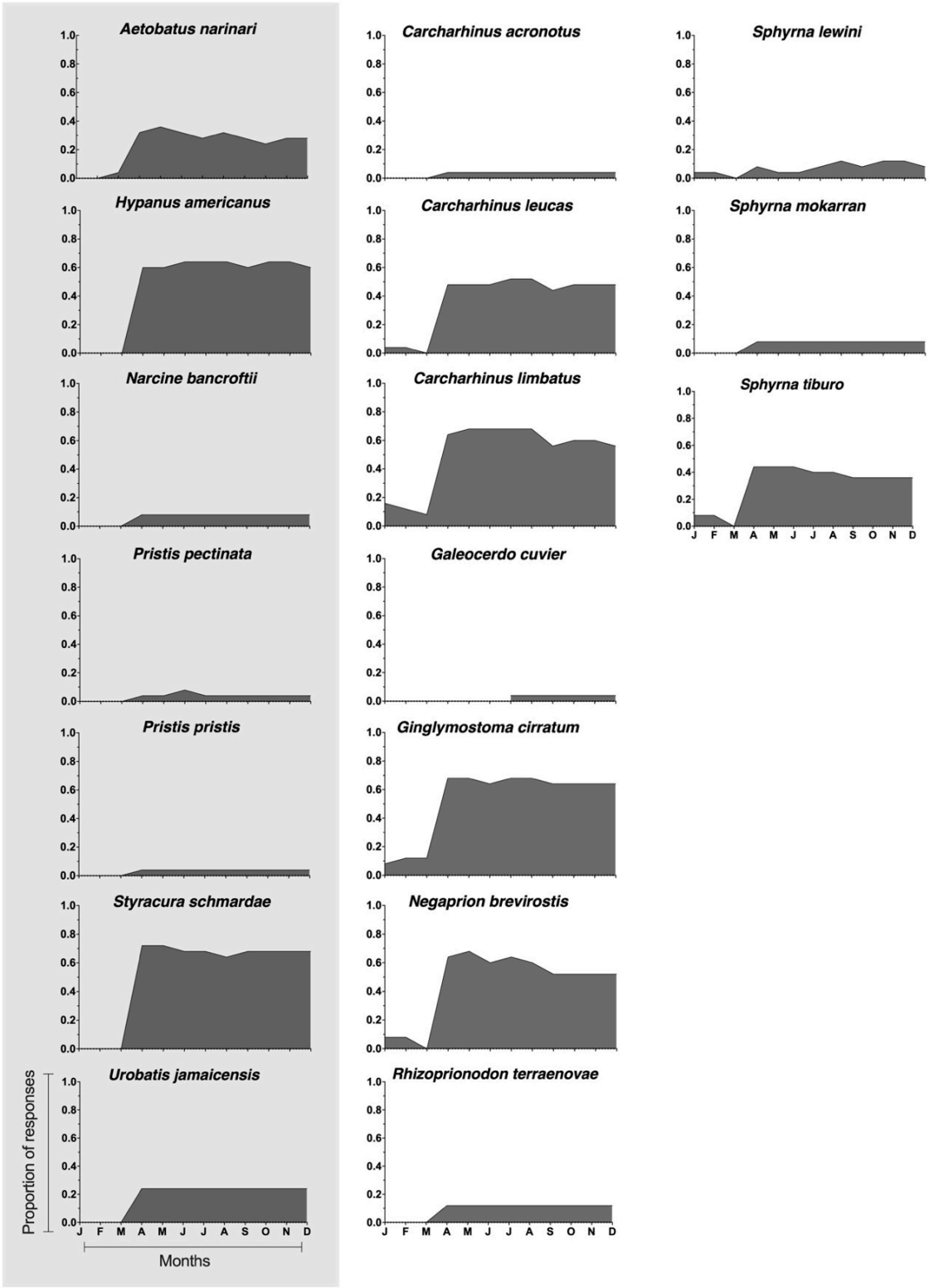


Figure 3

Permanence of early offspring of shark and ray species in the bay 30-50 years ago, according to fishers' knowledge (n=25),. Each panel corresponds to a different elasmobranch species, where gray-shaded panels correspond to ray species.

