Understanding Aggregations Sites of Elasmobranchs in selected islands of the Lakshadweep archipelago

by

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Under the supervision of

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DECLARATION

I hereby declare that the work conducted under the thesis entitled **"Understanding Aggregations Sites of Elasmobranchs in selected islands of the Lakshadweep archipelago"**, is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science** at the **Academy of Scientific and Innovative Research**. This research work has been carried out under the guidance and supervision of **Ms. Chinmaya Ghanekar, Scientist- C**, and co-supervision of **Dr. J. A Johnson, Scientist - F** of Wildlife Institute of India, Dehradun. The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my work, analysis, observation, understanding, and the particulars given in it are true to the best of my knowledge.

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Chinmay Prakash Sawant has put one semester of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

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EXECUTIVE SUMMARY

This Study shows the identification of the aggregation sites of the elasmobranchs, i.e., sharks, rays, and skates, belonging to the Lakshadweep archipelago, emphasising the identification of aggregation places and traditional knowledge regarding related habitats and species. The presence of elasmobranch aggregations is biologically important as it addresses essential life processes like feeding, reproduction, and nursery grounds. Semi-structured interviews were conducted with 120 respondents, including fisherfolks and scuba divers at four selected Islands of Kavaratti, Kadmat, Bitra, and Agatti on traditional ecological knowledge and information about the presence of elasmobranch species and their aggregation sites.

Sixteen aggregation sites were reported, nine for rays and eight for sharks. These aggregations occurred most frequently during the post-monsoon season and the early morning hours. The major habitats encountered with these aggregations were shallow sandy lagoon, coral and rocky reef, sand, and open ocean pelagic zone.

The interviews conducted for assessing species composition included a collective 24 species of sharks and 13 species of rays, with dominant encountered species such as the Whale shark, Blacktip Reef Shark and Tawny nurse shark, for rays Spotted eagle ray, Porcupine ray and Oceanic manta ray. 14 species of sharks are aggregating: Whitetip reef shark, Blacktip shark, and Blacktip reef shark are dominant in the aggregation sites. For the ray aggregation site total of 10 species were reported as they formed aggregations from the Porcupine ray, Spotted eagle ray, Cowtail Ray, and Indian Ocean blue-spotted mask ray. Key aggregation sites are such as Cheriyapani, Valiyapani, and Suheli Par, were identified as key elasmobranch aggregation hotspots. Pole and line, hook and line the traditional fishing practices in the islands. The result of the habitat surveys confirmed these findings, showing that lagoon areas are particularly important for the aggregation of rays, whereas coral reefs in Kadmat, Kavaratti, and Bitra host potential shark populations. In Bitra, rays were observed feeding on a locally frequent prey species called "*Muchroli*," suggesting distinctive trophic interactions. Moreover, drone surveys validated the presence of huge aggregations of rays in pristine reef habitats, such as Cheriyapani, Valiyapani, and submerged banks offshore, including Suheli Par and Perumal Par. These locations are likely to serve as refugia, with the best possible conditions for feeding, resting, and potential nursery grounds, primarily due to minimal human disturbance.

This research provides the first comprehensive understanding of the ecological knowledge of sharks and rays, including their species and key habitats. The results highlight the imperative necessity for continuous long-term monitoring, understanding their ecology of specific fisheries management and habitat, to protect these ecologically specialised and at-risk species in the Lakshadweep archipelago.

Keywords: Elasmobranch aggregation, sharks, rays, Lakshadweep Archipelago, semi-structured interviews, Local ecological knowledge, Habitat characterisation,

CHAPTER 1

1. INTRODUCTION

1.1 BACKGROUND

Chondrichthyes Elasmobranchs (including sharks, rays, and skates) are vital to marine ecosystems, yet their populations are rapidly declining due to ongoing overfishing. Currently, around 1,199 elasmobranch species are classified as threatened worldwide, largely due to overexploitation by fishing pressure. (Dulvy et al., 2021) Recent study findings that that since 1970, populations of sharks and rays have decreased significantly, with overfishing driven by a 71% decline in oceanic shark and ray populations, demand for human consumption leading to ecological degradation and increasing extinction risks for these elasmobranchs (Dulvy et al., 2024). (Pacoureau et al., 2021). The Red List Index for these sharks and ray species has worsened by 19%, indicating an increase in extinction risk (Dulvy et al., 2024). Larger-bodied and widely distributed species are especially susceptible due to their higher trophic levels and their exposure to various national jurisdictions with differing management practices (Sherman et al., 2023). In the southwest Indian Ocean, nearly 19% of endemic sharks and rays are threatened, as climate change impacts habitat reduction. Coral reef-associated species are at a significant risk as well, with 59% threatened, underscoring the urgent need for local protections and comprehensive fisheries management (Sherman et al., 2023). The substantial threat of overfishing is particularly prevalent in tropical regions, contributing to ecological depletion and subsequent biodiversity loss (Baum et al., 2004). Many elasmobranch species exhibit migratory behaviours, returning to vital nursery or pupping grounds necessary for their reproductive success. However, increasing pressures from overfishing, coastal development, and marine pollution are increasingly threatening these migratory routes and habitats. The combined effects of these stressors have led to severe population declines in multiple species, with their recovery potential being significantly lower than that of bony fish, resulting in accelerated decreases. Additionally, several elasmobranch species remain uncharacterized, with numerous others facing extinction threats (Dulvy et al., 2021).

A comprehensive understanding of the ecology of shark diversity, distribution, and abundance is essential for the development of effective conservation and management strategies; however, this critical knowledge is presently lacking in current studies (Southwood & Henderson, 2000; Garla et al., 2006). In spite of this pressing need, research concerning numerous elasmobranch species remains inadequate. Current data indicate that 46% of chondrichthyans are devoid of sufficient biological information, while an estimated 37.5% are categorised as threatened, a classification that may evolve as new research becomes available, mostly through the study is done on elasmobranch bycatch. Local ecological knowledge is very important to do further studies. (Gupta et al., 2022). In India, investigations into elasmobranch conservation have been notably limited, focusing on iconic and charismatic species, such as the whale shark, particularly within the southern states. There exists a pronounced shortfall of studies that examine socioeconomic factors and fisheries management considerations, underscoring the imperative for ecosystem-based fisheries management as opposed to conventional single-species methodologies throughout the Indian region (Gupta et al., 2022).

This research seeks to provide insight into the ecological knowledge gaps by concentrating on elasmobranch aggregation populations within the Lakshadweep archipelago, a location where these species are crucial to the marine ecosystem equilibrium (Ebert et al., 2013). Despite their ecological significance, elasmobranchs in this area confront escalating threats from targeted fishing, incidental bycatch while catching the tuna fish. Habitat degradation and climate change. The identification and mapping of aggregation sites helps us to get further information on nurseries and feeding grounds, which are vital for establishing baseline ecological data that can guide future conservation initiatives. This study aims to enhance the understanding of the elasmobranch family. Local ecological knowledge in identifying these aggregation sites is essential through multiple methods. And another different method. These systems facilitate the observation and analysis of shark and ray diversity within their natural environments, minimising human interference and allowing for accurate documentation of species behaviours and aggregation patterns.

