



# Distribution of the Critically Endangered Giant Guitarfish (*Glaucostegus typus*) based on Local Ecological Knowledge in the Andaman Islands, India.

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## ABSTRACT

For elusive, data-poor marine fauna, Local Ecological Knowledge (LEK) can be a rich and often underutilised source of biological and ecological data. We used a socio-ecological approach to assess LEK and provide key insights into the distribution, habitat use pattern, and threats facing giant guitarfishes (*Glaucostegus* spp.) in the Andaman Islands, India. We interviewed 175 fishers and other coastal users (SCUBA divers, coastal residents, researchers etc.), 142 of whom had seen giant guitarfishes. Due to the difficulty in distinguishing between species of this genus, this study did not attempt to collect species specific data. However, data presented here most likely refer to the Giant Guitarfish (*Glaucostegus typus*) as it is the only species from this family confirmed from the Andaman Islands. Our results show that LEK can be an invaluable asset in understanding the distribution of little-known species. With sightings from over 70 locations, our data indicate that giant guitarfishes occur widely and the frequent sightings of pup-sized (<45 cm) individuals in shallow coastal waters suggests they could be using these habitats as nursery grounds. The identification of several potential nursery areas highlights locations of their range that need urgent protection to aid in their conservation. The only other location where *G. typus* is reportedly still frequently observed is northern Australia, making the Andaman Island population globally significant. However, rapid coastal transformation and growing fisheries likely threaten the species. With more than 33% of reported observations being over a decade old, our data suggest that populations have drastically declined, highlighting the need to regulate fisheries and coastal development in the Andamans. Including giant guitarfishes under the Indian Wildlife Protection Act would also be an essential step towards managing this globally important population.

## 1. Introduction

A comprehensive understanding of the distribution and habitat use patterns of threatened marine species is key to designing and implementing effective conservation and management plans (Brooks et al., 2011; Simpfendorfer et al., 2010; White et al., 2013b). However, the sampling effort and funding required to collect such data on elusive, mobile and long-lived species can be substantial, making it especially difficult to conduct such studies in low-income countries (Simpfendorfer and Heupel, 2004; Johannes et al., 2000). But communities living in and around natural areas often have a wealth of knowledge about these places, born from frequent use and cultural transmission. Over the last two decades, this Local Ecological Knowledge (LEK) has become recognised as a vital tool in assessing and managing natural resources,

yielding data and trends comparable to conventional research methods (Azzurro, 2018; Garcia, 2005; Rochet et al., 2008). LEK has been used in a variety of contexts from assessing forest biodiversity, to conserving fisheries, evaluating threats, and providing baseline spatial and temporal data on marine species, especially in hard to access and data-poor areas (Braga et al., 2020; Charnley et al., 2007; Upreti et al., 2012; Moore et al., 2010; Valerio-Vargas and Espinoza, 2019). For example, the use of LEK has allowed the collection of spatial and ecological data on sawfishes (family Pristidae), from Papua New Guinea, Costa Rica and the United Arab Emirates, a family closely related to giant guitarfishes (Jabado et al., 2017; Leeney et al., 2018; Valerio-Vargas and Espinoza, 2019).

Giant guitarfishes belong to a monotypic family (Glaucostegidae) which includes seven species (Last et al., 2016; Habib and Islam, 2021).

Abbreviations: LEK, Local Ecological Knowledge.

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They inhabit shallow coastal and inshore waters of the eastern Atlantic and Indo-Pacific Oceans (Last et al., 2016; Habib and Islam, 2021). This selective habitat preference leaves these species susceptible to coastal development, habitat degradation and pollution and their distribution overlaps with some of the world's major fisheries (Kyne et al., 2020). This array of anthropogenic threats has led to drastic population declines being documented over a short period of time from regions of the world where data are available (Jabado, 2018; Kyne et al., 2020; Moore, 2017). Species specific landings data from Indian waters are scant, although data from the east coast indicate that landings of 'guitarfishes' (wedgfishes (family Rhinidae) and giant guitarfishes) declined by 86% between 2002 and 2006 (Mohanraj et al., 2009). Similar declines have been observed for giant guitarfish landings from Bangladesh, driven by the trade of their meat and fins (Haque and Spaet, 2021). In the Andaman Islands, fisheries have diversified and developed significantly in the last few decades with a variety of fishing vessels and gears being operated (Advani et al., 2013). Along with an increase in consumption of shark meat on mainland India, this has contributed to a steady increase in annual shark and ray landings (Pillai and Parakal 2000; Advani et al., 2013; D'Souza et al., 2013). While there are no data pertaining to giant guitarfish fisheries from the Andaman Islands, anecdotal information suggests that a targeted fisheries did exist in the past driven by the demand for their fins which were exported (Nazareth unpubl. data).

Due to their decreasing population trends, giant guitarfishes are one of the most threatened groups of marine taxa, with six species assessed as Critically Endangered by the International Union for the Conservation of Nature (IUCN) Red list of Threatened Species, and a newly described species yet to be assessed (Kyne et al., 2020; Habib and Islam, 2021; IUCN, 2021). They are also listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), which regulates international trade of their products to ensure they have been sourced legally and sustainably, however, this does not address domestic trade (Vincent et al., 2014; CITES, 2021). This is where national level regulation is required, but even though five species of giant guitarfishes (*Glaucostegus granulatus*, *G. obtusus*, *G. thoun*, *G. typus* and *G. younholei*) are reported to occur in the Bay of Bengal and Andaman Sea (Last et al., 2016; Habib and Islam, 2021), they are not protected under the Indian Wildlife (Protection) Act, 1972 (WLP) and their capture and trade remains unregulated in India (FAO, 2021a). Overall, across the Bay of Bengal region, Bangladesh is the only country that has enacted strict protection for this species group in September 2021 by adding them to its Wildlife (Conservation and Security) Act, 2012 (FAO, 2021b).

