SOSF Final Project Report

Small Grant SOSF 623

2023-2024

9953.84 (USD)

Strum with care: understanding fisheries impacts on threatened guitarfish in India to inform their conservation

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2023-2024

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InSeason Fish

Content

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Executive summary

Giant guitarfish are primarily found in tropical nearshore waters where they are highly vulnerable to overexploitation by coastal fisheries. The widenose guitarfish (*Glaucostegus obtusus*) is a Critically Endangered species, protected under CITES (Schedule II) and under Schedule I of India's Wildlife Protection Act (WPA) - yet, this species is exceptionally understudied. In the state of Goa, India, *G. obtusus* is found in shallow coastal waters, in spaces overlapping with fishing, tourism and other disturbances. Juveniles and pups are occasionally caught in small-scale fisheries, suggesting the presence of nursery grounds on Goa's coast. Identifying nursery grounds and understanding how these habitats overlap and interact with fisheries is a crucial step for conservation. Fine-scale data on guitarfish habitats can guide avoidance strategies and mitigation measures in the local small-scale fisheries.

This project aimed to identify critical habitats of guitarfish and understand the impacts of fisheries on their populations to develop locally-appropriate conservation solutions. We focused on three sites in Canacona, South Goa, collecting data on guitarfish abundance and demographics in nearshore waters, along with interactions and overlaps with fisheries, through mixed methods including walking surveys, fisheries monitoring and social surveys. In addition, we conducted outreach with fishing communities to raise awareness about guitarfish and promote live release as a conservation measure.

Our analysis estimated that around 539 juvenile widenose guitarfish are likely found in Canacona waters, which is the first abundance estimate for these Critically Endangered species in an Indian site. We explored the variation of guitarfish abundance across sites, seasons and with environmental factors, finding the highest guitarfish numbers in Galgibag, and in the month of November. Guitarfish habitats showed significant overlap with nearshore fishing grounds, but catch rates of this species in the local artisanal nets were relatively low. Galgibag emerged as a potential nursery ground for widenose guitarfish, with pupping likely occurring in December. The walking survey method we used proved to be simple, low-cost and effective for monitoring guitarfish abundance and habitat use, providing a feasible model for research in other developing countries.

Outreach activities with fishing communities appeared to perform well, and laid the groundwork for community engagement and live release conservation initiatives. Protecting critical habitats like Galgibag through spatio-temporal regulations may be essential to mitigate the impacts of fisheries as well as other threats like coastal development and tourism. Through our work, Galgibag beach has being identified as an Important Shark and Ray Area (ISRA). This ISRA notification can be a valuable tool in guiding the sustainable development, tourism and fisheries management in this region.

Future research efforts will focus on confirming nursery grounds, better understanding habitat use, and spatially expanding the study across India's coastline. We also aim to develop a robust monitoring network involving local stakeholders, including fishing communities, the state fisheries and forest departments. Live release programmes can be implemented through long-term community engagement, provision of appropriate training, and non-economic incentives for successful guitarfish conservation.

Summary of main research results/outcomes

This project aimed to identify critical habitats of widenose guitarfish and understand the impacts of fisheries on their populations, to develop conservation solutions. We conducted the first abundance estimate for these Critically Endangered species in an Indian site, forming a benchmark for long-term monitoring in Canacona, South Goa. Galgibag emerged as a potential nursery ground for widenose guitarfish, with pupping likely occurring in December. Guitarfish habitats showed significant overlap with nearshore fishing grounds, but catch rates in the local artisanal nets were relatively low. Live release initiatives showed promise as a conservation measure, with our outreach activities having some success in promoting live release. Identification of Galgibag as an Important Shark and Ray Area (ISRA) can be a valuable tool in guiding the sustainable development, tourism and fisheries management in this region. Our work laid the foundation for a long-term research, monitoring and conservation project for guitarfish in Goa and beyond.

Introduction

Globally, coastal habitats are facing increasing threat from human activities such as nearshore fisheries, infrastructure development, tourism and pollution, putting coastal biodiversity at significant risk of extinction (Bulleri & Chapman, 2010; Halpern et al., 2008). Giant guitarfishes (*Glaucostegus sp*.), a family of shark-like rays, are primarily found in tropical nearshore waters where they are highly vulnerable to coastal pressures. All species in this family are classified as Critically Endangered, due to severe population declines in recent decades through overexploitation (Kyne et al., 2020). Like other elasmobranchs, guitarfish utilize nearshore coastal waters and shallow bays as nursery grounds—habitats that provide pups or juveniles with essential food resources and shelter from predators (Heupel et al., 2007). Identifying nursery grounds and understanding how guitarfish use these habitats are pivotal steps in developing conservation measures (Gaskins et al., 2020).

Indian waters host a high diversity of elasmobranch species, including at least 5 *Glaucostegus* species (Akhilesh et al., 2014). With India being among the top fishing countries globally, elasmobranchs are especially threatened in this region (Dulvy et al., 2017; Jabado et al., 2018). Trade in all guitarfish species is regulated under the Convention on International Trade in Endangered Species (CITES Schedule II; CITES 2024). Furthermore, few species including the widenose guitarfish (*Glaucostegus obtusus*) have recently been listed under Schedule I of India's Wildlife Protection Act (WPA Amendment 2022; Parliament of India, 2022), which prohibits their fishing and trade, although this policy is yet to be implemented in most parts of the country. Despite these policies, guitarfish remain poorly studied and monitored in India, with little to no information on their populations, use of nursery grounds, and interaction with fisheries. In Goa, a state on the west coast, widenose guitarfish are known to aggregate in shallow coastal waters, in spaces overlapping with fishing, tourism and other disturbances (Figure 1; Gupta et al., 2023). Juveniles and pups are caught as incidental catch in small-scale fisheries, suggesting the presence of nursery grounds on Goa's coast. Characterising nursery grounds and collecting fine-scale data on guitarfish populations and their use of these habitats can guide avoidance strategies by small-scale fisheries.

Alongside area-based strategies, live release has been proposed as a bycatch mitigation measure for guitarfish (Gupta et al., 2020; Wosnick et al., 2022). Fishers in Goa have exhibited positive attitudes towards guitarfish conservation through live release, indicating that this may be a promising conservation strategy (Gupta et al., 2023). For live release to be successful, it is crucial that these strategies are developed with the participation of local stakeholders to ensure compliance and minimal impact on local livelihoods. Furthermore, survival rate of these individuals after capture and release remains unknown; this needs to be assessed to investigate the effectiveness of live release in conserving guitarfish populations. Therefore, investigating guitarfish habitat use and interaction with fisheries can inform the development of practical conservation plans for these species, to aid in the on-ground implementation of India's wildlife policies.

Figure 1: Widenose guitarfish at the study site (left), and a juvenile at the wave line swimming back into the water (right). Photos by Udayan Rao Pawar.

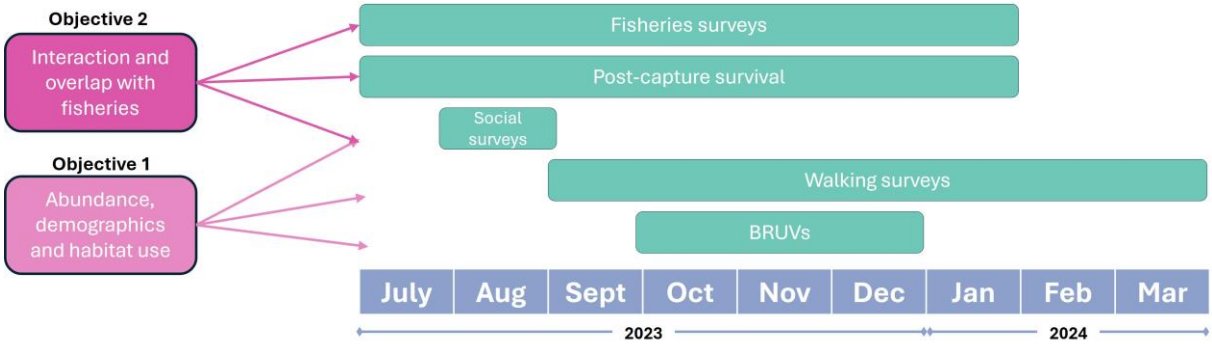

Figure 2: The main research objectives and the methods used across the project duration.

General aim

The broader aim of our project was to identify critical habitats of guitarfish and understand the impacts of fisheries on their populations, to develop locally-appropriate conservation solutions.

Our main research objectives were (Figure 2):

1. Abundance, demographics and habitat use:
    a. Assess the abundance of guitarfish in nearshore waters

   b. Understand biology and population demographics (sex ratio, size and maturity stages) in nearshore waters
   c. Understand patterns of habitat use and hence identify nearshore critical habitats such as nursery grounds
2. Interaction and overlap with fisheries:
   a. Monitor catch of guitarfish in nearshore fisheries
   b. Assess post-capture stress and survival in order to explore live release as a potential conservation strategy.
   c. Map the overlap of nearshore critical habitats of guitarfish with nearshore fishing grounds
3. Low-cost methodology: develop a feasible, simple and low-cost method to monitor guitarfish populations that can be applied in other data- and resource-limited contexts.

Our main conservation, outreach and long-terms objectives were:

4. Outreach for live release: raise awareness about guitarfish with the local fishing communities to promote live release.
5. Baseline for guitarfish: to initiate a long-term research, monitoring and conservation project on guitarfish in this region

Methods

Study sites:

The primary sites for this study were Galgibag, Rajbag and Palolem beaches in the Canacona *taluka* (sub-district) in South Goa (Figure 3). Guitarfish presence in these beaches has been confirmed by Local Ecological Knowledge (LEK; Gupta et al., 2023) as well as by pilot surveys (in Galgibag). These three sites were also chosen for our study due to their variation in biophysical characteristics, fishing activity and tourism levels (Table 1). Galgibag beach, in particular, is a marine turtle nesting site (olive ridley turtles *Lepidochelys olivacea,* Sea Turtles of India, 2017) and hence has limited tourism and fishing activities. This beach has also been identified as having particularly high presence of guitarfish (Gupta et al., 2023). Hence, our 3 study sites enabled us to explore guitarfish presence across these different conditions.