1.2 LITERATURE REVIEW

Critical Habitat Knowledge

Elasmobranchs are very specialised regarding the habitat and their ecological needs; they need a particular habitat for their life events. Which includes the foraging, breeding, migration, local movement, and resting. Research on these life histories is still lacking, especially in India, which limits attempts to preserve important habitats (Dulvy et al., 2021; Fowler et al., 2014; Kinney & Simpfendorfer et al., 2009). Although countries like Australia and Fiji have identified and recorded significant elasmobranch habitats (Heupel et al., 2007; Rasalato et al., 2010), India is still in the early stages of mapping these hotspot regions. There have been some preliminary studies, notably on some possible nursery sites for threatened elasmobranchs in Maharashtra, with an eye towards the bycatch of juvenile elasmobranchs.

Spatial ecology, us can map the important insights of the elasmobranchs' movements. There have been studies of Indonesian shark species that travel long distances for feeding and breeding locations (Booth et al., 2018). In contrast, India's spatial ecology research on sharks and rays is still insufficient, leaving significant ecological knowledge gaps in species habitat use, migration. Lack of potential funding issues for elasmobranch research is an early concern.

Identifying and protecting important habitat is essential for the long-term conservation and recovery of shark and ray populations. Some of the important areas, such as mangrove, lagoon, coral reef and seagrass bed, provide a nursery for this species. (Holst, Meghan et al., 2024)

Feeding grounds, including upwelling zones and coral reefs, sustain adult populations by offering rich prey sources, while mating and aggregation sites, often found in coastal waters and offshore islands, support reproductive success and social behaviours (Heupel et al., 2007).

Despite their importance, mapping and protecting these habitats pose challenges. Many elasmobranchs are highly mobile and elusive, making direct observation difficult. Furthermore, their habitats are dynamic, influenced by tides, currents, and climate change, leading to unpredictable shifts in distribution (Dulvy et al., 2014). Additionally, insufficient data on species' spatial and temporal movements complicates conservation planning, as the lack of long-term monitoring hinders the identification of key ecological patterns (Williamson et al., 2024). Addressing these challenges requires significant investment in research and monitoring. Advanced tracking technologies, such as satellite telemetry and acoustic tagging, can help map migratory corridors and high-use habitats. Integrating these findings into marine protected area (MPA) design and ecosystem-based fisheries management can provide targeted protection for elasmobranchs. Moreover, proactive measures, including habitat restoration and mitigating human activities such as overfishing and coastal development, are essential for ensuring long-term species survival. Finally, as climate change alters oceanic conditions, conservation efforts must prioritise the habitats to safeguard elasmobranch populations against future environmental shifts (Pimiento et al., 2023; Batista et al., 2024).

Use of Fisher's Traditional Ecological Knowledge (TEK)

The utilisation of Traditional Ecological Knowledge (TEK) from fishers (also known as Fisher Knowledge) to address data gaps in shark and ray habitat use in India remains limited. Fisher's knowledge has been applied successfully in places like Bangladesh and Fiji to identify critical habitats for sharks and rays (Rasalato et al., 2010). Local ecological knowledge (LEK) in Goa provides vital insights on rhino ray habitat use, seasonality, and socioeconomics, revealing that these species are now primarily bycatch, and fishermen are optimistic about their conservation. (Gupta, T., Warde et.al., 2020; Gupta et al., 2022) emphasise that local ecological knowledge (LEK) is vital for understanding the ecology and conservation of critically endangered rhino rays in Goa, providing insights into their habitat use and community attitudes. While LEK can enhance conservation strategies by integrating local perspectives, it also has limitations, such as potential biases and challenges in spatial accuracy, underscoring the need for a combined approach with scientific data for effective management (Gupta et al., d2022). The study utilised Local Ecological Knowledge (LEK) from 175 fishers and coastal users to assess the distribution, habitat use, and threats to the critically endangered Giant Guitarfish (Glaucostegus typus) in the Andaman Islands, India. Findings indicated a significant decline in sightings over the past decade, highlighting the urgent need for conservation measures, including regulatory actions on fisheries and habitat protection. The research underscores the importance of integrating community knowledge into marine conservation efforts. (E. Nazareth et al., 2022)

Elasmobranchs Aggregations

The patterns and diversity of animal aggregation are well studied in the broad area of species in terrestrial including invertebrates, birds, reptiles and Mammals. Very few studies are carried out in more dynamic marine environments, which stems from the logistical, technological financial constricts. However, there are large gaps in the understanding of aggregations, occurrences, drivers and functions. However, the habitat is not suitable for long-term observations. (Mcinturf et al. 2023)

Definition of Aggregation:-

It is the co-occurrence of two or multiple individuals in space and time due to a common driver. These aggregations are driven by a common factor, often the presence of prey. (Mcinturf et al. 2023)

Types of Aggregations:

Social group imaging has decided a three criteria: A minimum of two individuals must define aggregations, at a location where two or more elasmobranchs congregate. These elasmobranchs coalesce together, using their common driver, like feeding, breeding, or mating. This is the criterion that suits the social grouping of elasmobranchs. Non-social aggregation- aggregation must be defined by a minimum of two individuals. The place where all the individuals of sharks and rays come together in groups that also fit the criteria of non-group, because the main target here is to resource drive, specifically food. (Mcinturf et.al., 2023)

Elasmobranch Aggregations at the Global Level

These aggregations serve various biological purposes, such as feeding, mating, and nursery grounds. This review examines the key factors influencing elasmobranch aggregations and highlights significant research findings. Sharks and rays exhibit distinct spatial preferences for nurseries, mating, and feeding grounds, each playing a vital role in their life cycle and population sustainability. Nursery grounds are crucial for the early life stages of elasmobranchs, offering shelter, abundant prey, and reduced predation risks. These habitats, often found in estuaries, mangroves, shallow bays, and seagrass beds, provide ideal conditions for juvenile sharks and rays to grow before venturing into deeper waters. (Mancusi, C et al., 2021)

In India, nursery grounds have been documented for rhino rays in Goa (Gupta, Trisha, et al., 2022) and giant guitarfish in the Andaman Islands (Nazareth, Evan, et al., 2022), highlighting the importance of localised research in conservation efforts. Protecting nursery habitats is essential as juvenile survival rates significantly influence population dynamics. Mating grounds are equally critical, serving as key locations for reproductive behaviours, courtship displays, and copulation. These sites are often located in warm coastal waters, offshore reefs, or islands where environmental conditions support successful reproduction. Mating aggregations allow sharks and rays to increase reproductive success while facilitating social interactions. A well-documented example is the scalloped hammerhead shark mating site in Mexico (Klimley, A. P., 1995), where large numbers of individuals gather seasonally. Despite their importance, mating grounds remain the least studied, and identifying these locations is challenging due to the nature of shark gestations and long-distance migrations. Conservation of mating areas is necessary to ensure successful reproduction, particularly for species that breed infrequently or have low reproductive rates.