Until recently, giant guitarfishes have been the subject of considerable taxonomic uncertainty, with a new species being described in 2021, and morphological similarities between these species has led to frequent misidentification (Kyne et al., 2020; Habib and Islam, 2021). This has made them difficult to study at the species-level and as a result, they are biologically and ecologically poorly understood (Moore, 2017). Despite reports of several species of giant guitarfishes potentially occurring around the Andaman Islands (e.g., Last et al., 2016), only one species, the Giant Guitarfish (*G. typus*) has been confirmed based on morphological data collected during landing site surveys conducted between 2016 and 2019 and visual surveys conducted by the lead author across the islands (Bineesh et al., 2020; Tyabji et al., 2020; Nazareth unpubl. data). This highlights the potential data gaps pertaining to species diversity in the region. This lack of data has been a restricting factor in their conservation (Cerutti-Pereyra et al., 2014; Kyne et al., 2020; Last et al., 2016).

Giant guitarfishes are large, long-lived animals that give birth to live young and studies indicate they may use shallow coastal waters as nursery areas (Cerutti-Pereyra et al., 2014; Freeman, 2019; Gaskins et al., 2020; White et al., 2014a; White et al., 2014b; D'Alberto et al., 2019). These nurseries serve as the primary habitats for juveniles and facilitate their growth and survival (Heupel et al., 2019). For long-lived species such as giant guitarfishes, juvenile survival is critical to ensure

population growth (Frisk et al., 2001). As a result, the identification and protection of these habitats can be essential to their effective conservation (Heupel et al., 2007). For sharks and rays, nursery grounds have been defined as habitats or areas where (1) juvenile animals are more commonly encountered in an area compared to other areas, (2) areas where animals remain or return for extended periods of time, and (3) areas or habitats repeatedly utilised over multiple years (Heupel et al., 2007; Martins et al., 2018).

This study aimed to better understand the distribution and habitat use patterns of giant guitarfishes (*Glaucostegus* spp.) in the Andaman Islands and provide data that can inform conservation and management measures as well as promote research focusing on these species. LEK from coastal communities that frequently utilised the Andaman Islands coastline was used to collect vital data to help identify (i) areas where giant guitarfishes are most frequently observed, (ii) areas that could be functioning as potential nurseries for these species, (iii) if sighting frequencies have changed over time, and (iv) factors that may have influenced the distribution of these species.

## 2. Methods

### 2.1. Study area

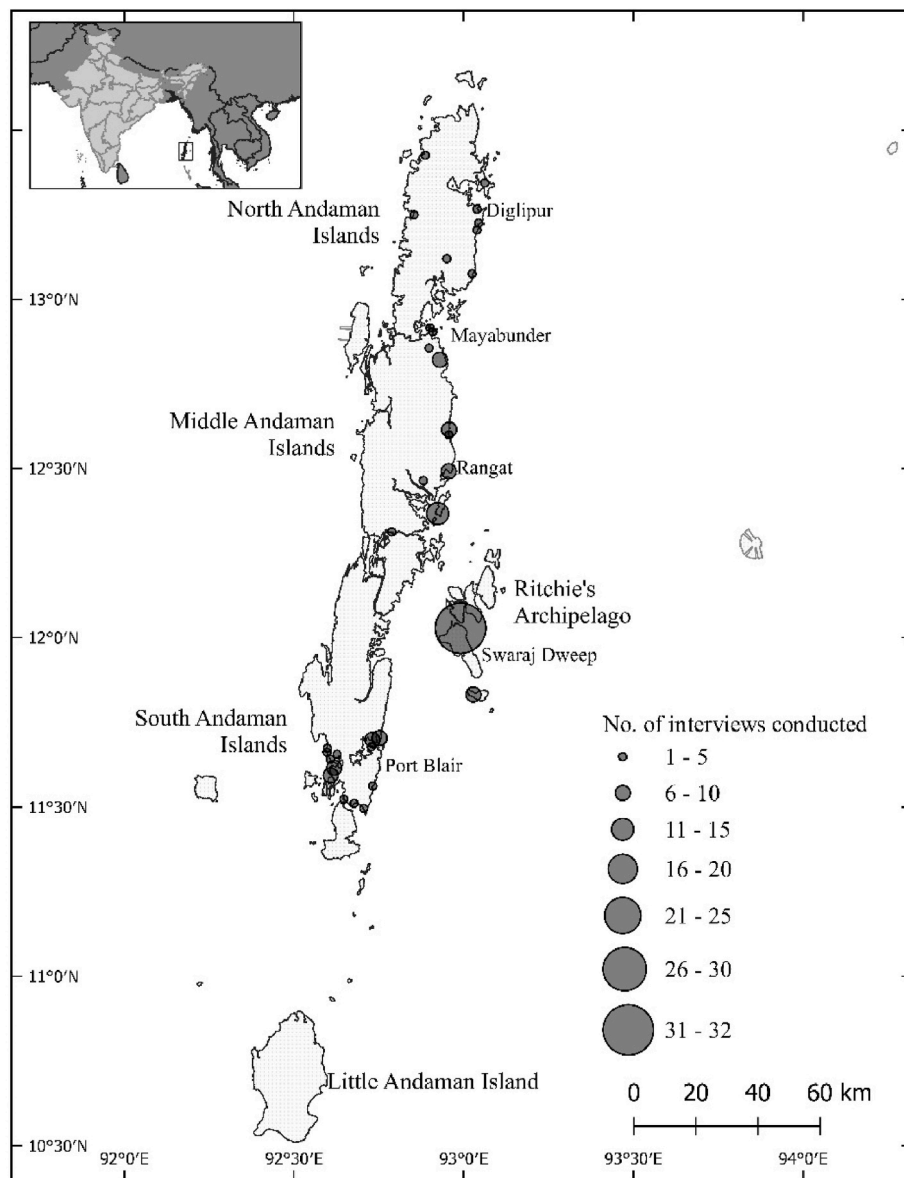
The Andaman and Nicobar Islands are an Indian archipelago, with over 1900 km of coastline and accounting for 28% of India's Exclusive Economic Zone (EEZ). Situated approximately 1360 km east of mainland India, these islands lie in the south-east Bay of Bengal and west of the Andaman Sea, between latitudes 10°30' and 13°41' N and longitudes 92°12' and 94°17' E (Fig. 1). They are part of the Indo-Myanmar and Sundaland biodiversity hotspot (Roberts et al., 2002). The entire island chain receives seven months of rain as a result of the south-west monsoon and the north-east monsoons which last from May to December (Patankar, 2019). In this study, we categorise seasons into dry (January to April) and wet (May to December).