Most fishing activity across our study sites is undertaken by small-scale fisheries such as gillnets, shore seines, cast nets, stake nets and other forms of traditional fishing, with 422 motorised and non-motorised fishing vessels registered in Canacona (CMFRI-DoF, 2020). Guitarfish are known to be bycaught in all these forms of fishing, particularly in gillnets (Gupta et al., 2023). Aside from fishing, coastal tourism is a major activity and source of income in this region. October to May forms the main tourist season. While fishing occurs year-round, June to September, being the monsoon and off-season for tourism, is the main season for small-scale fishers.

In addition to these three sites, abundance surveys were also conducted in 7 other sites Canacona (Figure 3) to estimate total abundance of juvenile guitarfish in this region.

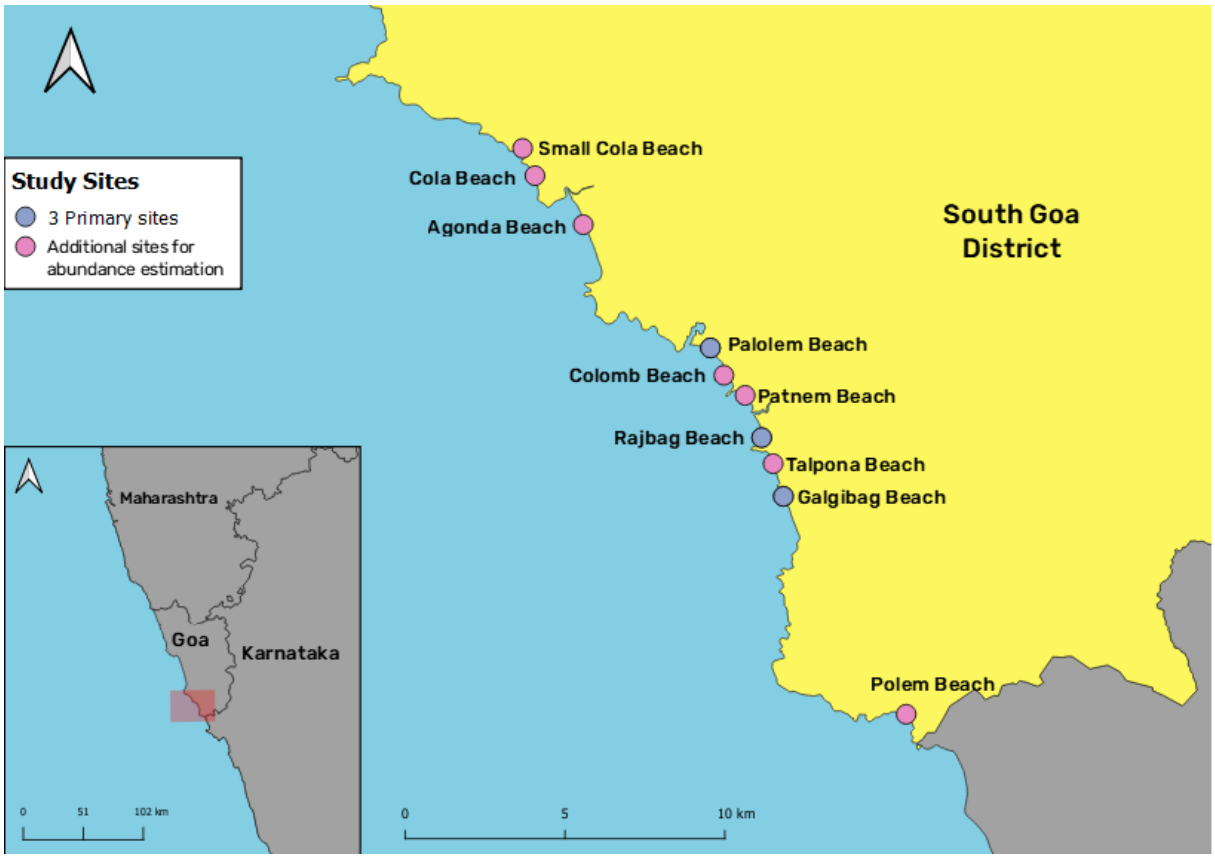

Figure 3: The study sites in South Goa, 3 primary study sites (Palolem, Rajbag and Galgibag) shown in purple and the additional sites surveyed for abundance estimation shown in pink.

Table 1: Description of the three primary study sites. Fishing activity and tourism levels were qualitatively categorised based on literature, field observations and discussions with local key informants.

	Palolem	Rajbag	Galgibag
Beach length (m)	1400	1000	1600
Artisanal fishing activity	High	Low	Medium/Low
Tourism	High	Medium	Low
Physical characteristics	Sheltered bay, relatively calm waters. Bound by a small creek in the north end	Bound by the Talpona river in the south	Relatively rough water and waves Bound by the Galgibag river in the south
Notes			Marine turtle nesting beach

Data collection

We used an interdisciplinary, mixed methods approach to collect data, which was useful given the extremely data-limited context of the study area. Pilot surveys were conducted over June and July, with most data collection starting in August 2023. Fieldwork continued till March 2024, with outreach and dissemination occurring in January 2024 (Figure 2).

a. Social surveys

Semi-structured interviews were conducted with key informants (defined here as experienced and knowledgeable fishers, community leaders or local lifeguards) at the study sites. These interviews helped further assimilate local knowledge on guitarfish, and identify potential critical habitats, times of the day and seasons to guide the design of our ecological surveys. We also conducted a preliminary mapping exercise with these key informants to map nearshore fishing grounds and activities at the study sites, in order to understand overlap of the same with guitarfish habitats. These interviews were completed over August 2023, the questionnaire can be found in Appendix 1.

b. Fisheries surveys

Surveys of catch of small-scale fisheries for guitarfish was carried out from July 2023 till January 2024. Our initial aim was to survey catch across different gear types (gillnets, shore seines and other artisanal gear). However, this proved to be challenging as timings and frequency of gillnetters was highly variable, with informal landings spread across the beach and at different times of the day. Hence, catch monitoring was limited to shore seine fisheries, as these operated in the nearshore shallow zone where juvenile guitarfish appear to aggregate, and where our other data collection methods such as walking transects were also focused.

Sampling initially occurred 3 times a week (distributed across the sites), where one or more of the operating shore seine nets on that day would be surveyed. However, shore seine fishing activity declined from October with the start of the tourism season; hence, fisheries surveys reduced in frequency in line with fishing patterns, and the nets were sampled opportunistically. Up to 6 different shore seine groups operated in Palolem, with fewer in Galgibag and Rajbag. Nets were most often cast in the morning between 6-8am and hauled out a few hours later. We surveyed the catch at the time the net was hauled out of the water, and recording the fishing time, effort and GPS location. If any guitarfish were present in the nets, they were carefully removed with permission of the fishers, measured (species, sex, maturity, Total Length TL and weight, Figure 4). Where possible, the guitarfish were released back into the water to assess post-capture survival.

Figure 4: Widenose guitarfish caught in shore seine nets (top), and measurement of guitarfish before release (bottom). Photos by Avanthika Kamath.

c. Post-capture survival

The post-capture survival rate was assessed for guitarfish caught in fishing nets, in order to explore how effective live release strategies may be as conservation measures. We used a simple, low-cost method that assessed the vitality state of the guitarfish through a set of indices as a proxy for post-capture survival (Braccini et al., 2012; Kottillil et al., 2022). Guitarfish that are alive at the time of landing were measured and carefully released, with each individual scored across 5 survival indices. These included activity

levels, response to stimuli, wounds, skin damage, physical response upon release, etc., each scored between 0-1. The scores were multiplied to derive the final survival rate, which ranged from 0 (least survival, dead) to 1 (highest survival probability, details in Appendix 2).

d. Walking surveys

Walking surveys were conducted over September 2023 to March 2024. These surveys involved walking the length of the beach along the shallow waters (<30cm deep water), at a steady pace, similar to a belt transect, and recording guitarfish present in this zone (see here for an example). Guitarfish, particularly small-sized individuals, have been observed in this shallow water zone - they come in with the wave towards the beach, often getting beached for a few seconds as the wave recedes, and then rapidly swim back into water along with the next wave. The guitarfish are particularly visible when they are beached, or swimming back into the sea. Our walking surveys therefore attempted to observe and count these individuals. This method was adapted from Gaskins et al. (2020) and Nazareth et al. (pers. comms.).

At every guitarfish sighting (recorded as a 'sighting event'), the GPS location was recorded. The number of guitarfish seen at that point was noted, the species (if relevant) and the size class. We broadly categorised every sighted guitarfish into size classes as <25cm, 25-40cm, 40-60cm, and >60cm, based on visual estimation. To validate our size classification and collect additional information, some guitarfish were opportunistically caught by hand, measured (TL, sex and maturity, Figure 5), and released. We made every effort to safely and carefully handle these individuals to not cause them any injury, stress or harm, and released them within one minute.

Walking surveys were conducted every alternate day, rotating between the 3 sites – hence every site was surveyed approximately once a week. Each site was surveyed over 3 different time periods on the survey day: Pre-sunrise (starting at 5am), day (starting between 12-3pm) and post-sunset (starting between 6:30-7:15pm). These time periods were chosen based on the social surveys and pilot walking surveys, in order to understand guitarfish presence and activity at different times of the day. Along with the guitarfish data, we recorded covariates such as the moon phase, tide regime (low, mid or high), tide action (rising or receding) and water visibility. For the latter variable, we created a visibility index and scored the water visibility for each survey between 1 (low) to 3 (high) based on three indicators.

Over the month of November 2023, we additionally surveyed 7 sites for guitarfish (Figure 3), in order estimate the total abundance of juvenile guitarfish in Canacona using an N-mixture model. Each site (10 in total) was surveyed three times (i.e. replicates) on consecutive days using the same protocol. These surveys were only conducted at each site once a day, in the pre-sunrise time period as preliminary analysis indicated that highest guitarfish numbers were recorded in this period. These surveys were completed over November and regular sampling of the 3 primary sites resumed.