Feeding grounds support sharks and rays by providing abundant prey resources. These areas, such as coral reefs, upwelling zones, and deep-sea canyons, attract elasmobranchs due to high productivity and prey availability. Many species display seasonal feeding aggregations, such as whale sharks in Indonesia (Rohner et.al.,2021), grey reef sharks in Australia (Heupel M. R. et.al.,2010), and tiger sharks in Western Australia (Heithaus et. al, 2006). In Africa, whale sharks and manta rays exhibit mixed-species feeding aggregations (Palacios, Marta D., et al, 2023). Feeding areas also determine the movement and habitat preferences of many shark species, influencing their role as apex predators in marine ecosystems. However, these sites face increasing threats from overfishing, pollution, and habitat degradation. Safeguarding feeding grounds ensures the stability of marine food webs and the overall health of shark populations. Understanding and protection, and conservation of this area are important. These critical habitats' nursery, mating, and feeding grounds are fundamental for the conservation of elasmobranchs. Targeted research and conservation efforts can mitigate threats, support population recovery, and maintain ecological balance in marine environments.

Feeding Aggregations

Grey Reef Sharks form aggregations at specific sites, particularly near coral reefs, to capitalise on abundant prey resources. Studies by Vianna et al. (2013) have shown that environmental factors, such as prey availability and water temperature, influence their vertical movement patterns and site fidelity. Leopard Sharks. These sharks gather at submarine canyons to forage on market squids, demonstrating a clear link between prey availability and aggregation behaviour (Nosal et al., 2012). Whale sharks are plankton feeders. These gentle giants congregate at feeding grounds, such as the Mexican Caribbean and Cenderawasih Bay, where they filter-feed on plankton. Oceanographic conditions, including nutrient upwelling and plankton blooms, play a crucial role in attracting these sharks (Motta et al., 2021; Rohner et al., 2021; Cochran et al., 2014).

Nursery Grounds:

Large spotted dogfish. These sharks utilise specific areas in the Mediterranean and the Black Sea as nursery grounds, where they lay egg cases (Serena et al., 2021). Smalltooth Sawfish: Juvenile sawfish aggregate in estuaries, such as the Caloosahatchee River, to benefit from the sheltered environment and abundant prey (Simpfendorfer & Wiley, 2011). Scalloped Hammerhead Shark. The Galapagos Marine Reserve serves as a nursery ground for the shark. (Salinas-de-León et al., 2021)

Mating and Other Aggregations:

Scalloped Hammerhead Sharks. Sharks form aggregations at seamounts in the Gulf of California for mating purposes (Klimley, 1995). Tiger Sharks. These apex predators gather in Shark Bay, Australia, to capitalise on abundant prey, such as seals and dolphins (Heithaus et al., 2006). White Sharks. These iconic sharks form aggregations at Seal Island in False Bay, South Africa, to prey on Cape fur seals (Wetherbee & Cortes, 2012). Shovelnose Guitarfish and California Bat Ray: These species utilise specific areas in the Southern California Bight as nursery grounds, suggesting potential social benefits and protection from predators (Espinoza et al., 2022). Elasmobranch aggregations are complex phenomena influenced by a variety of factors, including prey availability, environmental conditions, and social interactions. Understanding these factors is crucial for effective conservation and management strategies. Continued research on elasmobranch aggregations will provide valuable insights into their ecology, behaviour, and population dynamics, ultimately contributing to their long-term survival. Environmental factors: Factors such as water clarity, current strength, and temperature can affect the effectiveness of BRUV deployments (E J Brooks et.al., 2011

1.3 OBJECTIVES

1. Understanding the Species Composition of elasmobranchs in selected islands and aggregation sites in the Lakshadweep archipelago.
2. Characterising key aggregation sites of elasmobranchs.

Key questions

1. What is the species composition of elasmobranchs in the Study area?
2. Where are the key aggregation sites of elasmobranch species?
3. What is the species diversity of elasmobranchs in Key aggregation sites?
4. What are the habitat characteristics of aggregation sites?

2. STUDY AREA

The study area is in Lakshadweep Island, the smallest Union Territory of India. A chain of islands located in the Chagos-Laccadive Ridge off the southwestern coast of India in the Arabian Sea. It is divided into three groups: the Amindivi group of islands in the north, the Laccadive Islands in the middle, and the atoll of Minicoy to the south. It is sandwiched between the Laccadive Sea to the east and the Arabian Sea to the west. The geographical area is 32.69 sq km with a coastline of 132 km, which is spread over 36 islands, of which 11 are inhabited and 25 are uninhabited. The islands lie scattered in the Arabian Sea about 225 to 445 km from the Kerala coast between 8°N and 12°N and between 71°E and 74°E. Although the land area is smaller in size, with a lagoon area of about 4200 sq. km. Lakshadweep is a substantial territory with an exclusive economic zone of 4,00,000 sq. km and 20,000 sq. km of territorial waters. It has three subdivisions, one district, and 10 village panchayats. Kavaratti is the capital, while Agatti, Kadmat, Bitra, Kiltan, Chetlat, Andrott, Kalpeni, Amni and Minicoy from the Kavaratti is the capital, and Androth being the largest. Bitra is the smallest island, with a population of 271 according to the 2011 census of the UT of Lakshadweep. The total population is 64,473 (Census 2011), with a sex ratio of 947 and a literacy rate of 91.85%. English and Malayalam are the official languages, while Jeseri is the local dialect of the people of Lakshadweep. This dialect differs from island to island. Tuna fishing, coconut production and tourism are the main economic activities in Lakshadweep. (Jayaram, S et.al., 2013, Sarkar, Sukanta 2024).

2.1 Kavaratti Island

The Kavaratti is the capital of the Union Territory of Lakshadweep in India. The population is 11221 (2011 census). Kavaratti Island is the capital headquarters of the Union Territory of Lakshadweep. The length of the island is 5.8km and its width is 1.6 km. It has a lagoon having a length of about 6 km and an area of 4.96 sq. km. (Lakshadweep Administration. (n.d.). *Kavaratti,* Lakshadweep Government.)

2.2 Kadmat Island

The Kadmat Island is long and narrow. It is only 0.57 km wide at the broadest point, having a maximum length of 11km. The population is 5389 (2011 census). It has a lagoon on the western side, measuring about 2 km at the broadest point with a total area of 37 km^2. Sq. Km. The island is flat, rising 2 to 3 m in the east and 2 to 4 m in the west above sea level. The high ridge of sand runs down the western side of the island, and there is also a sand accumulation on the southern part of the island, giving rise to undulations. The northern side is flat. (Lakshadweep Administration. *Kadmat,* Lakshadweep Government.)

2.3 Bitra Island

The Bitra Island is the smallest inhabited island in the territory, having a land area of 0.105 sq. km. The population is 271 (2011 census). It has a length of 0.57 km and a width of 0.28 km at the broadest point. Though the land area is Small, its lagoon area is 45.61 sq. km. (Lakshadweep Administration. (n.d.). *Bitra,* Lakshadweep Government.)

2.4 Agatti Island

Agatti Island, covering an area of 17.5 sq. km, with a maximum length of 10 km and a width agatti km has the lagoon has a large population of green sea turtles.