The Andaman group of islands (hereafter referred to as 'the Andamans') comprises of over 325 islands, of which 21 are inhabited (Census of India 2011). While a majority of inhabitants are settlers from mainland India, the Andamans are also home to several indigenous communities (Andamanese, Jarawa, Nicobarese, Onge, and Sentinelese) (Sankaran et al., 2005). A large part of the west coast is occupied by the Jarawa Reserve, making it off limits to local communities and fishers (UNESCO 2010). However, local communities, including fishers actively visit and inhabit much of the Andamans east coast (Advani et al., 2013).

### 2.2. Interview surveys and analysis

#### 2.2.1. Site selection and sample size

Interview surveys were conducted with local community members to determine the distribution of giant guitarfishes (*Glaucostegus* spp.) and identify potential nursery sites based on respondent sightings. These surveys were conducted between September 2019 and June 2020 across seven inhabited islands which are home to approximately 94% of the Andamans total population (Census of India 2011). Interview locations were selected based on their accessibility and proximity to the coastline or a fishing community. To ensure a broad informant network, we chose individuals that worked or lived along the island's coastline (Fig. 1). Respondents were selected opportunistically, based on interactions with them at fishing jetties/landing sites, in coastal settlements, dive centres, forest department campsites, and research stations, as well as their willingness to participate in the survey. Respondents were categorised into fishers and other coastal users. Fishers were not further categorised based on gear or crafts operated, while the other coastal users were further categorised into scuba divers, coastal residents, forest guards (Andaman & Nicobar Forest Department staff employed to monitor and protect the Andamans' biodiversity), tourism/diver centre staff, researchers/local field assistants, and minor factions (Navy officers,



**Fig. 1.** Map of Andaman Islands, India, and its major settlements, indicating where interviews were conducted, and the number of interviews conducted at each location to collate Local Ecological Knowledge on giant guitarfishes (*Glaucostegus* spp.).

police officers, and a lifeguard). Interviews were conducted at each location, until no new respondents could be identified.

#### 2.2.2. Pre-interview consent and ethical clearance

Prior to conducting these surveys, the appropriate research permits were acquired from the Department of Environment and Forest, Port Blair and the survey protocol and questionnaire design was approved and granted an ethical clearance from the ethics committee at the Nature Conservation Foundation. No personal details were collected and all interviews were conducted one-on-one to avoid other participants from influencing the respondents replies.

All interviews were conducted by the lead author in Hindi or English. Interviews began with the interviewer introducing himself as a non-government researcher collecting data on fish and acquired informed consent before proceeding.

#### 2.2.3. Questionnaire design

The questionnaire included closed and open-ended questions,

designed to collect information on (i) the respondents' ability to accurately identify giant guitarfishes; (ii) location(s) where they had seen giant guitarfishes, size of animal(s) most frequently observed, time since last sighting, and sighting frequency at each location; (iii) the season, time of day, tide, and depth where giant guitarfishes were sighted; and (iv) if giant guitarfishes were fished at these location(s). Interviews ended with an open-ended question encouraging respondents to share any additional information they had pertaining to these species (Supplementary Material). Interviews lasted approximately five to 10 mins, but sometimes continued for longer.

#### 2.2.4. Respondents' ability to identify giant guitarfishes

Respondents were first shown an unlabelled colour illustration of a Giant Guitarfish (*G. typus*) and the visually similar Bottlenose Wedgefish (*Rhynchobatus australiae*) based on species known to occur locally (Bineesh et al., 2020; Tyabji et al., 2020; Last et al., 2016). The objective was not to determine the respondent's ability to identify individual species of giant guitarfishes, but rather assess their ability to identify the

family (Glaucostegidae) as a whole and distinguish them from morphologically similar families such as wedgefish (Rhinidae).

### 2.2.5. Sighting locations and frequency

Those respondents who could distinguish between the two families and had seen giant guitarfishes were asked to indicate sighting location (s) on forest division maps (DoEF, 2021) and provide a reference or landmark in order to triangulate the location.

Respondents were asked to estimate the size (total length in centimetres) of giant guitarfishes they had observed most frequently at each location. Size estimates were collected in relation to the interviewers' arm (fingertip to inner elbow) or leg (hip to heel), which measured approximately 45 cm and 100 cm, respectively. This approach proved to be practical and maintained a standardised basis of measurement throughout all interviews. These data were then categorised into three size classes: Small/pup-size (<45 cm total length), Medium (45–100 cm total length), and Large (>100 cm total length). The smallest size class was determined based on the size at birth and pup size of *G. typus*, since this is the only species for which these data are available (Last et al., 2016; Freeman, 2019).

Respondents were also asked to provide an estimate of the number of times they had seen giant guitarfishes at various location(s), the number of animals observed each time, as well as an approximate time since their last sighting of giant guitarfishes at each location they mentioned, which was classified into the following categories: < 1 week, 1 week to < 1 month, 1 month to < 1 year, 1 to < 5 years, 5 to < 10 years, and 10–25 years ago.

### 2.2.6. Factors influencing sightings and fishing pressure

Information was collected on the time of day (day or night), season (wet or dry), tide cycle (low or high), and depth (in meters) at which giant guitarfishes were seen, to determine if any of these factors influenced abundance and distribution patterns. Since fishers are often apprehensive about sharing catch data, fearing it could be used to justify the need for additional restrictions and regulations on their fishing practices (Moore et al., 2010), respondents were not asked if they fished or targeted giant guitarfishes. However, to assess the threat fishing practices may pose to giant guitarfishes, respondents were asked in general terms if they had observed the animals being fished (intentionally or accidentally) at these location(s) and if captured, if giant guitarfishes were consumed/sold or released.