Figure 5: Walking survey for guitarfish in Galgibag beach post-sunset (left), and measurement of a guitarfish at Rajbag beach. Photos by Udayan Rao Pawar.

e. BRUVs

Baited Remote Underwater Videos (BRUVs) were customised and designed for shallow water deployments. We built these mini-BRUVs using easily available local material such as PVC pipes to make simple, low-cost structures. Three mini-BRUVs were constructed in total, each with a single camera (GoPro Hero 9 black, Figure 6). BRUVs were deployed in two different zones at our study sites: In very shallow nearshore waters (<1m), overlapping with the walking transect zones, and in slightly deeper waters (1-6m) that were 60-250 m from shore. This was done to understand if juvenile guitarfish were moving into deeper waters during the day. The shallow water deployments were done from the beach and the deeper water deployments were done with a boat.

Like the walking surveys, BRUV deployments were conducted both during the day and under darkness. For the day surveys, 3 BRUVs were deployed at a minimum distance of 250m from each other, parallel to the beach. For the surveys during the dark, we deployed only 2 BRUVs as only 2 suitable underwater lights were available; these were deployed along the parts of the beach known to have higher guitarfish presence through the walking surveys. Sardines (cut into small chunks) were used as bait for all surveys. BRUV deployments were conducted only in Palolem and Rajbag, and not in Galgibag as our fieldwork overlapped with the olive ridley turtle nesting season at this site. BRUV surveys, and all other fieldwork, were conducted after receiving required permits from the Goa Forest Department (Permit no. 2-66-WL-RESEARCH PERMISSION-FD-2023-24-Vol. VIII/5363).

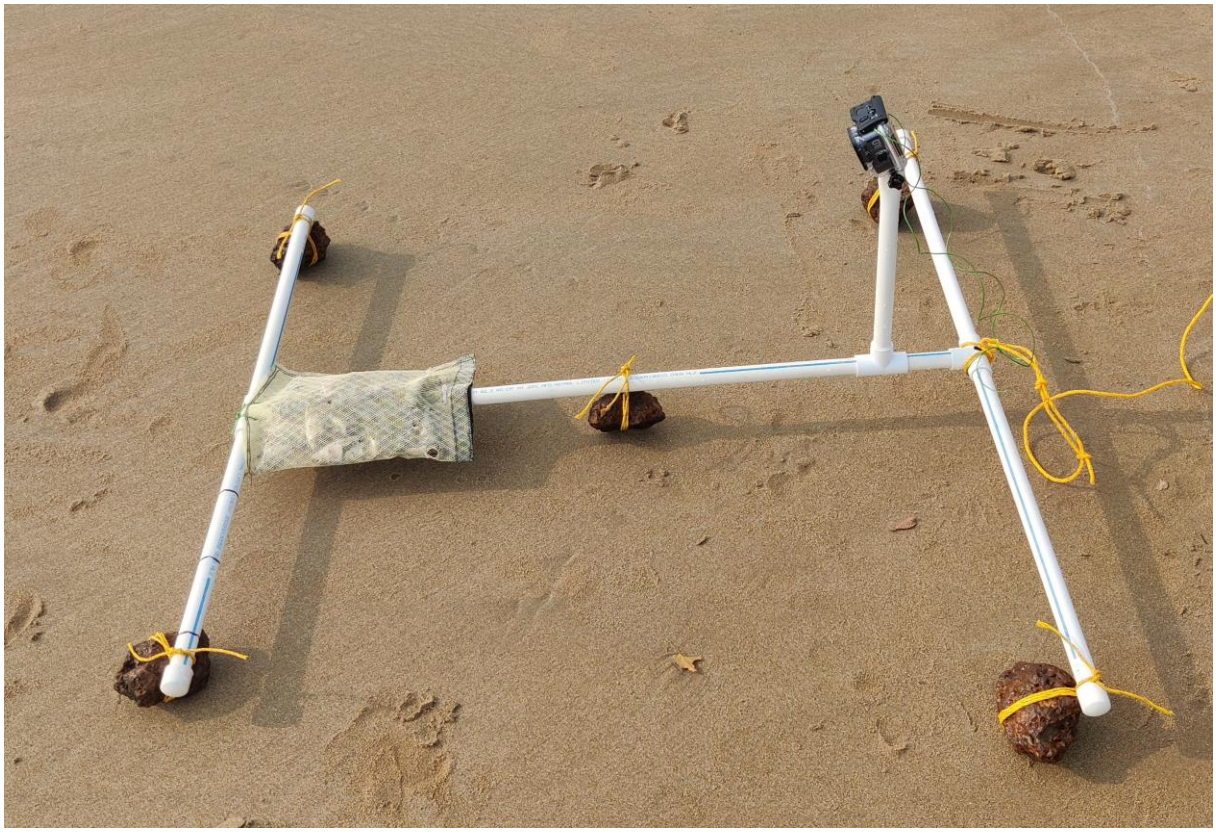

Figure 6: Structure of the mini-BRUV used in the study. Photo by Bryan Miranda.

Data analysis

Generalized Linear Models (GLMs) with a Negative Binomial distribution were used to analyse patterns in relative guitarfish abundance, using the main dataset from the 3 primary study sites. The explanatory variables used in the analysis are given in Table 2. Model selection was done using Akaike Information Criterion (AIC) with a backward selection method starting from the full model and removing models with the highest p-values. The model with the lowest AIC value was selected as the best fitting model. Post-hoc pairwise comparisons for the variables retained in the best fitting model were conducted using Estimated Marginal Means.

To estimate the absolute abundance of widenose guitarfish we used N-mixture models, with the dataset of guitarfish counts across 10 beaches with 3 replicates per beach. The variables used for the analysis were beach length and rock cover as site covariates and visibility as observation covariates. The models were run using Poisson and Negative Binomial distribution. The model selection was again done based on AIC.

Data from the fisheries and social surveys were analysed for descriptive statistics. The spatial information obtained from the social surveys on fishing grounds and nearshore activities were transformed to spatial polygons on a map. GPS data points collected from the fisheries surveys (representing catch of guitarfish) and from the walking surveys (representing sightings of guitarfish) were added to these maps, to visualise the guitarfish habitats and nearshore human activity at study sites.

All data analyses were conducted on RStudio (Version 2024.4.1.748; Posit team, 2024) and QGIS (Version 3.36.3, QGIS, 2024)

Table 2: Variables used in the GLMs to assess factors affecting relative guitarfish abundance.

Variable	Description
Month	September 2023 – March 2024
Beach	Galgibag, Rajbag, Palolem
Visibility	Average score across 3 indicators, ranging from 1 – 3
Tide	Low, Mid, High
Tide Action	Rising, Receding
Time period	Pre-sunrise, Day, Post-sunset
Moon Phase	Categorised as a proportion of illumination percentage ranging from 0 to 1

Results

Abundance, demographics and habitat use

We conducted 184 walking transect surveys in total across 7 months (Galgibag = 60, Palolem = 59, Rajbag = 65). Surveys were conducted in different time periods during the day: pre-sunrise (n=61 for all sites), day (n=55), and post-sunset (n=68).

A total of 25 BRUV deployments were conducted with 10 at Palolem and 15 at Rajbag. Out of the 25 BRUVs, 6 were deployed from the beach in shallow water and 19 were deployed from the boat in slightly deeper waters. No guitarfish were sighted on the BRUV surveys, with many deployments having poor water visibility (see example here). Hence, all data for guitarfish habitat use, abundance and demographics were obtained through walking transects.

a. Relative abundance and seasonality

Relative abundance of guitarfish varied across the study duration and between the 3 primary sites, ranging from a maximum of 139 sightings, recorded in Galgibag during a pre-sunrise survey, to as low as 1 sighting, recorded often in Palolem. No guitarfish were recorded during any day survey in Palolem.

The best-fitting GLM included 3 significant explanatory variables: beach, time period and month. Galgibag beach showed a significantly higher relative abundance of guitarfish, followed by Rajbag and then Palolem ($p<0.05$, Figure 7). Relative abundance was significantly higher during the dark as compared to daytime, with higher numbers at pre-sunrise than post-sunset ($p<0.05$, Figure 7). Relative abundance also increased significantly after the months of September and October (Appendix 3). Other explanatory variables like tide, moon phase and water visibility were not included in the best fitting model.

Although we recorded additional data such as beach profile (Appendix 4), biotic factors such as crab presence, etc., these variables were ultimately not considered robust enough to be used in our current analysis, and need to be improved in future work.

b. Absolute abundance of juvenile guitarfish along the Canacona coast

Models with a Negative Binomial distribution were found to perform better than Poisson. The best-fitting model using a negative binomial distribution included rock cover as a covariate, although the variable was not significant. The estimated abundance of juvenile widenose guitarfish through this model was 539 individuals, 95% CI [489, 594]. Looking at the beach-wise estimates, Galgibag showed the highest estimated abundance of juveniles with 205 individuals, which aligned with the results of the GLM of relative abundance (Figure 7). The beaches with no guitarfish presence were Cola, Small Cola, Colomb and Polem (Figure 8).