Agatti's lagoons are rich in coral growths and a variety of colourful coral fishes. (Lakshadweep Administration. (n.d.). *Agatti,* Lakshadweep Government)

2.5 Island Reefs

The Lakshadweep reef is divided into the lagoon reef and the open reef. The lagoon is shallow in most islands, with a maximum depth of 5m. However, in Bitra, Suheli par, Minicoy, and Bangaram, in some parts, the lagoon depth can reach up to 15 m. The reef crest is narrow and is exposed during low tides. Beyond the reef crests, however, the depth increases rapidly and can reach up to 3000m. continental shelf is virtually absent, and the open reef consists mostly of reef wall. (Apte, Deepak, et.al.,2010)

2.5.1 Cheriyapani reef – It is a coral atoll also called as it is also called as Cheriyapanniyam, belonging to the Amindivi Subgroup of islands of the UT of Lakshadweep. There are a few sand banks at the atoll that are submerged with reefs. The total geographical area is 239 sq. km, and the lagoon area is 172.59 sq km. It’s a marine protected area called Dr. K.K Mohammed Koya Sea Cucumber Conservation Reserve. It was established in February 2020. It's the world’s first Conservation area specifically dedicated to the protection of sea cucumbers. (Shaji, K.A. 2020)

2.5.2 Valiyapani - It is a submerged reef it is also called as Beleapani reef or Valiyapanniyam. The total geographical area is 62 sq. km, and the lagoon area is 757.46 sq. km. It’s a marine protected area called Valiyapani Marine Bird Conservation Reserve.

2.5.3 Suheli par – Suheli par is a coral atoll, it is oval-shaped, 17 km long. It has three islands, Valikara and Cheriyakara and Suheli pitti Islands. The Total geographical area is 810.5 sq. km, and the lagoon area is 78.96 sq km.

2.6 STUDY AREA MAP:-

Figure 1 STUDY AREA MAP

CHAPTER TWO :

3. METHODOLOGY

3.1 STUDY DESIGN FIELD METHODS:

(A) SEMI-STRUCTURED INTERVIEWS TO UNDERSTAND SPECIES COMPOSITION AND AGGREGATION SITES

Semi-structured interviews were conducted with fisherfolk SCUBA divers who have expertise in the Lakshadweep archipelago. The four major islands, based on logistical and time constraints, were selected for semi-structured interviews, and the survey was completed in Kavaratti, Kadmat, Bitra, and Agatti. By the method of convenience sampling, 25 fishermen were interviewed from each island that will be the sampling methodology involved asking questions on socio-ecological questions. The interview consisted mostly asked open open-ended and closed-ended questions regarding the fishermen and the species aggregations where they were seen. We conducted semi-structured interviews using a questionnaire to gather information on the species composition of sharks and rays encountered during the fishermen's trips, collected data on aggregation species, aggregation sites, season, tidal state, time, and aggregation type, which will aid in understanding this information. The number of shark species and ray species encountered by the fishermen is listed for each island. Fisherfolk on each island will be standardised in all the places. The fisherfolk are a primary focus as they have a long history of working in the region and possess intricate knowledge about the local marine biodiversity, including sharks & rays. Locally known as *"Shurav" and "Tirandi",* they possess local ecological knowledge about the habitat and species, based on their traditional practices. Fishermen were specifically shown photos of each species of shark and rays from a photographic field guide. Their observations on fishing trips, encounters with species, and specific times or locations of sightings, natural history were recorded. For elasmobranch aggregations, a map of Lakshadweep is shown to mark the location where the aggregations are seen by fishermen. SCUBA divers encountered elasmobranchs during their underwater explorations and interviewed scuba divers about the species' presence, aggregation species and depth and habitat where the species are found. The questionnaire is structured so that scuba divers and fisher folks can understand it clearly. Existing researchers working on various aspects help to bring scientific expertise and may provide data from previous studies or ongoing monitoring efforts. To facilitate accurate species identification, interviewees will be presented with photographs of shark and ray species known to inhabit the region. Interviewees will also be shown maps of the Lakshadweep Islands. These maps will allow them to pinpoint specific locations where they have observed elasmobranch aggregations. For instance, fishers may indicate reefs, lagoons, or open-water areas frequented by sharks or rays, while SCUBA divers might highlight dive sites known for consistent sightings. These locations further helped to do the actual field BRUV surveys and habitat characteristics of the region.

(B) DEPLOYMENT OF BRUVS (BAITED REMOTE UNDERWATER VIDEO SURVEYS) IN IDENTIFIED AGGREGATION SITES.

After identifying the aggregation locations from the fisher surveys and scuba surveys, the deployment of Baited Remote Underwater Video Systems (BRUVs) will be conducted to assess elasmobranch species diversity in both identified aggregation sites and corresponding control sites in the Lakshadweep archipelago. For each aggregation site, BRUVs were deployed twice daily, once in the morning and once in the evening, to account for temporal variations in species activity. But it was not logistically possible to do it twice a day at each site. Each sampling session lasts 60 minutes, with three replicates conducted at each site. The results in a total of 3 deployments per aggregation site over three days. Across the study, sampling efforts include 42 total BRUV deployments, comprising 6 deployments at each of the 11 aggregation sites of Kavaratti, Lagoon, Kavaratti southern tip, Kadmat lagoon, Kadmat southern tip, Bitra panjarakon, Bitra lagoon, Cheriyapani, Valiyapani, Agatti west side, Suheli par reef, and Suhelipar lagoon. These sites were identified through questionnaire surveys. At these places, I did not find any active aggregations in my reconnaissance survey and actual the time of the deployment, I have not taken the control points. A standardised bait, tuna, and lagoon fishes also used for all deployments to attract elasmobranchs and ensure consistency in species detection.

(C) HABITAT CHARACTERISATION: DROP-DOWN QUADRANT METHOD

A drop-down quadrant method was utilised to describe the habitat at the identified aggregation sites, ensuring thorough documentation of habitat and environmental factors. To encompass the entire habitat, the aggregation points were centred with the sites; a 1 km transect was established, featuring five individual segments extending 1 km to the left and 1 km to the right of each aggregation point, covering the full 2 sq. km area. The distance between each transect was set at 500 meters, providing sufficient coverage of the study area. At 200-meter intervals along each transect, habitat variables were documented using a GoPro camera mounted within the quadrant, which measures 10cm by 50 x 50 cm in size. The quadrant is lowered from the surface to the designated sampling point on the seabed, and the camera will be positioned on the seabed and left for two minutes to gather detailed footage of the substrate to get the percentage cover of the bottom substrate and the surrounding environment. Habitat data were collected from 25 points in each aggregation site, which included eleven identified aggregation sites: Kavaratti, Lagoon, Kavaratti southern tip, Kadmat Lagoon, Kadmat southern tip, Bitra Panjarakon, Bitra Lagoon, Cheriyapani, Valiyapani, Agatti west side, Suheli Par Reef, and Suhelipar Lagoon. A total of 275 points were collected from all 11 aggregation sites. Key habitat variables recorded during each deployment included the date, time, and precise GPS location to contextualise findings. Habitat types, such as open ocean, reef, or lagoon, were identified based on the percentage cover of the bottom substrate.