### 2.2.7. Analysis

These data were organised using Microsoft Excel and pivot tables. They were explored to look at general trends in the information provided and coded into categories and groups that were consistent. Information pertaining to sighting locations was used to acquire the corresponding coordinates on Google Earth and these coordinates, along with related data, were transferred to QGIS 3.4 to create georeferenced locations on maps.

## 3. Results

### 3.1. Ability to identify giant guitarfishes

A total of 175 informants were interviewed at 33 locations across the Andaman Islands (Fig. 1). The number of fishers (n = 87) interviewed was almost equal to the number of other coastal users (n = 88) interviewed (Fig. 2).

In total, 87.4% (n = 153) of respondents could identify and distinguish giant guitarfishes from wedgefishes. This was primarily based on the colouration and lack of markings (spots) on the animals' body with 54.9% (n = 84) of respondents mentioning these as the main distinguishing features. Another 14.3% (n = 22) of respondents identified them based on morphological features such as body shape and fin shape, size, or position of dorsal fin on the body with respect to other fins.

Of the 153 respondents who could identify giant guitarfishes, 92.8% (n = 142) had seen one, while 7.2% (n = 11) had never seen one but had seen other species groups such as wedgefishes or had seen pictures of giant guitarfishes.

### 3.2. Sightings of giant guitarfishes

#### 3.2.1. Sighting location and frequency

Giant guitarfishes (*Glaucostegus* spp.) were seen by respondents at 70 locations across the Andamans (Fig. 3). The highest number of respondents (15.5%, n = 22) had observed giant guitarfishes at Swaraj Dweep in Ritchie's Archipelago (Fig. 3). Less than half of these individuals (40.9%; n = 9) reported having seen giant guitarfishes on a daily basis at Swaraj Dweep. In comparison, 100% (n = 10) of individuals who had observed giant guitarfishes at a remote island to the north of Diglipur, reported seeing them daily at this location (Fig. 3).

We did not conduct any interviews at Little Andaman Island due to the onset of COVID-19 and the resulting travel restrictions; however, eleven respondents from other islands reported observations of giant

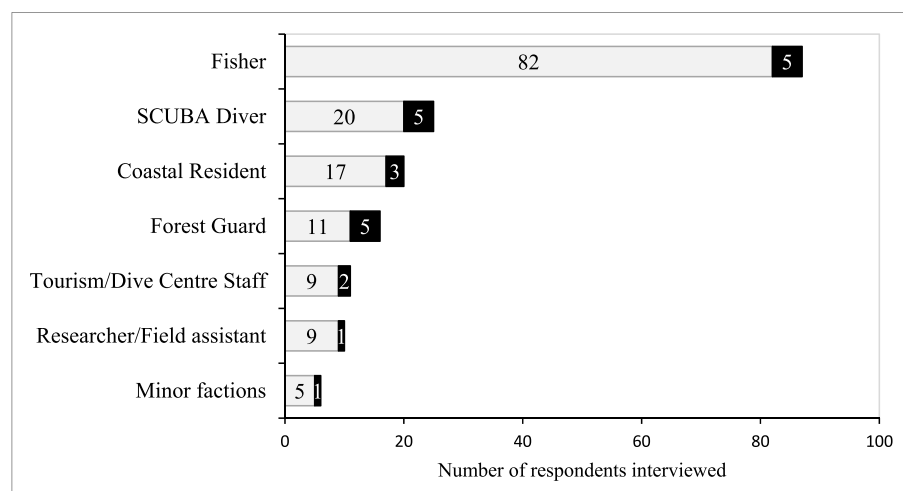
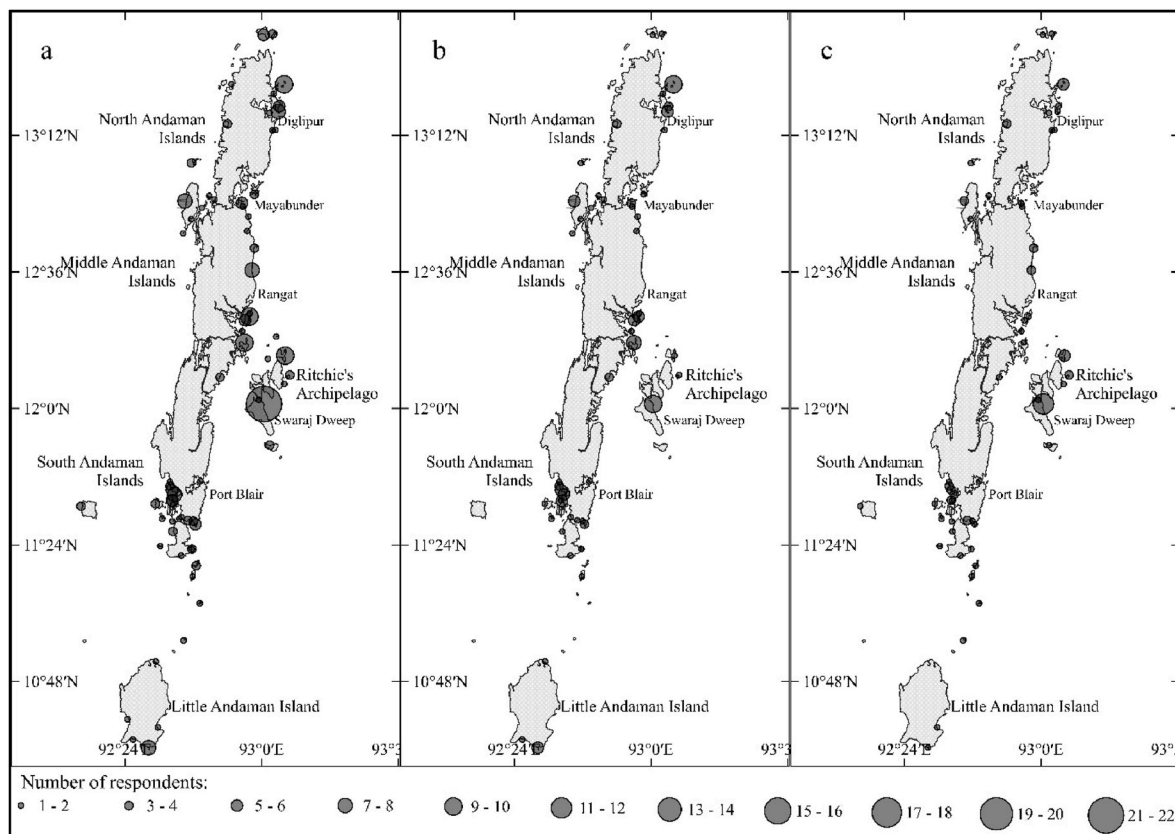


Fig. 2. Respondent demographics based on interview surveys conducted in the Andaman Islands showing the number of respondents from coastal communities that could (grey) and could not (black) identify giant guitarfishes (*Glaucostegus* spp.).