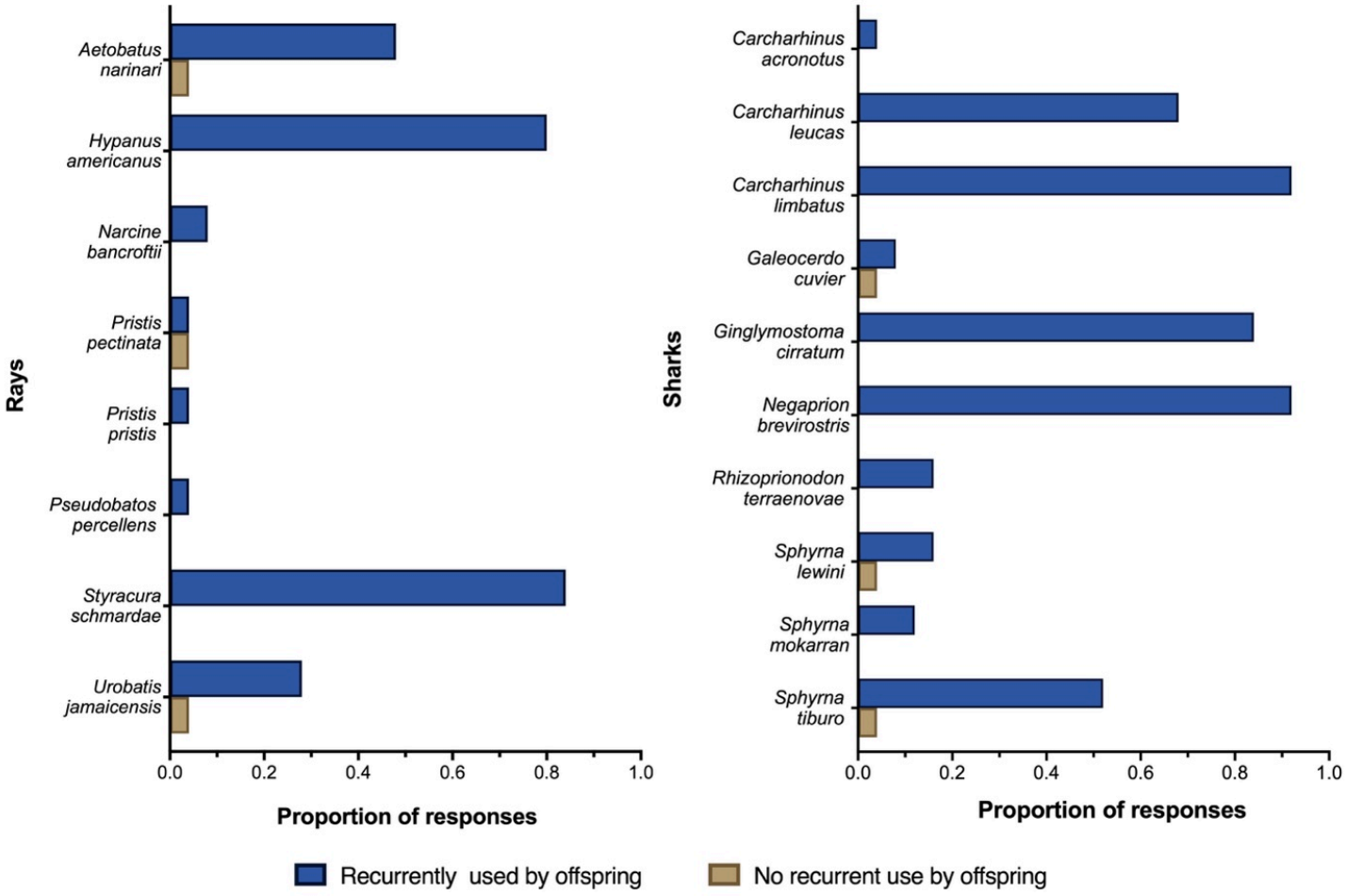


Figure 4

Proportion of responses (n=25) indicating recurrent use (year-after-year) and non-recurrent use of Bahía de la Ascensión 30-50 years ago by early offspring of batoid and shark species.