The covariates mentioned below were taken from what Habitat characterises and the Environmental parameters influencing the aggregations.

Water depth: the depth profile is measured from each quadrant at every 200 m points by a depth sounder. Substrate: The substrate coverage was measured at each point in the transect, and the substrate type was classified as sand, coral boulders, coral rubbles, live corals, algae, and open pelagic. Water temperature: The temperature affects the aggregation sites. The temperature record from the fishing points app. Water current: water currents change every time on an interval it influencing the species' movement. Tidal state: High tide and low tide influence the aggregation sites the tide chart, while taking the habitat characterisation. Wind speed and wind direction are also taken into consideration as they might affect sea waves. Wind speed and wind direction are also taken into consideration as they might affect sea waves. Tidal state: High tide and low tide influence the aggregation sites the tide chart, while taking the habitat characterisation.

4. ANALYSES

The data were organised in Microsoft Excel using pivot tables. I analysed the general trends in the data and classified it into consistent categories and groups. Information related to species composition at sighting locations and aggregation locations was utilised to obtain the corresponding coordinates in Google Earth and ArcGIS 10.281. These coordinates, along with other relevant data, were then imported into ArcGIS 10.281 to establish georeferenced locations on maps for mapping the aggregation sites of elasmobranchs.

5. RESULTS

5.1 FISHERMEN AGE GROUPS:-

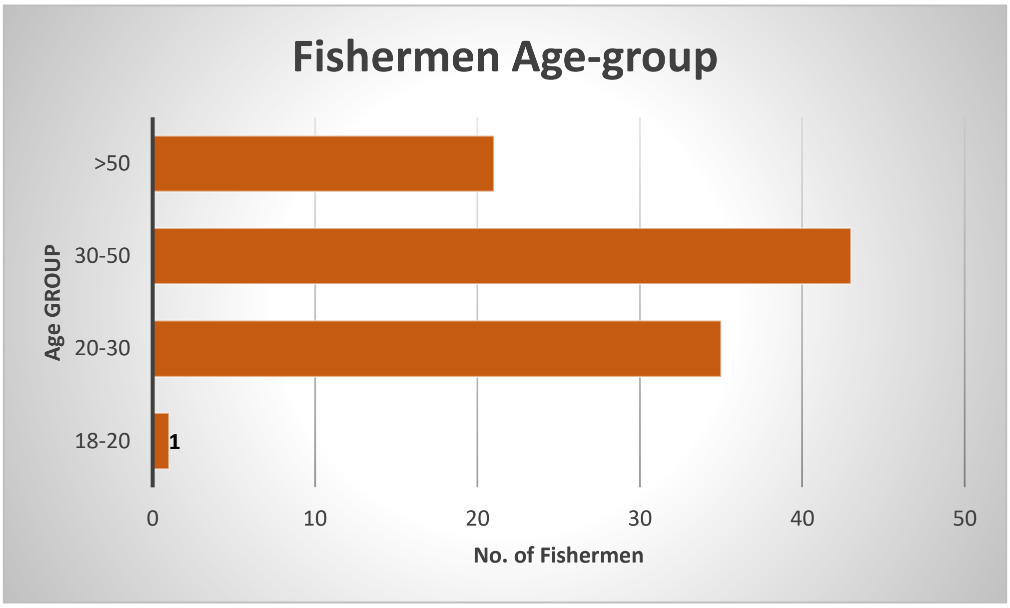

Figure 2 Fishermen Age- groups

A total of 120 respondents were interviewed, comprising fishermen from four selected islands, Kavaratti, Kadmat, Bitra, and Agatti and scuba divers from Kavaratti, Kadmat, and Agatti. To ensure equal representation of fishermen, 25 fishermen were interviewed from each island, resulting in a total of 100 fishermen. Across the four Islands. Additionally, 20 scuba divers were interviewed, with 6 from Agatti, 4 from Kadmat, and 10 from Kavaratti. Among the fishermen, 43% of respondents were in the age group of 30-50 years, 35% were aged 20-30, and 21% were over 50 years old, indicating they had significant experience in fishing. The average age of the fishermen was 25 years, with a median age of 28 years. (see Figure 2).

5.2 FISHING EXPERIENCE

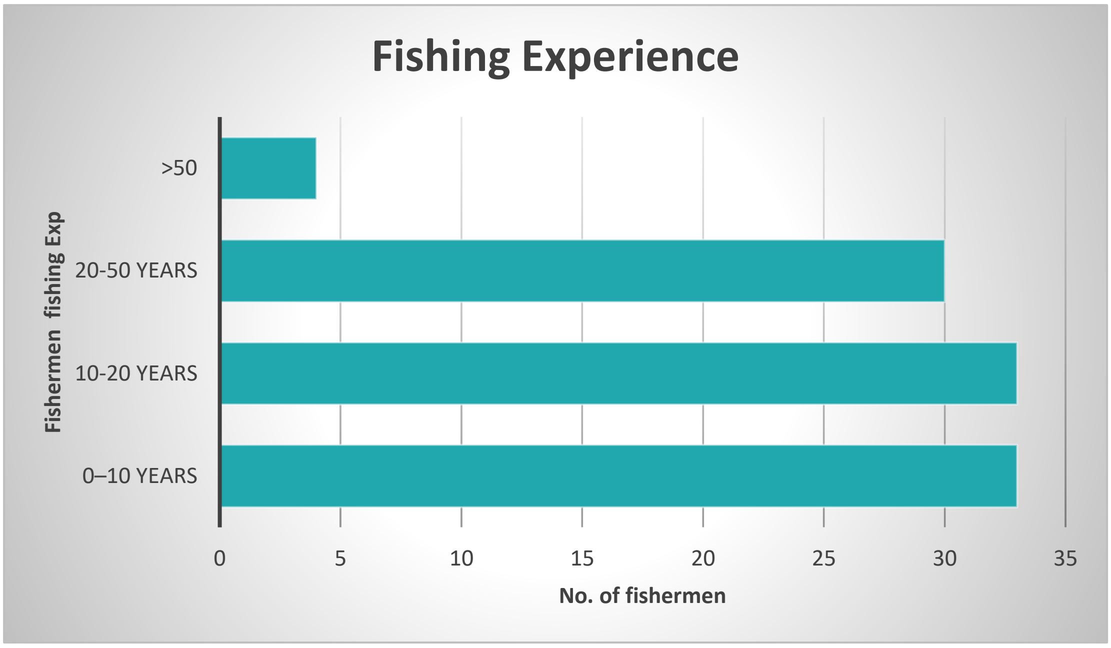

Figure 3 Fishing experience

The fishing experience among the study area 33 respondents has 0-10 years of experience, 33 respondents have 10-20 years, 30 respondents have 20-50 years, and 4 respondents have more than 50 years. The average experience among the respondents is 25 years, suggesting that they have a relatively long duration of fishing Practices. This significant level of experience could help identify important fishing sites as well as recognise shark and ray species and their aggregation, through the contribution of their traditional ecological knowledge. (See Figure 3.)