**Fig. 3.** The Andaman Islands with points indicating the locations where giant guitarfishes (*Glaucostegus* spp.) were observed and the size of the point indicating the number of respondents who (a) had seen giant guitarfishes, (b) had seen giant guitarfishes daily, and (c) reported giant guitarfishes being fished at the location.

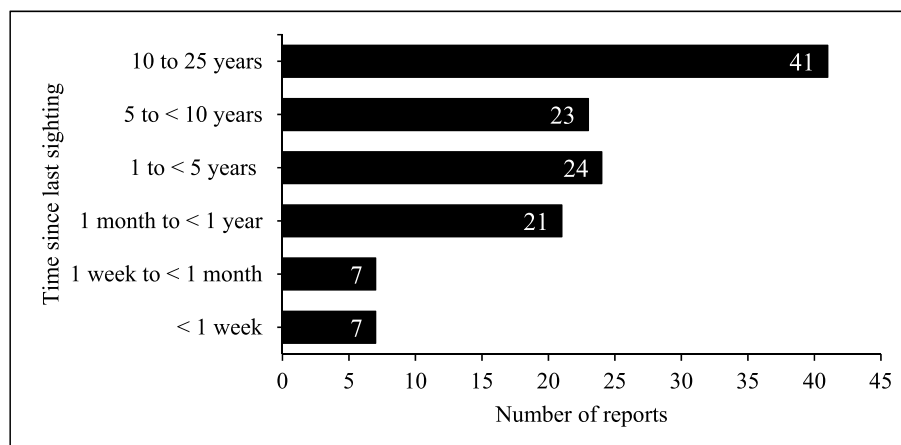
guitarfishes along the coastline of Little Andaman Island.

### 3.2.2. Size of animals observed

Small/pup-sized giant guitarfishes were the most frequently observed size class by 76.1% ( $n = 108$ ) of respondents. Almost all these sightings occurred along the shore and in shallow waters less than 1 m in depth, with only a few respondents (4.2%,  $n = 6$ ) observing small giant guitarfishes in waters greater than 5 m depth. Large giant guitarfishes were less frequently seen, with only 33.8% ( $n = 48$ ) of respondents having encountered one. Furthermore, the majority (75%,  $n = 36$ ) of those individuals who had observed large giant guitarfishes were fishers who either caught them intentionally or accidentally in waters ranging from 5 to 100 m depth.

### 3.2.3. Time since last sighting

Some respondents were unable to recall the time since their last giant guitarfish sighting, but 86 respondents could recall this information and provided data for 123 sightings (Fig. 4). These data indicate that 33.3% ( $n = 41$ ) of sightings were from 10 to 25 years ago, with sightings steadily declining for more recent observations: only 5.7% ( $n = 7$ ) of sightings were within a week of the interview surveys. Of the 22 respondents that had seen giant guitarfishes at Swaraj Dweep, only 36.4% ( $n = 8$ ) had seen one at this location within the last year. Four respondents who had observed giant guitarfishes along the coast of Swaraj Dweep said that they used to be common but were not seen anymore. Two of them had not seen giant guitarfishes in over 10 years, one fisher who frequently operated cast nets along the Andamans' coastline stated



**Fig. 4.** Time since respondents last sighting of giant guitarfishes (*Glaucostegus* spp.) from locations across the Andaman Islands based Local Ecological Knowledge.



that he used to see more small giant guitarfishes than any other fish in shallow waters but had not seen one in the last two to three years, and the fourth respondent last saw one animal a month prior to the surveys.

### 3.2.4. Diel and seasonal variations in sightings

Among those respondents who had seen giant guitarfishes ( $n = 142$ ), 52.8% ( $n = 75$ ) said they were unsure about or had not noticed any diurnal variation in sightings, 33.8% ( $n = 48$ ) stated they were more frequently seen during the day, 9.2% ( $n = 13$ ) said they were more frequently seen during the night, and 4.9% ( $n = 6$ ) said that animals were equally abundant during the day and night.

Respondents who had observed giant guitarfishes along the shoreline were asked if they had observed any changes in sighting frequency with respect to the tidal cycle. Since only 102 respondents had observed giant guitarfishes along the shore and all sightings were of small sized animals, these data are only available for the small size class. Among these respondents, 59.8% ( $n = 61$ ) said they were unsure about or had not noticed any variation in giant guitarfish sightings in relation to tidal variations, 30.4% ( $n = 31$ ) said they were more frequently seen during low tide, 5.9% ( $n = 6$ ) said they were equally common during high and low tides, and 3.9% ( $n = 4$ ) said they were more frequently sighted during high tide.

Most respondents (61.3%,  $n = 87$ ) were unable to provide any information regarding seasonal variation in giant guitarfish sightings. However, most of those that had observed a seasonal variation in sightings said that giant guitarfishes were observed more frequently during the wet season (May to December) (Fig. 5.).

### 3.3. Fishing pressure

When respondents were asked if giant guitarfishes are fished, 12.7% ( $n = 18$ ) said they were no longer captured but were captured in the past, and over 30.9% ( $n = 44$ ) said they were still caught by fishers across the Andamans. Among those who stated that giant guitarfishes were still captured ( $n = 44$ ), 72.7% ( $n = 32$ ) said that if captured they were consumed by the fisher or sold at local markets while 27.3% ( $n = 12$ ) said that if caught, they were released. Although the survey did not include questions regarding what influences fishers to retain or release captured giant guitarfishes, it appears that a perceived local ban has led some fishers to refrain from capturing or selling these species (Table 1).