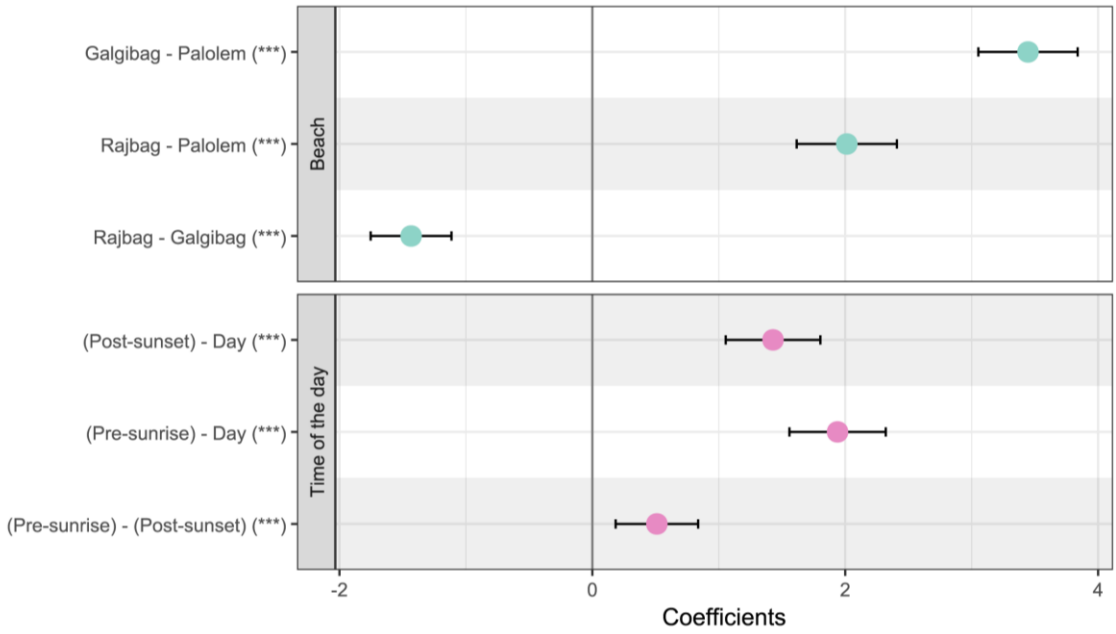

Figure 7: Results of the best fitting GLM showing model coefficients of guitarfish relative abundance for study site (i.e. Beach) and time period. Pairwise comparisons for the categories are shown, with *** indicating a significant difference between the pair. Model coefficients for month of study can be found in Appendix 3.

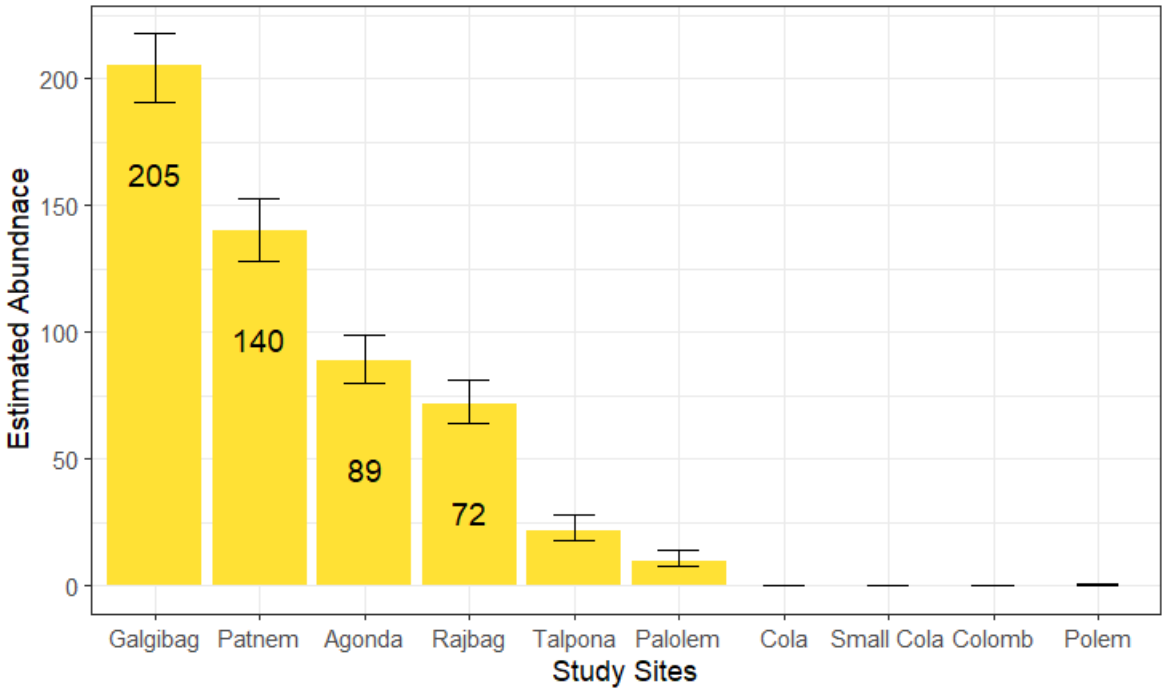

Figure 8: Guitarfish abundance per site, derived from the N- mixture model.

c. Demographics

Over the project duration, 81 guitarfish were opportunistically caught by hand and measured across the study sites. This data was biased towards smaller, younger individuals as they were more abundant and easier to catch. Individuals of the smallest size class (<25cm) were 22.4±1.3 cm TL (n=59) on average, with the smallest measured individual at 18.5 cm. Although the size at birth for the widenose guitarfish is unknown, we assume that guitarfish under 25 cm are neonates or young-of-the-year (YOY). The sex ratio in this size class was nearly equal (female=30, male=29). For the size class 25-40cm, guitarfish were an average TL of 32.2±4.6 cm (n=19). Guitarfish of the class 40-60cm were 48.5±9.1 cm (n=3). We were unable to measure any larger guitarfish (>60cm size class).

These measurements validated the size classes that we visually assigned for all encountered guitarfish during the walking surveys. Further analyses of these size classes revealed a seasonal and spatial pattern in use of nearshore waters (Figure 9). In Galgibag, the first few survey months (September-November) were dominated by guitarfish of the 25-40cm size class. This shifts in December, when there is a sharp increase of <25cm individuals (neonates), which continued to dominate the guitarfish assemblage till March. Abundance of all other size classes in Galgibag decreased relatively with very few larger guitarfish (>40 cm) recorded December onwards. A similar trend was seen in Rajbag, although the appearance of neonates is seen earlier, in November. In Palolem, guitarfish abundances were low overall, and differences between size classes were not as apparent. Palolem also exhibited a relatively higher proportion of adult guitarfish as compared to the other sites (Figure 9).

In all sites, larger guitarfish (40-60cm and >60cm) were usually encountered as single individuals, rather than in groups. These larger guitarfish appeared to show a preference for the rocky areas at the north and south ends of each site (Appendix 5). In contrast, neonates were often found in aggregates of up to 13 individuals at a single point. Neonates also appeared to prefer river or creek mouths – for instance, in Rajbag beach large aggregates of neonates were often recorded at the mouth of a creek towards the north end of the beach.

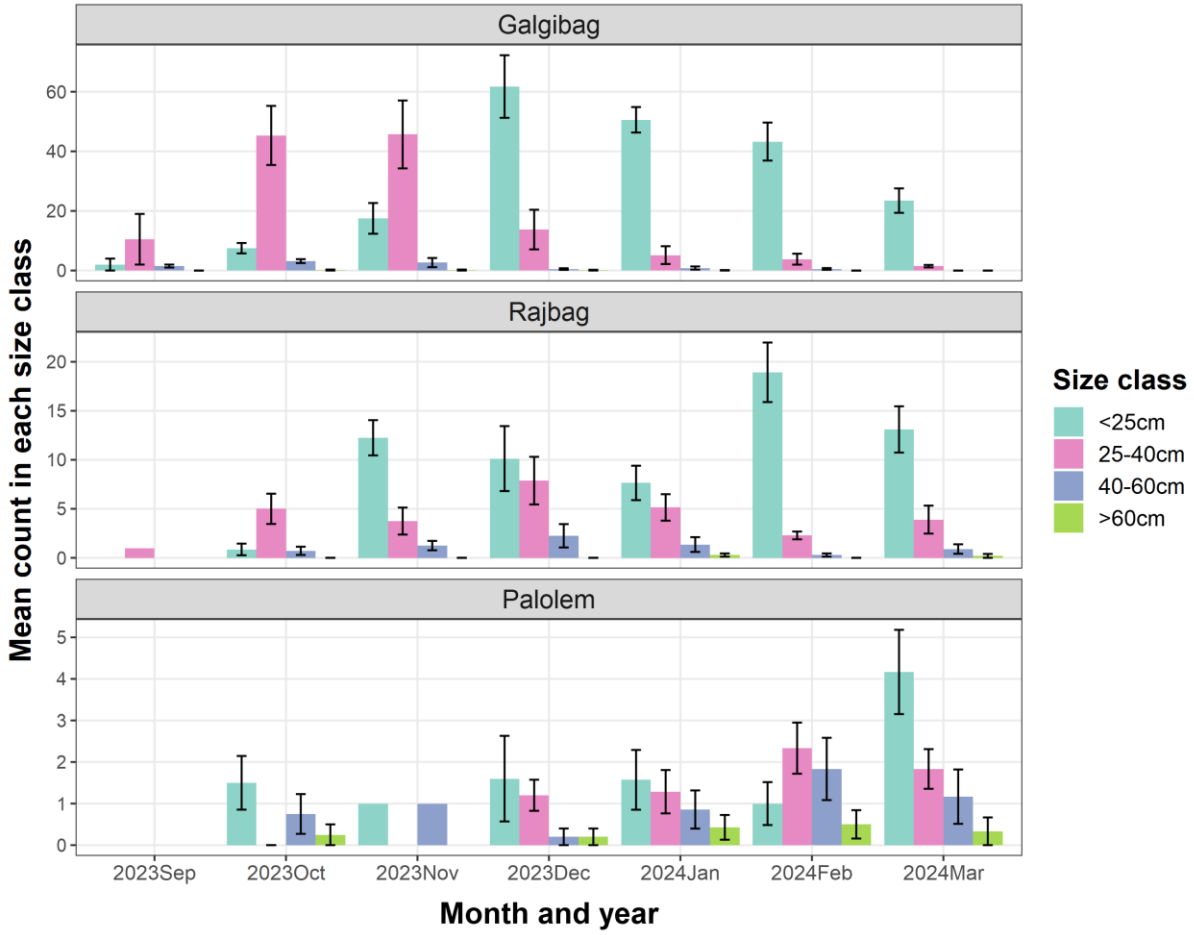

Figure 9: Mean count (i.e. relative abundance) of each size class, averaged across the month, for each study site. Error bars represent standard error. Individual sightings where size class could not be estimated (n=202) are not shown in this graph.