5.3 PRIMARY FISHING METHODS

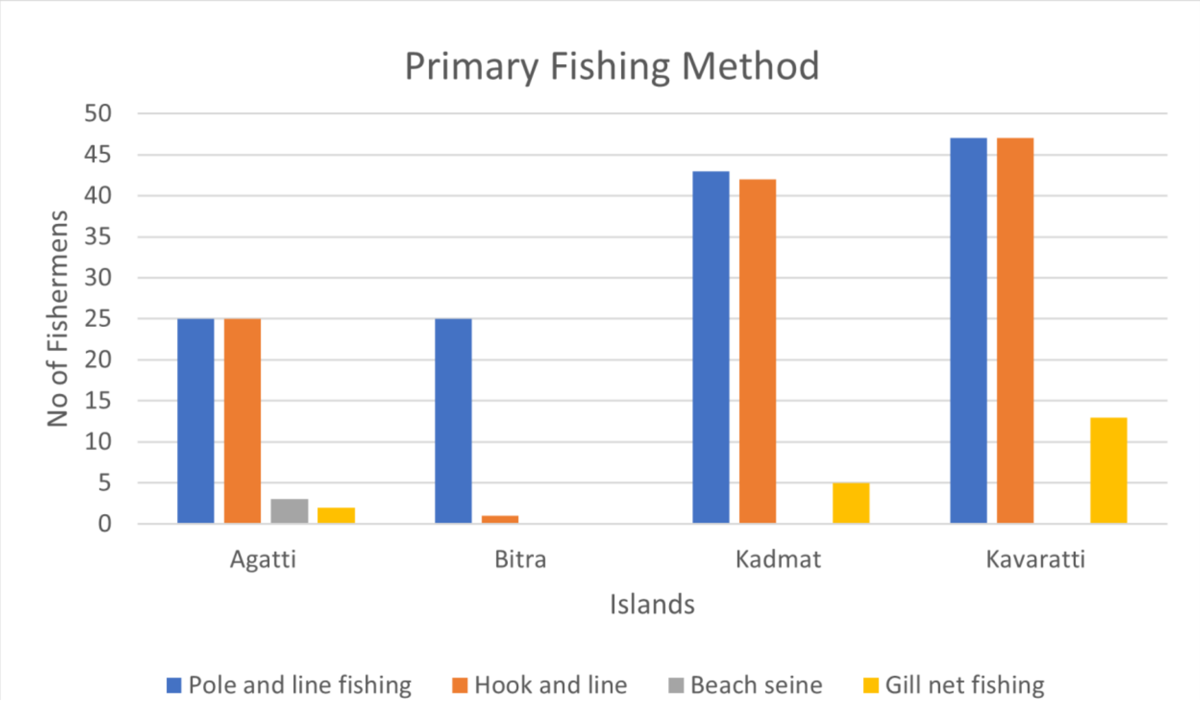

Figure 4 Primary Fishing Method

The primary fishing methods practised by fishermen across the four surveyed islands. The results were 43 respondents from Kadmat practised hook and line, and 42 respondents practised pole and line. And 5 respondents practised gill net fishing. In Kavaratti, 47 respondents practised both pole and line, and hook and line, and 13 respondents practised gill net fishing. Bitra 25 respondents practised Pole and line fishing. Overall, pole and line fishing, hook and line, is the most common fishing method in all the Islands. Beach seine and gill net fishing is minimal. (Figure 4), The analysis of primary fishing methods across four Lakshadweep islands reveals a strong reliance on traditional fishing gear. (Figure 4)

5.4 ISLAND-WISE SHARK SPECIES COMPOSITION

1. KVARATTI ISLAND SHARK SPECIES COMPOSITION

Interviews were conducted on Kavaratti Island. A total of 23 species of sharks have been reported to be present of shark species. The respondents mostly reported were the Indo-Pacific leopard shark (*Stegostoma tigrinum*) (11.7%), the Blacktip reef shark (*Carcharhinus melanopterus*) (11%), the common thresher shark (*Alopias vulpinus*) (10.4%), and the Whale shark (*Rhincodon typus*) (9.8%). Other notable species included the grey reef shark (*Carcharhinus amblyrhynchos*) and whitetip reef shark (*Triaenodon obesus*), each at 7.4%, and the Blacktip shark (*Carcharhinus limbatus*) at 6.7%. Reports of the Longfin mako shark (*Isurus paucus*), sharptooth Lemon shark (*Negaprion acutidens*), silky shark (*Carcharhinus falciformis*), and hooktooth shark (*Chaenogaleus macrostoma*) were rare, each species reporting less than 1.2% of the total observations. (Figure 5)

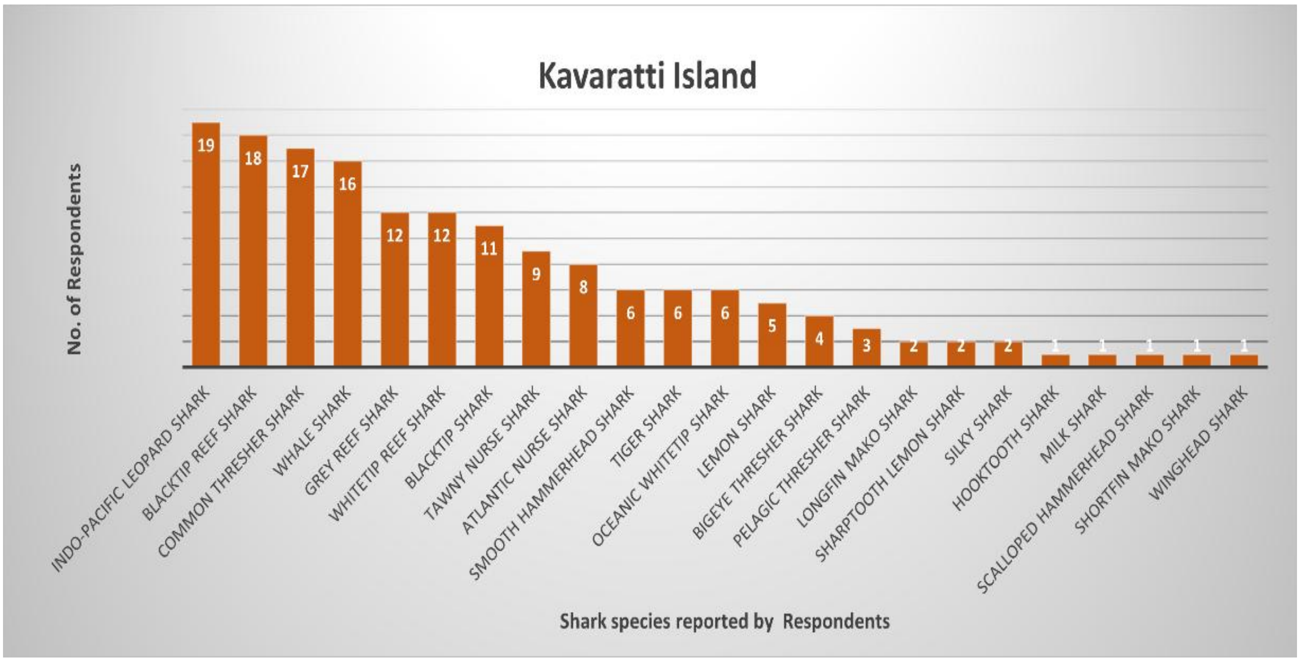

Figure 5 KVARATTI ISLAND SHARK SPECIES COMPOSITION

2. AGATTI ISLAND SHARK SPECIES COMPOSITION

A total of 22 shark species were reported from Agatti Island based on responses from respondents. During fishing trips. The most commonly observed species were the Whale shark and the blacktip reef shark, each reported by 9.1% of respondents. Following these, the tawny nurse shark and whitetip reef shark were reported by 8.7% of respondents. Sightings included the shortfin mako shark and winghead shark, each reported by only 0.4% of respondents. Notably, the bigeye thresher shark, a rare pelagic species, was not reported by any respondents in Agatti. (Figure 6)