### 3.4. Additional information provided by respondents

The main focus of this survey was to collect information on the distribution and habitat use patterns of giant guitarfishes in the Andamans, however, some respondents did share additional information they had pertaining to these species (Table 1).

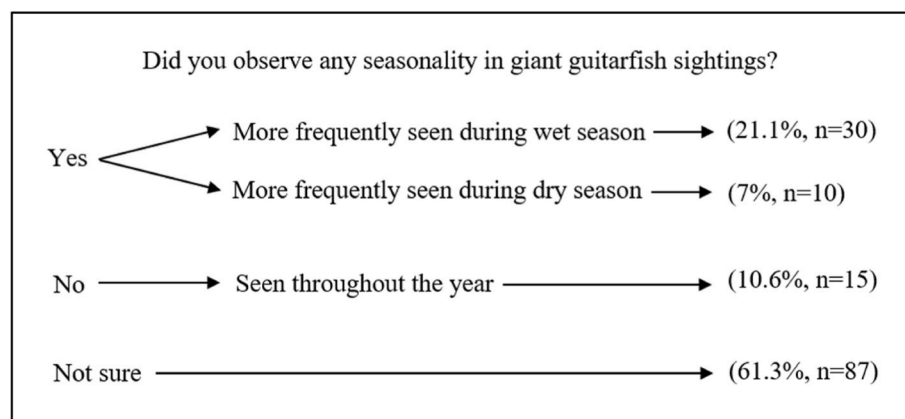
**Table 1**

Additional information on giant guitarfishes (*Glaucostegus* spp.) provided by respondents interviewed in the Andaman Islands. Comments provided below are paraphrased and not direct quotes from respondents.

Subject	Respondent category	Comment
Seasonality	Fisher ( $n = 1$ )	Pups are more abundant in coastal waters during the wet season, as that is the time when prawns are found in high numbers and giant guitarfishes come to feed on the prawns.
Seasonality	Fisher ( $n = 1$ )	Pups are drawn to shallow coastal waters during the wet season due to the cold rainwater that flows into the sea.
Reproduction	Fishers ( $n = 4$ )	Gravid females come close to shore and into shallow waters to give birth around the start of the wet season (May).
Reproduction	Fisher ( $n = 1$ )	Gravid females abort 10–15 pups after being captured and hauled onto the boat.
Fisheries	Fishers ( $n = 4$ )	They were targeted in the past but are not any more due to a local ban on capturing them. This is also the reason why they are released alive or discarded dead if captured.
Fisheries	Fishers ( $n = 3$ )	They were caught primarily for their fins which were sold for a high value.
Gear susceptibility	Fishers ( $n = 12$ )	They are more susceptible to being caught in gill nets and shore/beach seine nets.
Gear susceptibility	Fishers ( $n = 7$ )	They are more susceptible to being caught using hook and line.

## 4. Discussion

This study highlights the important role that LEK can play in providing data on occurrence and distribution of rare species in remote locations. While the identification of which species of giant guitarfish is found in the Andamans was not addressed in this study, the results very likely only refer to *G. typus*. This is based on extensive recent survey efforts at landing sites, coastal habitats, and Baited Remote Underwater Videos (BRUV) surveys that have only confirmed the occurrence of this species across the Andamans (Bineesh et al., 2020; Tyabji et al., 2020; Nazareth unpubl. data). Our data show that giant guitarfishes are widespread across the archipelago and likely represent a globally important population, with several potential nurseries located in shallow coastal waters. The only other location where Giant Guitarfish (*G. typus*) are still commonly seen is in northern Australia, where they mostly occur in shallow coastal habitats (Freeman, 2019; Gaskins et al., 2020; Kanno et al., 2019; Kyne et al., 2020; Vaudo and Heithaus, 2009, 2012; White et al., 2014b). Our data also suggest that Giant Guitarfish populations in the Andamans may be declining. Similar population declines have been documented across the range of giant guitarfishes except for locations in northern Australia where fisheries are regulated (White et al., 2013a), highlighting the susceptibility of these species to



**Fig. 5.** Assessing seasonal variations in giant guitarfish (*Glaucostegus* spp.) sighting across the Andaman Islands based on Local Ecological Knowledge.

rapidly developing coastal fisheries as well as habitat modification and degradation.

#### 4.1. Distribution and abundance

Data collected through the interview survey indicates that giant guitarfishes are widely distributed along the Andaman Islands' coastline and they may exhibit habitat partitioning with an ontogenetic shift in habitat use. Indeed, small individuals were most frequently and primarily encountered in shallow near shore waters, while larger individuals were primarily observed in deeper waters. Similar habitat preferences have been documented for *G. typus* and the Halavi Guitarfish (*G. halavi*) from nearshore waters in Australia and United Arab Emirates respectively (Whelan et al., 2017; Freeman, 2019; Gaskins et al., 2020; Vaudo and Heithaus, 2012, 2013; White et al., 2014b). The dorsoventrally flattened morphology of giant guitarfishes allows juveniles to enter very shallow waters which are inaccessible to larger marine predators such as Tiger Sharks (*Galeocerdo cuvier*), providing a refuge from predation that increases survival (Vaudo and Heithaus, 2012, 2013). However, it is important to note that these observations may also reflect ease of detection rather than natural abundance patterns. Indeed, it might be easier for respondents to encounter smaller individuals in shallow coastal waters and during daylight hours as this is likely the time when they are undertaking their water related activities or when these animals might be most 'visible'. Studies using acoustic telemetry in Australia found that *G. typus* were detected more frequently in near shore waters at night and during flood tides (Vaudo and Heithaus, 2012, Gaskins et al., 2020). A majority of respondents in this study had not observed any such diurnal trend and this is likely a reflection of the time in which they are undertaking their water related activities. Similarly, while a majority of respondents in our study were unsure about seasonal fluctuations in sightings of giant guitarfishes, this could be a result of not all respondents being able to visit sites on a frequent enough basis to notice a fluctuation in their numbers. Most respondents who did observe a variation in the seasonality of sightings stated that giant guitarfishes were more frequently seen during the wet season (May to December), with four respondents linking this higher abundance to gravid females entering shallow waters to give birth around the start of the wet season (May). This aligns with findings from studies conducted on *G. typus* in northern Australia, which found that females with mid-late embryos and mature males with sperm running returned to shallow coastal waters (White et al., 2014b). If similar diurnal and seasonal movement patterns are being exhibited by the giant guitarfishes in the Andamans, it could be one of the factors leading to a lack of sightings in certain locations where respondents only visit during the day or at a particular time of year which does not correspond with the time that giant guitarfishes are present and active. Additional periodic surveys at these sites are warranted to better understand these patterns in habitat use.