Interaction and overlap with fisheries

a. Catch of guitarfish and post-capture survival

From July 2023 to January 2024, 82 shore seine fishing trips were sampled for guitarfish bycatch. Most samples were from Palolem (n=61) as shore seine activity was the most frequent here, followed by Galgibag (n=18), with very few samples from Rajbag (n=2) as shore seine fishing there was limited, and an opportunistic sample from Agonda (n=1). Of those surveyed, 12% of fishing trips (n=10) had caught one or more guitarfish, with 15 guitarfish captures recorded in total over 126.5 hours of fishing. Guitarfish landings were similar between Palolem (n=8) and Galgibag (n=7), despite the latter site having fewer sampled fishing trips. Catch per unit effort (CPUE) was found to be 0.119 guitarfish/hour of shore seine fishing across all sites; this was considerably higher in Galgibag at 0.483 guitarfish/hour of shore seine fishing.

All surveyed guitarfish were widenose guitarfish (*G. obtusus*), with a varied size range caught in the nets (Mean: 48.9 cm TL, ranging from 29.5 cm to 68.5 cm). Majority of the surveyed guitarfish were male (n=9), with few females (n=3) and few individuals where the sex could not be recorded (n=3).

Upon capture, 3 individuals were retained by fishers as take-home catch for consumption, rest were released (n=12). Although in some cases (n=2) guitarfish were released by fishers before they could be measured, most surveyed guitarfish were given to the team (in almost all cases for free) to measure and release. Post-capture survival was recorded for these individuals, with an average of 0.64 post-capture survival rate across 5 indicators. While this suggests a relatively high survival rate for guitarfish after release from shore seine nets, our sample size was too low (n=10) to make any meaningful conclusions.

b. Overlap with fishing grounds

We conducted an exploratory mapping exercise to understand use of the nearshore waters and overlap of anthropogenic activities (fishing and tourism) with guitarfish habitats. We combined multiple data sources, including information from social surveys, fisheries surveys and walking surveys, to produce preliminary maps of nearshore guitarfish presence and hotspots, along with hotspots of fishing activities (Figure 10).

Fishing activity is highest in Palolem beach, where multiple forms of fishing (gillnets, shore seines, cast nets etc.) occur within 1 km from shore. Galgibag also exhibited some nearshore fishing activity, but nearshore fishing was limited in Rajbag with almost no shore seine operations during our study period. In all 3 sites, fishing grounds overlapped with guitarfish presence. In Palolem, catch of guitarfish occurred throughout the beach, despite guitarfish being primarily sighted in the southern part during the walking surveys. In addition to the fishing activities shown on the maps, the entire beach zone was used by tourists for swimming, water sports, etc.

Notably, LEK from interviews aligned with some of the guitarfish hotspots, particularly at Palolem beach where fishers suggested guitarfish were found mostly towards the South end of the beach, confirmed by our walking transects.

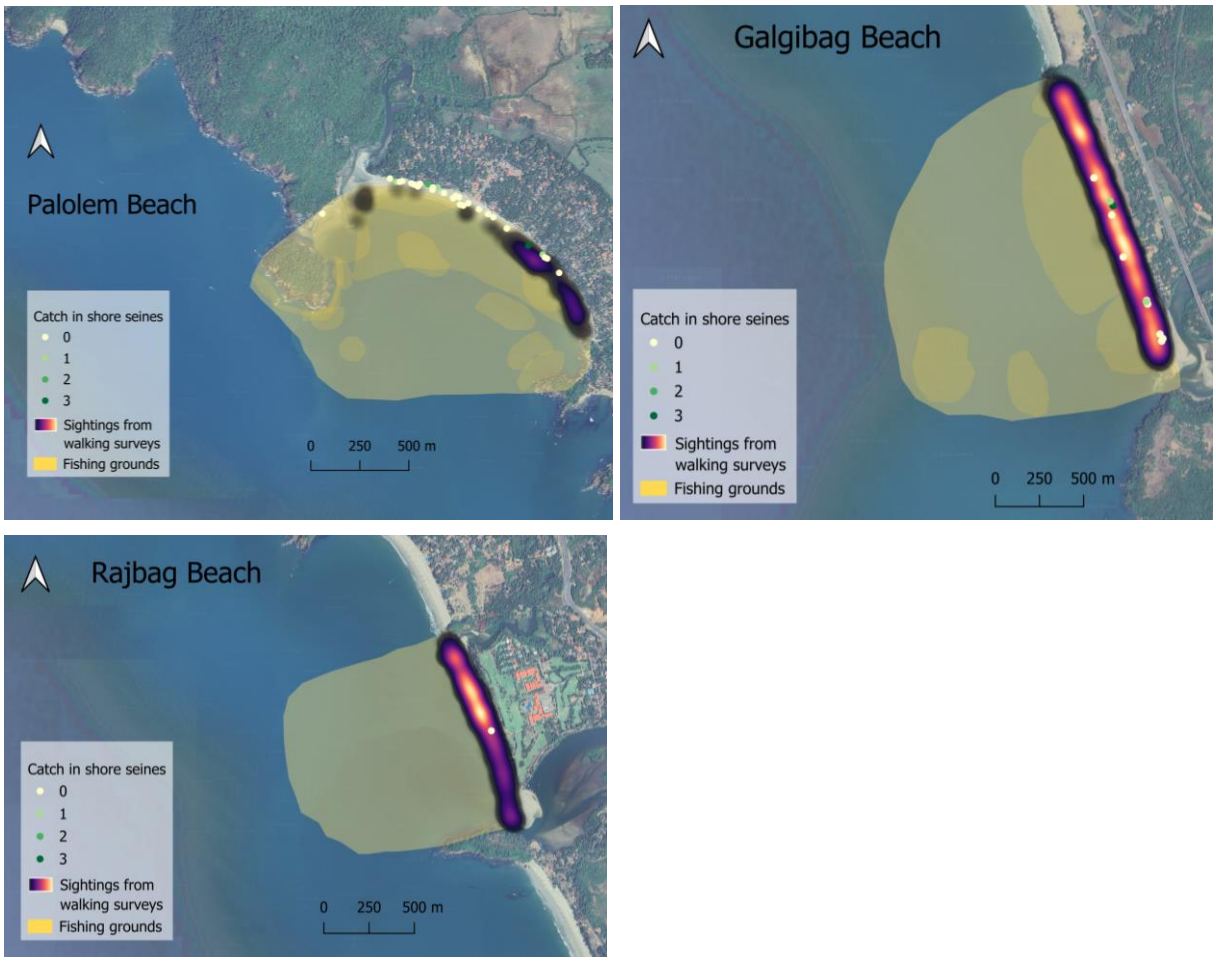

Figure 10: Preliminary maps of nearshore guitarfish sightings, fisheries surveys and guitarfish captures, and nearshore fishing grounds at each site. Guitarfish sightings are mapped with walking survey data, with black-purple representing few guitarfish and red-yellow representing high guitarfish counts. Fisheries surveys are represented through points, with light yellow being fishing trips where no guitarfish were caught, and the shades of green showing trips where guitarfish were caught. Yellow polygons represent fishing grounds – the largest one at each site depicts the entire nearshore zone where fishing takes place, whereas the smaller polygons within this are specific fishing ground (shore seines and gillnets primarily) obtained through social surveys.

Outreach for Live Release

Our outreach efforts were primarily aimed at fishing community members to advocate for live release of these species. We produced a short film (2.5 minutes), in the local language (Konkani), for fishing community members to raise awareness about guitarfish, develop local pride for these species and promote live release.

Most fishers in Goa have access to smartphones and regularly use the messaging service WhatsApp, which has now become the main mode of communication in this region. Hence, it formed a good platform to disseminate our outreach film. We first showed it in-person to fishers in our network, including local key informants, influential fishers and community leaders, who were all encouraged to share it among their friends and family (Figure 11). We subsequently uploaded it to YouTube, and the link was shared through WhatsApp with local fishers, other influential individuals such as local

scientists, conservationists, government officials, as well as various WhatsApp groups and networks.

For those with no access to smartphones or WhatsApp, we produced and distributed pamphlets (in Konkani and English), that contained the same messaging as the video. Other outreach material included t-shirts with 'Friends of Guitarfish' written in the local language, distributed to partners and 'guitarfish champions' within the fishing communities (Figure 11).

The film has 430 views on YouTube, and shared and distributed among at least 50 people, while 50 copies of the pamphlet were distributed. The film appeared to be well received with fishers responding and reacting positively. One fisher stated "We see this fish regularly, but didn't know that it was endangered. We'll make sure to release it now, and also tell our friends about this".

Figure 11: Top: Outreach film being shown to local fishers in Goa, photos by Manini Bansal. Bottom: Project t-shirts distributed to local 'guitarfish champions', and other outreach material created for the project. Photos by Trisha Gupta and Udayan Rao Pawar.

Conservation achievements

Important Shark and Ray Area (ISRA) – Galgibaga beach

Data from our project contributed to the identification of Galgibag beach, one of our main study sites, as an Important Shark and Ray Area (ISRA). ISRAs are portions of ocean or coastal habitat that have been identified as important for one or more elasmobranch species, in terms of their abundance, reproduction, feeding, or other ecological activities. The Galgibaga ISRA includes the area of Galgibag beach, the neighbouring Talpona beach, and surrounding waters of up to 2 km (Figure 12). It was notified due to the presence of guitarfish aggregations in these waters, as well as presence of juvenile blacktip sharks (*Carcharhinus limbatus*). As the final results of our project now show, the waters of Galgibag beach mostly likely serve as a nursery ground for these Critically Endangered species.