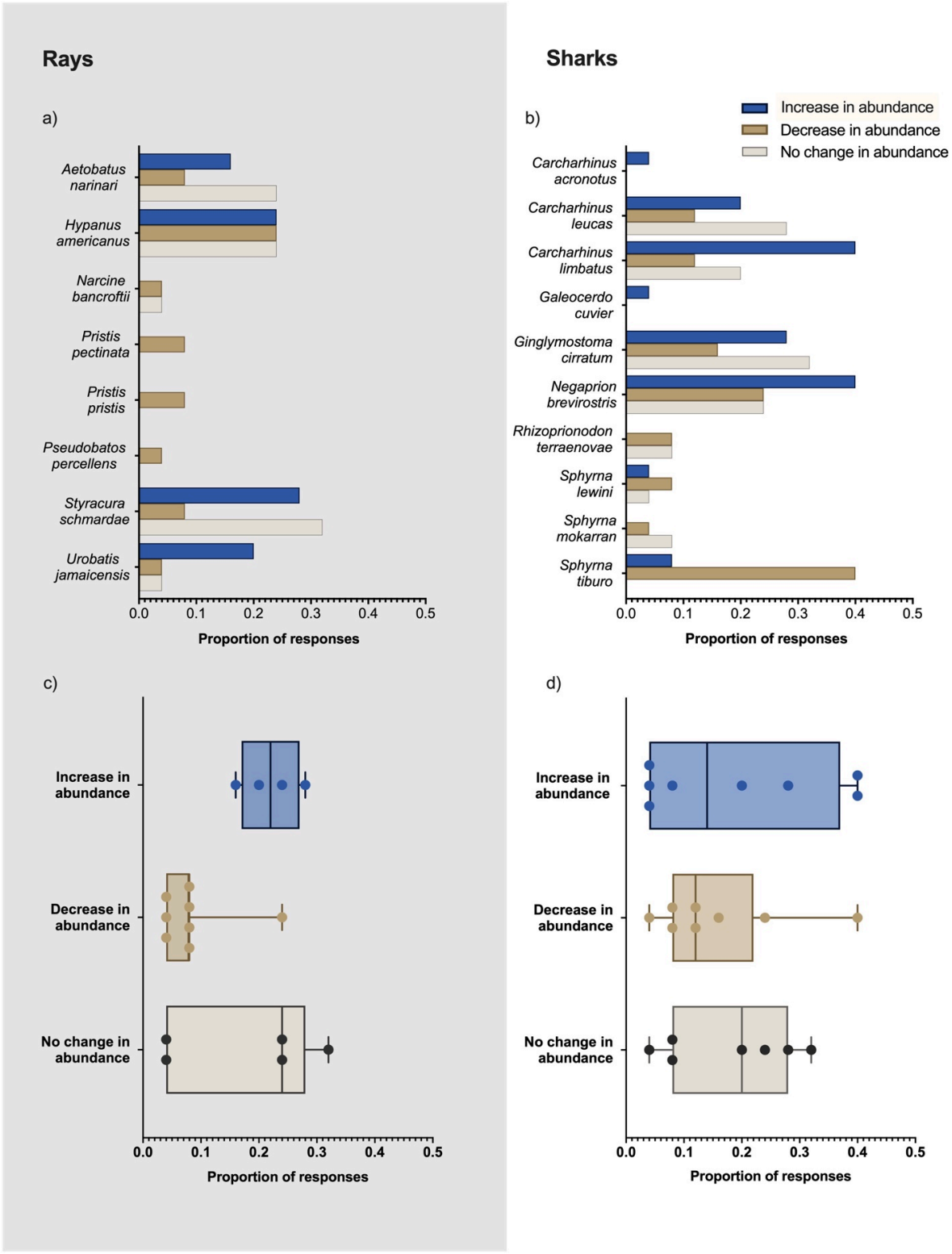


Figure 5

Proportion of fishers' responses (n=25) indicating changes in abundance of early offspring for ray (a) and shark (b) species, in Bahía de la Ascensión, between 30–50 years ago and the present.