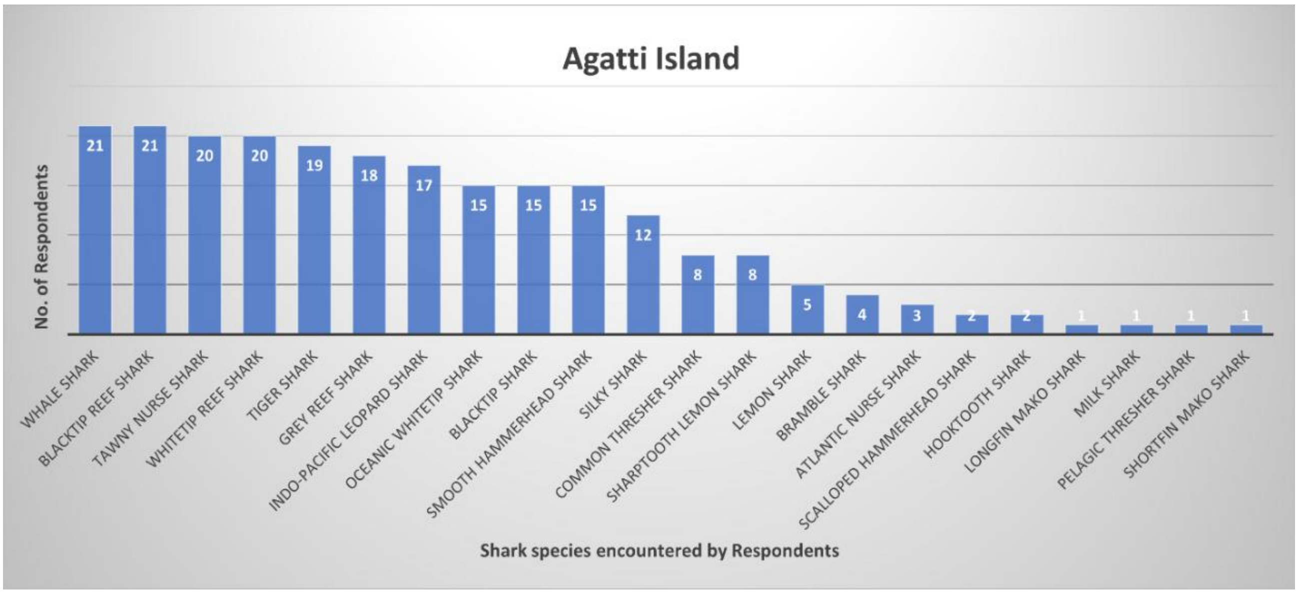

Figure 6 AGATTI ISLAND SHARK SPECIES COMPOSITION

3. KADMAT ISLAND SHARK SPECIES COMPOSITION

A total of 24 shark species were documented through respondent interviews on Kadmat Island. During fishing trips. The blacktip reef shark was the most frequently reported species, with

11.7% of respondents noting its presence. This was followed by the tawny nurse shark at 7.5%, and the winghead shark, which was rarely reported at 2.5% (Figure 7)

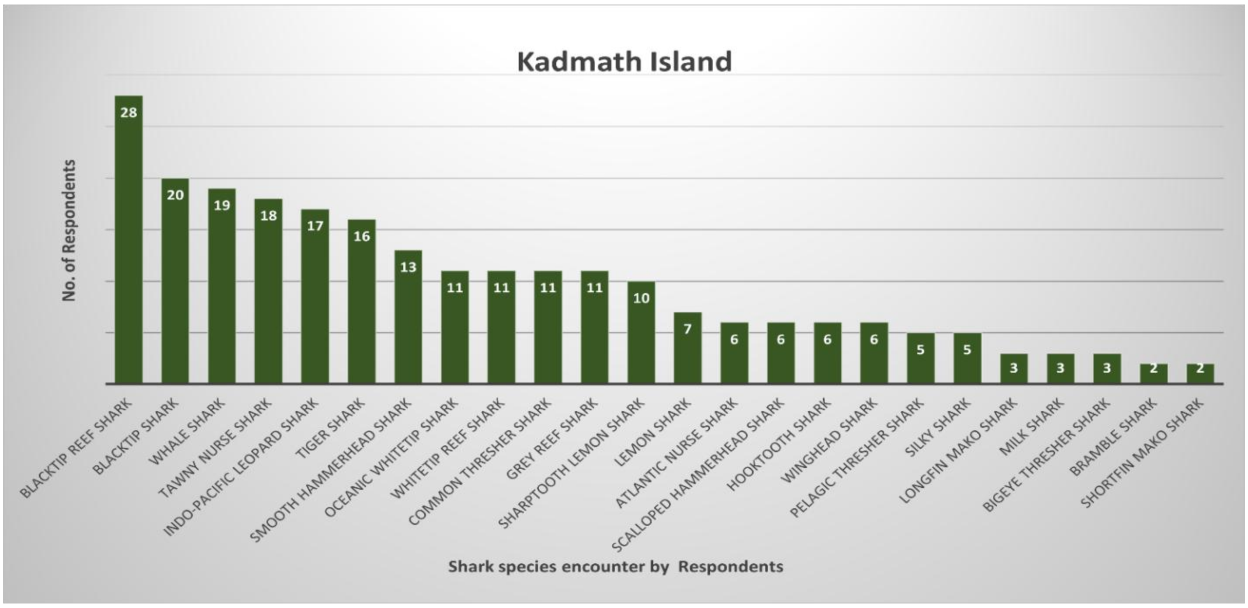

Figure 7 KADMAT ISLAND SHARK SPECIES COMPOSITION

4. BITRA ISLAND SHARK SPECIES COMPOSITION

Respondents from Bitra Island reported 22 shark species during fishing activities. The most frequently mentioned was the Tawny nurse shark (9.8%), followed by the Blacktip reef shark (8.2%) and the Tiger shark (7.8%). Few respondents (2%) reported seeing the scalloped hammerhead shark. (Figure 8)