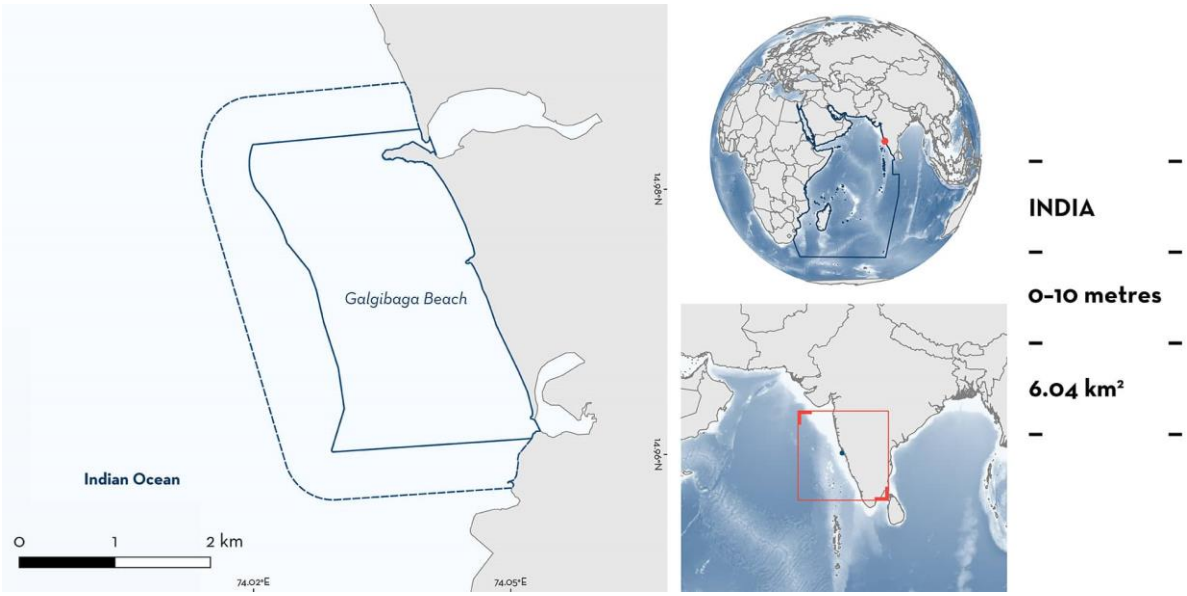

Figure 12: Galgibag and Talpona beaches, and their adjacent waters, that have been identified as the Galgibaga Important Shark and Ray Area (ISRA) by the IUCN shark specialist group.

Figure 13: Fishers voluntarily releasing guitarfish back into the water. Photos by Puja Mitra.

Guitarfish live release

Although we could not monitor the impact of our outreach film within the scope of this project, we received reports of live releases resulting from our efforts. Local collaborators shared photos of a few fishers voluntarily releasing young widenose guitarfish in North Goa (Figure 13). These incidents serve as positive indicators for the potential of live release conservation strategies for guitarfish. Our project hence laid the groundwork for community engagement and live release initiatives.

Education and public awareness achievements

Alongside outreach with the fishing community, we conducted outreach with the broader public to raise awareness about guitarfish. Updates and field stories from this project were published in an article on Roundglass Sustain, a popular online platform for India's biodiversity, habitats, and conservation. Our work was also covered by a local journalist and published in the Times of India newspaper in Goa, reaching a broad and large audience of local residents (Figure 14). Small outreach posters (50 in number) were put up on shacks, restaurants and hotels at our study sites for tourists – informing them of the presence of these threatened species in the nearshore spaces.

We produced several social media posts on guitarfish and our research, shared through the social media handles of our project partner InseasonFish. Our posts ranged from sharing basic information about guitarfish and their threatened status, raising awareness on national and international legislation, conservation challenges, perceptions of local fishers on guitarfish, and fieldwork updates. The posts appeared to be well received and showed good engagement. On Instagram, our guitarfish posts collectively reached over 18,000 accounts, with more than 1640 likes and 20900 views (for videos), and were shared and saved 228 and 94 times respectively.

Our research has also been shared with scientific audiences nationally and globally. Findings from this project have been presented to Marine Conservation Society of Oxford, virtually shared at the UN Ocean Decade Conference in Barcelona, Spain, and at the Indian Wildlife Ecology Conference in Bangalore, India (Figure 15).

Goa's coastal waters strum hope for critically endangered guitarfish

Paul Fernandes

Panaji: The critically endangered widenose guitarfish has caught the conservationists' attention, as its reproductivity rate is very low and its unintended catching by artisanal fisherfolk needs to be tackled to arrest its depleting numbers in Goa.

A major boost to its conservation came recently after the central government included this species — along with the species of bowmouth, clubnose, and ghant guitarfish — in Schedule I of the Wildlife Act, 1972. It is now a criminal offence to catch, sell, or consume the highly threatened fish.

More than seven guitarfish species have been recorded on India's west coast but

The widenose guitarfish is more critically endangered than a tiger

sources said a couple of them may be rhino rays. Of these seven, sharpnose is another species found in Goa, but the widenose species (Glaucostegus obtusus) is seen by ecologists as being more vulnerable.

"The widenose guitarfish is more critically endangered than a tiger. Even though it is sometimes caught, it is not commercially important," said Divya Karnad of InSeason Fish, a sustainable seafood initiative. Karnad added, "It lives quite close to the shore and large groups of them are found off Goa's coast, making the state special."

Though they are out of the fisherfolks' active ambit, they mostly end up as a by-catch in their nets.

Concern also arises over the low recovery of their population, prompting conservationists to call for prioritising the protection of juveniles.

"The guitarfish are understudied and we only generally know that they give birth to a low number — just six to nine offspring," said Bryan Miranda, a marine biologist with the Foundation for Ecological Research, Advocacy and Learning (FERAL).

▶ 'Outside water', P 3

'Guitarfish can survive for up to one hour outside water'

▶ From P 1

These being prone to dangers of anthropogenic activities, the recovery of their population takes time if they are harmed."

Nester Fernandes, in an outreach video prepared by InSeason Fish and other organisations, says, "They give birth like human beings. It's not a case like mackerels which lay eggs in the thousands." Posted on social media, the video urges fisherfolk to release the guitarfish juveniles. "The sad part is the fish ends up accidentally trapped in nets nearshore and is declining in numbers," Fernandes said.

State govt is yet to implement the rules, but some local fishers are aware of the buzz over guitarfish.

With a few sites showing a good presence of guitarfish, conservationists cite the state's coastal waters as a possibly suitable habitat

"We have taken note of its critical status after publicity by govt and conservationists. We release the fish from our gillnets," said Sanjay Pereira, a fisherman from Cacra, St Cruz.

The longevity of guitarfish outside the water is a crucial factor for their survival. "They can survive for even up to an hour outside water and can thus be released into the sea while they are alive," Karnad, a conservationist said.

Several stressors pose a threat to juveniles in the intertidal zone. "Pollution in rivers and development in ports may be affecting them as they are close to human habitations. But we need to do more research into this aspect," said Trisha Gupta, a PhD student at the University of Oxford.

With a few sites showing a good presence of guitarfish, conservationists cite the state's coastal waters as a possibly suitable habitat.

"A proper survey needs to be done but a few sites indicate that Goa has a high number of guitarfish and may be a hotspot for this species," Gupta said.

Figure 14: Article published by a local journalist in the Times of India newspaper about our project.

Figure 15: Presentations of this project given at the Indian Wildlife Ecology Conference (top), for the Marine Conservation Society (bottom right) and at the UN Ocean Decade Conference (bottom left).

Discussion

Our project estimated that 539 juvenile widenose guitarfish are found in Canacona waters, which is the first abundance estimate for these Critically Endangered species in an Indian site. We explored the variation of guitarfish abundance across sites, seasons and with environmental factors, finding the highest guitarfish numbers in Galgibag, and in the month of November. Guitarfish habitats showed significant overlap with nearshore fishing grounds, but catch rates of this species in the local artisanal nets were relatively low. Galgibag emerged as a potential nursery ground for widenose guitarfish, with December likely being the pupping season. Outreach activities with fishing communities appeared to perform well in raising awareness of these species and encouraging live releases, and laid the groundwork for community engagement and live release conservation initiatives.

Habitat use and nursery grounds

We identify Galgibag beach as a likely nursery habitat for widenose guitarfish based on the following criteria (Heupel et al., 2007; Martins et al., 2018): (1) Galgibag beach displayed the highest abundance of (juvenile) guitarfish, significantly more than any other beach in the region, and (2) juvenile guitarfish appear to remain here for several months and hence show high site fidelity. The third criteria that defines a nursery ground is that the area is repeatedly used across years, which would require a longer-term study. Sites like Rajbag, Agonda and Patnem also displayed high abundances of juvenile guitarfish (Figure 8) and hence may potentially serve as nursery grounds as well. Additionally, our data suggests that December may be the pupping season for widenose guitarfish. Nursery grounds can play a crucial role in the life history and hence survival of many elasmobranch species, but these habitats remain poorly studied in India (Gupta et al., 2022). Identification of these habitats for Critically Endangered guitarfish is the first step towards their conservation.

Young guitarfish may be using these shallow water habitats as refugia, as other batoid species are known to do, receiving protection from predators (Davy et al., 2015). Their higher presence at nights and early mornings may also be linked to predator avoidance (Gaskins et al., 2020), or potentially avoidance of anthropogenic disturbance. Our analysis suggests that guitarfish may prefer coastal habitats with limited rock cover, and potentially with gentler beach profiles. This aligns with LEK of fishers (Gupta et al., 2023), and with studies of other guitarfish species (Gaskins et al., 2020). LEK also suggests that guitarfish prefer to inhabit river and estuary mouths. Although we found juveniles in these habitats, they were also found in beaches without a nearby river (such as Agonda). Hence, it is unclear whether river mouths are an essential characteristic of critical habitats for guitarfish. Our study also attempted to explore how guitarfish abundance related to biotic factors such as presence of crabs, but we were unable to robustly assess this. Guitarfish species are documented to feed on fish and crustaceans (Bengïl et al., 2020; Sreekanth et al., 2021), however, diet of the widenose guitarfish, particularly of juveniles, is unknown. Prey availability is likely an important characteristic of a nursery ground and hence needs to be better understood.

Identifying and understanding key characteristics and features of guitarfish nursery habitats, such as rock cover, beach profile, sediment type, prey availability as well as anthropogenic activities, can help model and identify other potential habitats along India's coastline. Further study in Galgibag through methods like tagging and mark-recapture can help better estimate juvenile populations and understand movement patterns and residency in these nursery grounds.

BRUV challenges and usefulness of the walking survey methodology

The walking survey methodology used in our project proved to be a simple, low-cost approach to monitor guitarfish, requiring minimal equipment and expertise. This method enabled us to collect data on guitarfish abundance, location and size class at a fairly good quality and resolution. In our study, this method outperformed BRUV surveys, allowing us to assess guitarfish abundance as well as seasonal and environmental variations for the first time.