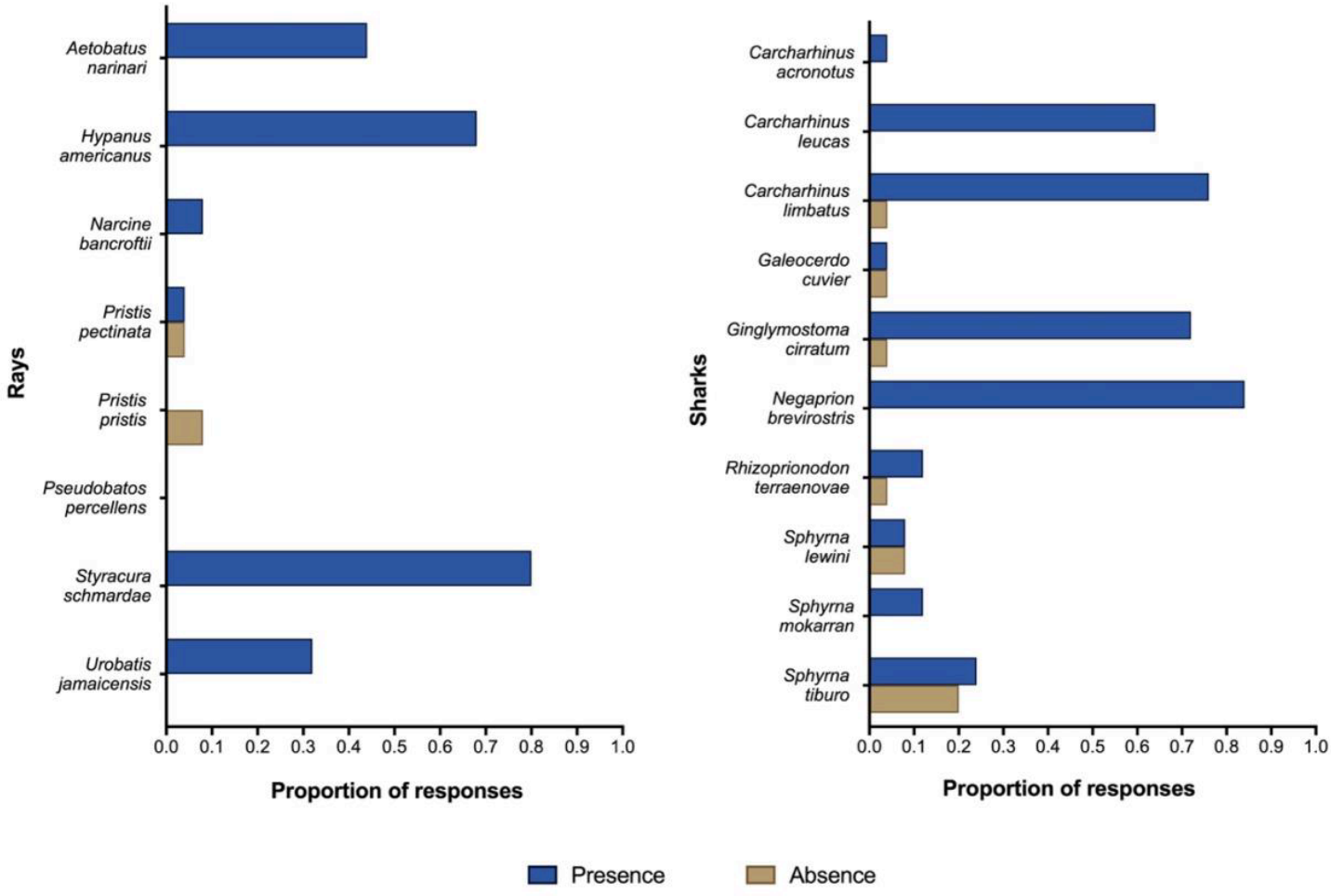


Figure 6

Proportion of fishers' responses (n=25) regarding current presence of early offspring of batoid and shark species in Bahía de la Ascensión