#### 4.2. Threats

Given the increase in number of people living on and traveling to the Andamans in the last few decades (Census of India, 2011; Ministry of Tourism, 2019; 2012; Sridhar et al., 2016), and in turn an increase in number of people using the coastline, we would expect an increase in the number of recent giant guitarfish sightings. However, our data suggests that the number of guitarfish sightings have declined in the last two decades, which is indicative of a declining giant guitarfish population. This is probably due to extensive coastal development and expanding fisheries that have accompanied the influx of people. The stretch of coastline at Swaraj Dweep where respondents had seen giant guitarfishes in the past is now a beachfront for resorts and an anchorage site for boats (pers. obs.). Given that giant guitarfishes are susceptible to coastal habitat modifications and degradation (Kyne et al., 2020), such anthropogenic disturbances could have led to these coastal habitats becoming unsuitable for giant guitarfish pups. This is further supported

by the fact that giant guitarfishes were still frequently observed at remote islands such as those to the north of Diglipur, which were less influenced by anthropogenic activities. With the Indian governments' plans to further develop inhabited islands and open some uninhabited ones to the tourism sector (Kumar et al., 2019), it is likely going to affect many more coastal habitats that giant guitarfishes and other marine species depend on. This highlights the need to identify critical habitats that giant guitarfishes depend on before they are impacted by coastal development activities and ensure that coastal management plans are developed, and actions are taken to reduce the impact of development projects at important locations.

While there are no long-term data on giant guitarfish landings from the Andamans, fishers have observed an overall decline in shark and ray abundance (Advani et al., 2013). This perceived decline, accompanied with a steady increase in the Andamans' annual fish landings (Kiruba-Sankar et al., 2021), and the declines observed from adjacent waters, indicates the susceptibility of these species to fishing activities. Given that the Ministry of Fisheries aims to further develop the fisheries sector and its output, this growth, if not regulated and managed in a sustainable manner, could lead to further declines in giant guitarfish populations, similar to those documented from the east coast of India and neighbouring countries (Directorate General of Capture Fisheries DGCF, 2015; 2017; Kyne et al., 2020; Mohanraj et al., 2009; Haque and Spaet, 2021). While this study did not focus on evaluating the impact of fisheries on giant guitarfishes, studies from Bangladesh and the United Arab Emirates have highlighted the impact that artisanal fisheries can have on these species (Jabado et al., 2014; Haque et al., 2021). Given that artisanal fisheries are the most prominent form of fisheries in the Andamans (Advani et al., 2013), they represent a significant threat to giant guitarfish. Even if not targeted, bycatch mortality is likely to impact the population. Our study does not allow us to determine the rate of decline and further research into fishing pressure and catch trends of the Andaman's artisanal fisheries is needed to better understand the impact that they may have on giant guitarfishes. To reduce the likely impact of these fisheries, it may be beneficial to conduct awareness programmes with artisanal fishers to ensure they understand the importance of releasing these animals alive if captured (Squires et al., 2018; Gupta et al., 2020), especially in the case of giant guitarfish pups which may be too small to provide a substantial source of protein (i.e., very little meat on the body).

While no species of giant guitarfishes are listed on the WLPA, the morphologically similar Whitespotted Wedgefish (*Rhynchobatus djiddensis*) is listed under Schedule I of this Act, despite not occurring in Indian waters (Last et al., 2016; Tyabji et al., 2020). Government bodies in the Andamans commonly confuse these two families, leading to giant guitarfishes being included in posters and awareness campaigns in relation to protected species. As a result, the landings and trade of giant guitarfishes in the Andamans are *de facto* restricted, even though they remain officially unlisted on the WLPA. These perceived restrictions could have deterred fishers from sharing information on the true extent of current giant guitarfish fisheries interactions. As a result, it is possible that fisheries pose a greater threat to the species than highlighted here. Despite this, 30.9% (n = 44) of respondents stated that giant guitarfishes are still captured and other studies have also recorded *G. typus* landings (Bineesh et al., 2020; Tyabji et al., 2020). This suggests that even the perceived ban is likely not being adequately enforced or monitored. To support the long-term conservation of threatened species such as giant guitarfishes, the WLPA needs to be updated to include species found in Andaman and Nicobar waters, and these regulations need to be more carefully implemented.

While enforced bans on giant guitarfish fisheries may inhibit targeted fisheries, if they still exist, they may not affect bycatch (Collins et al., 2020). To effectively reduce giant guitarfish bycatch from an expanding fishery, it is critical to identify location and seasons or time periods that are vital to the species and their susceptibility to specific gear so that spatio-temporal, gear or catch restrictions can be imposed

(White et al., 2013a; Heupel et al., 2019). In the Andamans, young giant guitarfish were frequently observed in shallow coastal habitats during the monsoons (May to December), which was likely their potential breeding season; restricting fishing at these locations and times could help reduce the impact of fisheries on these stocks.