BRUVs are a popular tool for studying fish diversity, abundance, and behaviour, but they come with several limitations. The main challenge faced in our project was the poor

water visibility – BRUVs perform poorly in turbid waters. Use of baits can also lead to attraction bias, where the bait selectively attracts (or repels) certain species or individuals (Harvey et al., 2007). We used oily fish like sardines in the present study, which is the standard bait used for elasmobranchs in baited underwater cameras (MacNeil et al., 2020). However, oily fish may not perform well for guitarfish (Evan Nazareth pers. comms.), and other types of baits may need to be trialled. BRUV deployments proved challenging in sites like Palolem with high frequency of tourism and fishing activities, where we ran the risk of the BRUV overlapping with one of these activities. Lastly, BRUVs can be associated with higher financial costs, due to the camera equipment as well as operational costs (boat hires, etc.) of deployments. Therefore, while BRUVs can be a very useful tools of marine research, they are not effective in many contexts and there is a need to develop alternative methods.

The walking survey method also comes with its limitations – it is restricted to monitoring individuals occupying the shallow wave line and near the beach. It assumes minimal recaptures, meaning we likely did not count the same individual more than once during a survey, based on our walking speed and guitarfish behaviour. However, this may not be true for all contexts and species. While water visibility may be a limitation for this method as well, our analysis suggested that visibility may not be important in influencing abundance estimations (as this variable was not retained in the best fitting models). Hence, walking surveys show promise as a standard method for monitoring guitarfish and other coastal batoids, especially in tropical, developing countries where similar species behaviour may be present and resources for other methods are limited. Walking surveys can be adapted to varying levels of expertise—anyone with some training can record and monitor guitarfish nearshore, while the N-mixture modelling approach can be used when technical expertise is present to estimate absolute abundance. The latter can help establish an important baseline for long-term population monitoring and contribute valuable knowledge to species ecology.

Threats to guitarfish

Nearshore fishing grounds appear to overlap with juvenile guitarfish habitats at our study sites, especially in Galgibag where juvenile guitarfish are abundant. While we recorded some captures of guitarfish in the nearshore-operating shore seine nets, catch rates of guitarfish were low overall. Our findings suggest that one guitarfish may be caught in every 10 shore seine hauls. Moreover, despite the relatively high abundance of neonates in these sites (Figure 9), we did not record any guitarfish of this size class (<25cm) caught in fishing gear – suggesting that young guitarfish are potentially avoiding these nets. While a few captured individuals were retained for consumption, others were released by the shore seine fishers. Although we were unable to systematically monitor gillnets and other nearshore fisheries, our interviews and field observations indicate that bycatch of guitarfish were relatively low. Hence, our work suggests that, in these shallow nearshore habitats, local fisheries may not be a significant threat to (juvenile) widenose guitarfish populations.

Global, regional, and local evidence indicates that guitarfish populations are severely declining, putting this species at risk of extinction (Gupta et al., 2023; Jabado, 2018; Kyne et al., 2020; Nazareth et al., 2022). While overfishing is identified as the primary threat, nearshore populations and their critical habitats are likely also endangered by coastal development and tourism. The Goan coastline is undergoing rapid development

through port construction, tourism infrastructure, and other projects, causing significant harm to marine biodiversity via habitat loss, degradation, fragmentation, and pollution (Herald Goa, 2022; Act for Goa, 2018; Dakshin Foundation 2021). Although these impacts have been studied in other marine species (Bulleri & Chapman, 2010), the effects on guitarfish and other coastal batoids remain poorly understood.

Furthermore, beach tourism has been found to negatively affect marine and coastal biodiversity (Teerthala et al., 2024). Coastal tourism has surged in Goa over recent decades, with Palolem being one of the most popular destinations in South Goa. LEK suggests that disturbances from tourism and other non-fishing human activities on the beach negatively impact guitarfish and other nearshore species (Gupta et al., 2023). However, it is unclear if the low abundance of guitarfish in Palolem is linked to tourism-related disturbances or the inherent biophysical characteristics of the beach habitat. The present study focused on fisheries interactions and impacts, and there is a need for further investigation on the effects of other anthropogenic activities on nearshore guitarfish populations.

Measures for guitarfish conservation

Although a simple and low-cost intervention, live release is not often discussed in the context of elasmobranch conservation (Wosnick et al., 2022). In Goa, where guitarfish are not targeted, live release has been identified as a promising conservation strategy (Gupta et al., 2023). The current project supports this with some evidence from nearshore fisheries, where guitarfish catch rates and economic values were low. Notably, shore seine fishers sometimes released young, live individuals back into the water without any prompts from the research team. Qualitative response to our outreach film has been positive, with some preliminary successes as a few fishers released guitarfish (Figure 13). Hence, we recommend developing live release plans for guitarfish conservation in Goa and other similar contexts, in partnerships with fishing communities.

Live release measures have been successfully implemented for guitarfish and other rhino rays in various parts of the world, such as Brazil (Wosnick et al., 2020) and Indonesia (Hollie Booth pers. comms.), where economic payments were used to incentivise releases. In Goa, fishers have previously indicated that they do not always feel the need for compensation payments for live release (Gupta et al., 2023), and the present study has found that fishers were often willing to release guitarfish without any payment or reward. Therefore, long-term community engagement, provision of appropriate training, encouragement and non-economic incentives in Goa could lead to successful live release and guitarfish conservation.

Our data suggest potentially high post-capture survival rates for guitarfish in shore seines, but our sample size was low, and we did not investigate other forms of fishing. Hence further study on post-capture survival is crucial in order to ensure that live release would be a viable and effective measure.

In addition to live releases, protecting critical habitats through spatio-temporal regulations may also be essential. Efforts should focus on Galgibag beach, a potential nursery ground, particularly during the possible pupping season. As a turtle nesting site, Galgibag already has certain regulations on fishing and tourism activities, such as restrictions on beach lights, development of tourist shacks, and beach activities at night (Dakshin Foundation, 2021). Similar regulations can be implemented for guitarfish,

incorporating them into existing measures for marine turtles. With habitat degradation and loss likely forming a threat nearshore juvenile populations, it is crucial to regulate coastal development in areas like Galgibag.

The ISRA notification can play a pivotal role here. Although the ISRA is currently a purely scientific process with no direct policy and management links, recognising sites like Galgibag as an Important Shark and Ray Area can be a valuable tool in guiding the sustainable development, tourism and fisheries management in this region. The presence of an ISRA may also shape future environment or development policies in Goa. It is vital that any regulations in this region are developed and implemented in partnership with the local community for ethical and effective outcomes.

Lastly, our work focused on the nearshore habitats and the guitarfish present here, particularly juveniles. However, guitarfish occupy a broader habitat, and face multifaceted threats from different fisheries like trawlers, and other factors, and these need to be included for effective conservation.

Conclusion and next steps

Our work underscores the importance of developing simple, low-cost methods for ecological research, which are particularly feasible in developing countries. The walking surveys we employed proved to be effective for gathering high-quality data on guitarfish abundance and habitat use, providing a model for similar studies in other regions. Our project collected crucial baseline data, built capacity and established networks with local stakeholders, laying the foundation for a longer-term project in Goa. Future research efforts will focus on confirming nursery grounds, better understanding habitat use through methods like tagging, and spatially expanding the study across India's coastline. In addition, we aim to develop a robust monitoring network involving local stakeholders, including fishing communities, the fisheries and forest departments. Our community engagement efforts have shown promise, and we hope to implement live release programs. This integrated approach, combining ecological research with community-based conservation strategies, holds great potential for ensuring the long-term sustainability of guitarfish populations in Goa and beyond.

Acknowledgements

We are grateful to a number of people for their assistance and involvement in this project. From the fishing community: Utkarsh Pagi, our field assistant who was vital in conducting surveys. Carvahlo, Kunal and Arnold for field accommodation, Yogesh, Subhash, Sujata, Tukaram, Ravi, Shekar, Krishna, Ajith, Santosh, Ashok, Ulhas, Parshuram, Guru, Yesu and many others for their help and participation in this project in various ways. We thank Evan Nazareth for his assistance in designing this project, Nester Fernandes, Priyank Patil, Avanthika Kamath and Munib Khanyari for their help with fieldwork, Kulbhushansingh Suryawanshi for assistance with the N-mixture model, Manini Bansal, Udayan Rao Pawar and Puja Mitra for photography and outreach, and Mukund for editing of the outreach film. We are grateful to the Goa Forest Department: Forest Officer Ankush Karakpur, DCF Santosh Fadte and RFO Rajesh Naik for their support of our work. Lastly, we acknowledge co-funding and support from the Levine Family Foundation and Ashoka University for this project.

References

Act for Goa (2018). Port Development in Goa Threatens to Wipe out Fishing Communities. Retrieved 20 June 2024, from https://actforgoa.org/portfolio/port-development-in-goa-threatens-to-wipe-out-fishing-communities/

Akhilesh, K. V., Bineesh, K. K., Gopalakrishnan, A., Jena, J. K., Basheer, V. S., & Pillai, N. G. K. (2014). Checklist of Chondrichthyans in Indian waters. *Journal of the Marine Biological Association of India*, *56*(1), 109–120. https://doi.org/10.6024/jmbai.2014.56.1.01750s-17

Bengil, E. G. T., Bengil, F., & Özaydın, O. (2020). Feeding ecology and reproduction biology of *Glaucostegus cemiculus* (Geoffroy Saint-Hilaire, 1817) from the eastern Aegean Sea. *Regional Studies in Marine Science*, *33*, 100952. https://doi.org/10.1016/j.rsma.2019.100952

Bulleri, F., & Chapman, M. G. (2010). The introduction of coastal infrastructure as a driver of change in marine environments. *Journal of Applied Ecology*, *47*(1), 26–35. https://doi.org/10.1111/j.1365-2664.2009.01751.x

CITES (2024). Convention on International Trade in Endangered Species of Wild Fauna and Flora. https://cites.org/eng

CMFRI-DoF (2020b). Marine Fisheries Census 2016 - Goa. Central Marine Fisheries Research Institute, Indian Council of Agricultural Research, Ministry of Agriculture and Farmers Welfare; Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India. 62p.

Dakshin Foundation, 2021. Galgibaga Turtle Conservation Reserve. Final Report

Davy LE, Simpfendorfer CA, Heupel MR. 2015. Movement patterns and habitat use of juvenile mangrove whiprays (Himantura granulata). Marine and Freshwater Research 66: 481-492.

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L. N. K., Fordham, S. V., Bräutigam, A., Sant, G., & Welch, D. J. (2017). Challenges and Priorities in Shark and Ray Conservation. *Current Biology*, *27*(11), R565–R572. https://doi.org/10.1016/j.cub.2017.04.038

Gaskins, L. C., Morton, J. P., Renzi, J. J. ., Valdez, S. R., & Silliman, B. R. (2020). Habitat features associated with newborn Giant Shovelnose Rays (Glaucostegus typus). *North Queensland Naturalist*, *50*(November), 73–79.

Goa: Shifting sands ring death knell for the coast – ICSF. (n.d.). Retrieved 20 June 2024, from https://www.icsf.net/newss/goa-shifting-sands-ring-death-knell-for-the-coast/

Goa—Sea Turtles of India. (2017, May 8). https://www.seaturtlesofindia.org/about/distribution/goa/

Gupta, T., Booth, H., Arlidge, W., Rao, C., Manoharakrishnan, M., Namboothri, N., Shanker, K., & Milner-Gulland, E. J. (2020). Mitigation of elasmobranch bycatch in trawlers: A case study in Indian fisheries. *Frontiers in Marine Science*, *7*(July), 571. https://doi.org/10.3389/FMARS.2020.00571

Gupta, T., Karnad, D., Kottillil, S., Kottillil, S., & Gulland, E. J. M. (2022). Shark and ray research in India has low relevance to their conservation. *Ocean & Coastal Management*, *217*(August 2021), 106004. https://doi.org/10.1016/j.ocecoaman.2021.106004

Gupta, T., Milner-Gulland, E., Dias, A., & Karnad, D. (2023). Drawing on local knowledge and attitudes for the conservation of critically endangered rhino rays in Goa, India. *People and Nature*. https://doi.org/10.1002/pan3.10429

Halpern, B., Walbridge, S., Selkoe, K., Kappel, C., Micheli, F., D'Agrosa, C., Bruno, J., Casey, K., Ebert, C., Fox, H., Fujita, R., Heinemann, D., Lenihan, H., Madin, E., Perry, M., Selig, E., Spalding, M., Steneck, R., & Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. *Science (New York, N.Y.)*, *319*, 948–952. https://doi.org/10.1126/science.1149345

Harvey, E. S., Cappo, M., Butler, J. J., Hall, N., & Kendrick, G. A. (2007). Bait attraction affects the performance of remote underwater video stations in assessment of

demersal fish community structure. *Marine Ecology Progress Series*, *350*, 245–254. https://doi.org/10.3354/meps07192

Herald Goa (2022). Shifting sands ring death knell for Goa's coast. Retrieved 20 June 2024, from https://www.heraldgoa.in/Review/Shifting-sands-ring-death-knell-for-Goa%E2%80%99s-coast/196258

Heupel, M. R., Carlson, J. K., & Simpfendorfer, C. A. (2007). Shark nursery areas: Concepts, definition, characterization and assumptions. *Marine Ecology Progress Series*, *337*(Nmfs 2006), 287–297. https://doi.org/10.3354/meps337287

Jabado, R. W. (2018). The fate of the most threatened order of elasmobranchs: Shark-like batoids (Rhinopristiformes) in the Arabian Sea and adjacent waters. *Fisheries Research*, *204*(March), 448–457. https://doi.org/10.1016/j.fishres.2018.03.022

Jabado, R. W., Kyne, P. M., Pollom, R. A., Ebert, D. A., Simpfendorfer, C. A., Ralph, G. M., Al Dhaheri, S. S., Akhilesh, K. V., Ali, K., Ali, M. H., Al Mamari, T. M. S., Bineesh, K. K., Elhassan, I. S., Fernando, D., Grandcourt, E. M., Moazzam Khan, M., Moore, A. B. M., Owfi, F., Robinson, D. P., … Dulvy, N. K. (2018). Troubled waters: Threats and extinction risk of the sharks, rays, and chimaeras of the Arabian Sea and adjacent waters. *Fish and Fisheries*, *March*, 1–20. https://doi.org/10.1111/faf.12311

Kyne, P. M., Jabado, R. W., Rigby, C. L., Dharmadi, Gore, M. A., Pollock, C. M., Herman, K. B., Cheok, J., Ebert, D. A., Simpfendorfer, C. A., & Dulvy, N. K. (2020). The thin edge of the wedge: Extremely high extinction risk in wedgefishes and giant guitarfishes. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *December 2019*, 1–25. https://doi.org/10.1002/aqc.3331

MacNeil, M. A., Chapman, D. D., Heupel, M., Simpfendorfer, C. A., Heithaus, M., Meekan, M., Harvey, E., Goetze, J., Kiszka, J., Bond, M. E., Currey-Randall, L. M., Speed, C. W., Sherman, C. S., Rees, M. J., Udyawer, V., Flowers, K. I., Clementi, G., Valentin-Albanese, J., Gorham, T., … Cinner, J. E. (2020). Global status and conservation potential of reef sharks. *Nature*, *July 2019*. https://doi.org/10.1038/s41586-020-2519-y

Martins, A. P. B., Heupel, M. R., Chin, A., & Simpfendorfer, C. A. (2018). Batoid nurseries: Definition, use and importance. *Marine Ecology Progress Series*, *595*, 253–267. https://doi.org/10.3354/meps12545

Nazareth, E., D'Souza, E., Arthur, R., & Jabado, R. W. (2022). Distribution of the Critically Endangered Giant Guitarfish (Glaucostegus typus) based on Local Ecological Knowledge in the Andaman Islands, India. *Ocean and Coastal Management*, *220*(August 2021). https://doi.org/10.1016/j.ocecoaman.2022.106075

Parliament of India. (2022). *The wild life (protection) amendment act, 2022*. https://prsindia.org/files/bills_acts/bills_parliament/2021/Wild%20Life%20(Protection)%20Amendment%20Bill,%202021%20as%20passed%20by%20LS.pdf

Posit team (2024). RStudio: Integrated Development Environment for R. Posit Software, PBC, Boston, MA. URL http://www.posit.co/.

QGIS.org (2024). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.org

Sreekanth, G. B., Jaiswar, A. K., & Akhliesh, K. V. (2021). Feeding Ecology of Giant Guitarfish, Glaucostegus cf. Granulatus (Glaucostegidae: Rhinopristiformes) from Eastern Arabian Sea. *National Academy Science Letters*, 1–6. https://doi.org/10.1007/s40009-021-01078-3

Teerthala, M., Patankar, V. J., & Chatakonda, M. K. (2024). Assessing the ecological impact of beach tourism on crustacean abundance: A case study from West Coast of India. *Discover Oceans*, *1*(1), 9. https://doi.org/10.1007/s44289-024-00009-6

Wosnick, N., Da Costa De Lima Wosiak, C., & Machado Filho, O. C. (2020). Pay to conserve: What we have achieved in 10 years of compensatory releases of threatened with extinction guitarfishes. *Animal Conservation*, 1–3. https://doi.org/10.1111/acv.12651

Wosnick, N., Giareta, E. P., Leite, R. D., Hyrycena, I., & Charvet, P. (2022). An overview on elasmobranch release as a bycatch mitigation strategy. *ICES Journal of Marine Science*. https://doi.org/10.1093/icesjms/fsac164

Outputs / Media / Communication

- Short Outreach film on guitarfish – this film has been shortlisted for the Conservation Optimism Short Film Festival, and will be showcased in Oxford in July 2024.
- Popular article on guitarfish published in Roundglass Sustain
- Newspaper article in the Times of India (Figure 14)
- Social media posts with project partner InseasonFish.
- Other outreach material – pamphlets, posters and t-shirts.
- Blogs on the Save Our Seas Foundation website

Published papers

We are preparing a scientific article from this project, which will be submitted to a high impact, peer-reviewed journal for publication and shared with the Save Our Seas Foundation as soon as published.

Appendices

The appendix documents and material for this report are as follows:

Appendix 1: Questionnaire guide used for the social surveys

Appendix 2: Indices used to estimate post capture survival rate of guitarfish

Appendix 3: Results of the Generalised Linear Model (GLM) for guitarfish relative abundance, showing pairwise comparisons of abundance over each study month.

Appendix 4: Beach profile of the 10 study sites

Appendix 5: Maps of guitarfish abundance at each site across the entire study duration, per size class.

Financial statement

Consolidated financial report

Project Title:	**Strum with care: understanding fisheries impacts on threatened guitarfish in India to inform their conservation**
Organization:	**Foundation for Ecological Research Advocacy and Learning**
Reporting Period:	**1 March 2023 – 31st March 2024**
Budget Category	**Amount in USD**
Field consumables/equipment	1075
Indemnity & outsourcing	3732
International Travel Cost	0
Lab consumable/equipment	0
Miscellaneous	1192
Personal costs	3386
Administrative charges	550
Total Result	**9934**

Detailed financial statements of each budget category is attached as a separate file.

Your evaluation of the Save our Seas Foundation

The Save our Seas Foundation has been a very pleasant funding organisation to work with. The team has been extremely supportive, friendly, helpful and quick to respond to my emails, and overall created a positive experience. The grant and project guidelines, timelines, deliverables, etc were clearly listed and easy to follow. I appreciate the opportunity to publish blogs on the website in order to increase the visibility of our work, and I'm also grateful for the flexibility the Foundation provided in terms of following project budget lines, report submission deadlines, etc. My only request is that the Foundation can be more open to supporting and funding salaries of project team members. Our current project would have been impossible without my research assistant and local field assistant, and as we are only affiliated with a local Indian NGO, we had no other source of funds. I am grateful that the Foundation allowed me to compensate these team members for their work on the project, and I hope that grant guidelines can be reworked so that future project leaders will be able to support themselves and their team members through the Foundation grants.