#### 4.3. Potential nurseries

Our results have helped identify several coastal areas where pup-sized individuals are observed more frequently than larger individuals and where they have been observed across multiple years. These results satisfy two of the three criteria required to classify these areas as ray nurseries (Martins et al., 2018). Indeed, since the identification of species and individual animals was not possible, we cannot confirm site fidelity of juveniles to these habitats. To identify which of these sites may be functioning as nurseries would require dedicated surveys to confirm the species of giant guitarfish at these sites, understand their fine scale movements, dependence of juvenile giant guitarfish on these habitats and the role the habitats play in their life history (Martins et al., 2018). However, given how critical nursery sites are to long-lived species such as giant guitarfishes (Frisk et al., 2001), the locations identified here should be demarcated as priority areas for conservation until further studies can confirm their use as nurseries. Therefore, the protection of nurseries would be a step towards protecting giant guitarfishes and aiding in recovery from population declines, provided they are adequately managed. Studies have also provided evidence that species such as *G. typus* exhibit strong philopatry, returning to the same site each year at around the same time (Vaudo and Heithaus, 2012; White et al., 2014b). This further highlights the importance of particular coastal habitats to local populations of giant guitarfish.

#### 4.4. Conservation implications

The results of this study can help guide conservation actions and coastal management plans to conserve giant guitarfishes and the habitats they depend on. Focused conservation efforts such as setting up national parks, marine protected areas, and regulating fishing practices have proven effective in protecting Smalltooth Sawfish (*Pristis pectinata*) along the coast of southern Florida, while the species has been depleted from adjacent unprotected areas (Simpfendorfer et al., 2010). The Smalltooth Sawfish has a similar rate of productivity as giant guitarfish such as *G. typus* (D'Alberty et al., 2019), indicating that these conservation measures could also prove effective in recovering and maintaining healthy giant guitarfish populations. A system of marine protected areas and fisheries regulations in northern Australia have proven effective at protecting *G. typus* in the region, and as a result, the region is considered as a 'lifeboat' for these species (Kyne et al., 2020). Our data suggest that if immediate and appropriate conservation actions are implemented, the Andamans have the potential of being an additional safe refuge for giant guitarfishes.

While shark and ray conservation in India is still in its infancy, other marine fauna such as sea turtles (five species) are protected under Schedule I of the WLPA and measures have been put in place to protect them and associated critical habitats (Sridhar et al., 2016). These efforts include a ban on the hunting of sea turtles and trade in their products, fisheries regulations with respect to nesting and breeding seasons, protection of nesting beaches, designation of protected areas based on the species' breeding and nesting grounds, and conducting workshops and awareness programmes with local communities (Jeyabaskaran and Kripa, 2018). Similar efforts could also help protect giant guitarfishes and their nursery grounds if implemented to the same extent.

#### 4.5. Caveats of this study

The rigorousness of data collected through LEK is dependent on respondents having actually encountered the species being studied,

correctly identifying them, recalling trends in sightings, and accurately reporting these details (Azzurro, 2018). The reliability of data collected is also dependent on the accessibility of all potential survey sites and the frequency with which they are visited by informants. Developed and densely populated islands would likely lead to more respondent-giant guitarfish encounters as well as respondent-interviewer interactions, and would result in more data being collected from such locations. This is evident when looking at the data from the present study, as Swaraj Dweep is a developed island with a diverse population, and as a result more interviews were conducted here leading to it being over-represented in the data. On the other hand, a major portion of the Andaman Islands' west coast falls under the Jarawa tribal reserve and is inaccessible to the public, resulting in this stretch of the coastline and adjacent waters remaining unexplored and a data deficient region. Therefore, although there are currently no data available, we recognise that giant guitarfish distribution may be even more widespread than our data indicate and that these locations might also be important habitats for these species.

Accurate species identification is also crucial in producing reliable LEK and due to the difficulty associated with identifying individual giant guitarfish species, we focused on the family Glaucostegidae as a whole. However, based on recent studies from the islands, and first-hand observations by the lead author, it appears that *G. typus* is potentially the only giant guitarfish species occurring in the islands (Bineesh et al., 2020; Tyabji et al., 2020; Nazareth unpubl. data.). Hence, it is likely that most if not all the observations recorded in this study are of *G. typus*. This highlights the importance of corroborating data collected through LEK with those acquired through scientific methods (McKelvey et al., 2008). However, it cannot be discounted that historic reports might include other species of giant guitarfishes that may have occurred in these waters but have since gone locally extinct.

Finally, while the interview surveys proved to be an effective method of accessing the rich source of LEK, we recognise that we did not collect data on the amount of time respondents spent working/living along the coast, how frequently they visited various locations, and specific to fishers, there were no questions regarding types of gear or crafts operated. These factors could have influenced the probability and frequency of respondent-giant guitarfish encounters. This could lead to locations that are frequently visited by respondents being overrepresented in our data while locations which are remote and less frequently visited by respondents being under represented in our data.

#### 4.6. Conclusion

The Andaman Islands could potentially be a globally important conservation hotspot for giant guitarfishes if immediate conservation and management plans are implemented. Our results help identify the importance of coastal waters as key habitats for these species, especially during the initial stages in their life. However, our results indicate a recent decline in giant guitarfish sightings, which will need to be urgently addressed if the Andamans are to be designated as a hotspot for giant guitarfishes. Protection measures should focus first on securing potential nursery locations and sites where giant guitarfish numbers are highest. Further studies should focus on validating the nursery role of sites identified in this study, and on evaluating the impacts of coastal development on these habitats. However, as highlighted by Kinney and Simpfendorfer (2009), the designation and protection of nurseries alone may not be enough to protect a species and therefore future studies should also aim towards better understanding the habitat requirements of other life stages and how to better conserve them.

At a larger scale, management of shark and ray fisheries and a clarification of the legal status of giant guitarfishes will be crucial to ensure conservation measures can be developed and implemented. One key thing to note is that the active participation and involvement of stakeholders in the development and implementation of management and conservation efforts can play a major role in the long-term success of



such initiatives (Charnley et al., 2007; Giaretta et al., 2021). Projects that incorporate LEK into their study, acknowledge the importance of perceptions and observation made by local communities, and in doing so help integrate these communities with scientific processes, could lead to more socially acceptable management and conservation efforts (Wendt and Starr, 2009).

### Declaration of competing interest

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.

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### Appendix A. Supplementary data

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