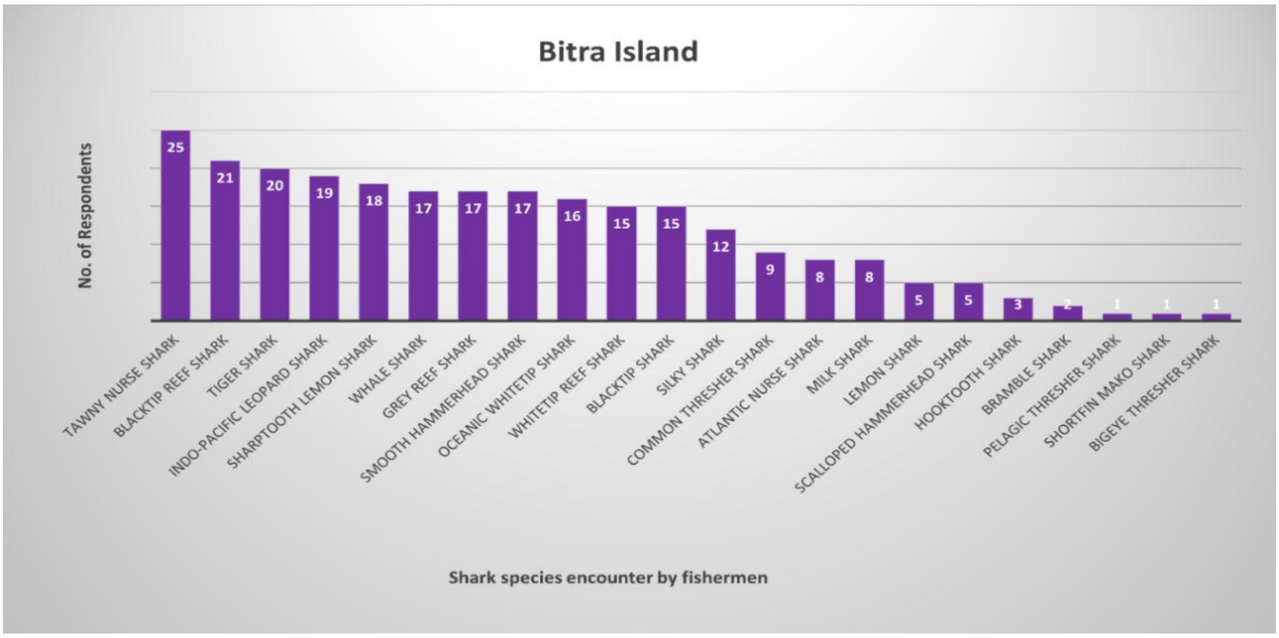

Figure 8 BITRA ISLAND SHARK SPECIES COMPOSITION

5.5 ISLAND-WISE RAYS SPECIES COMPOSITION

1. KAVARATTI ISLAND RAY SPECIES COMPOSITION

A total of 13 ray species were reported by respondents from Kavaratti Island. Among these, the spotted eagle ray (*Aetobatus ocellatus*) was the most frequently mentioned species, accounting for 19.7% of the responses. This was followed by the Oceanic manta ray (*Mobula birostris*) at 16.8%, the porcupine ray (*Urogymnus asperrimus*) at 15.3%, and the Cowtail stingray (*Pastinachus sephen*) at 8.8%. The least reported species was the Shorthorned pygmy devil ray (*Mobula kuhlii*), comprising only 2.2% of the responses. Additionally, the Whitespotted wedgefish (*Rhynchobatus djiddensis*) received very minimal mention, with only 1.5% of respondents reporting its presence. (Figure 9)

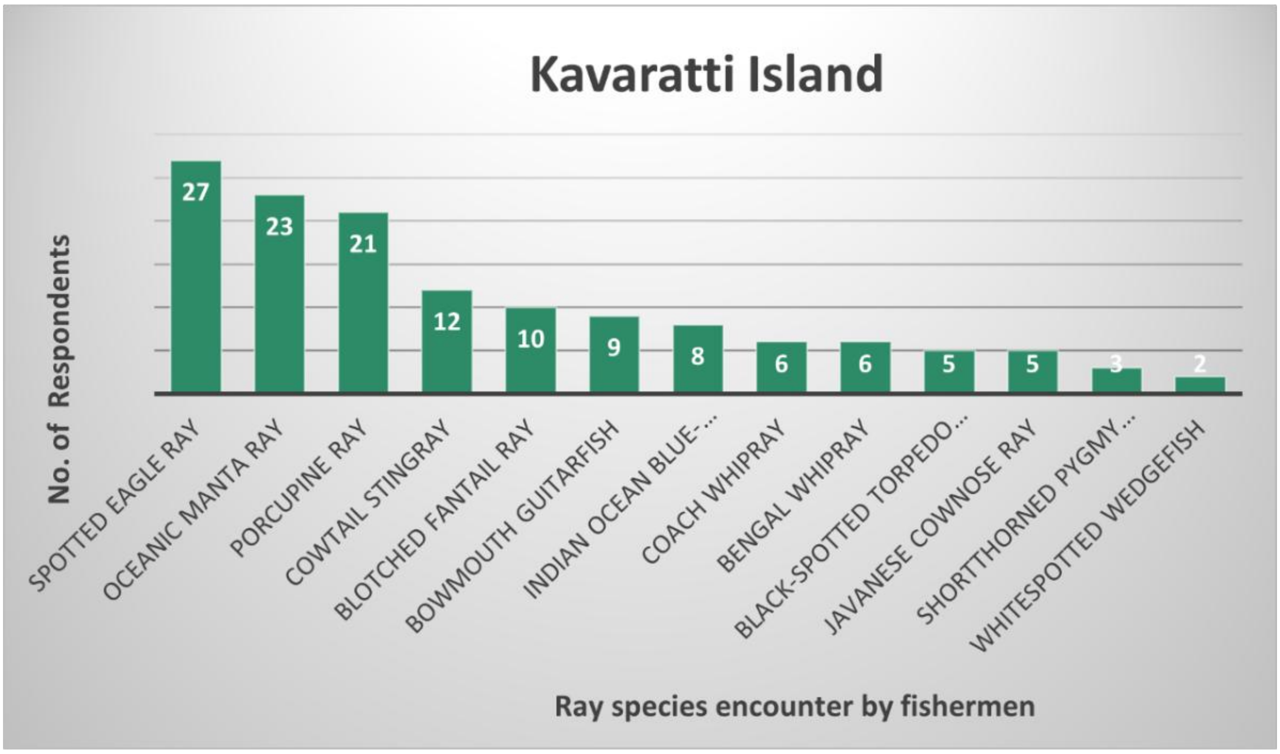

Figure 9 . KAVARATTI ISLAND RAY SPECIES COMPOSITION

2. AGATTI ISLAND RAY SPECIES COMPOSITION

A total of 13 ray species were reported by respondents from Agatti Island. The most encountered species by respondents were the Cowtail stingray and Porcupine ray, which were reported by 13.7% of respondents, followed by the Spotted eagle ray (12.7%) and the Indian Ocean blue-spotted mask ray. The Black-spotted torpedo ray was reported by only 0.9% of respondents, and the Bowmouth guitarfish was mentioned by just 0.5%, indicating it is rarely reported by respondents. (Figure 10)

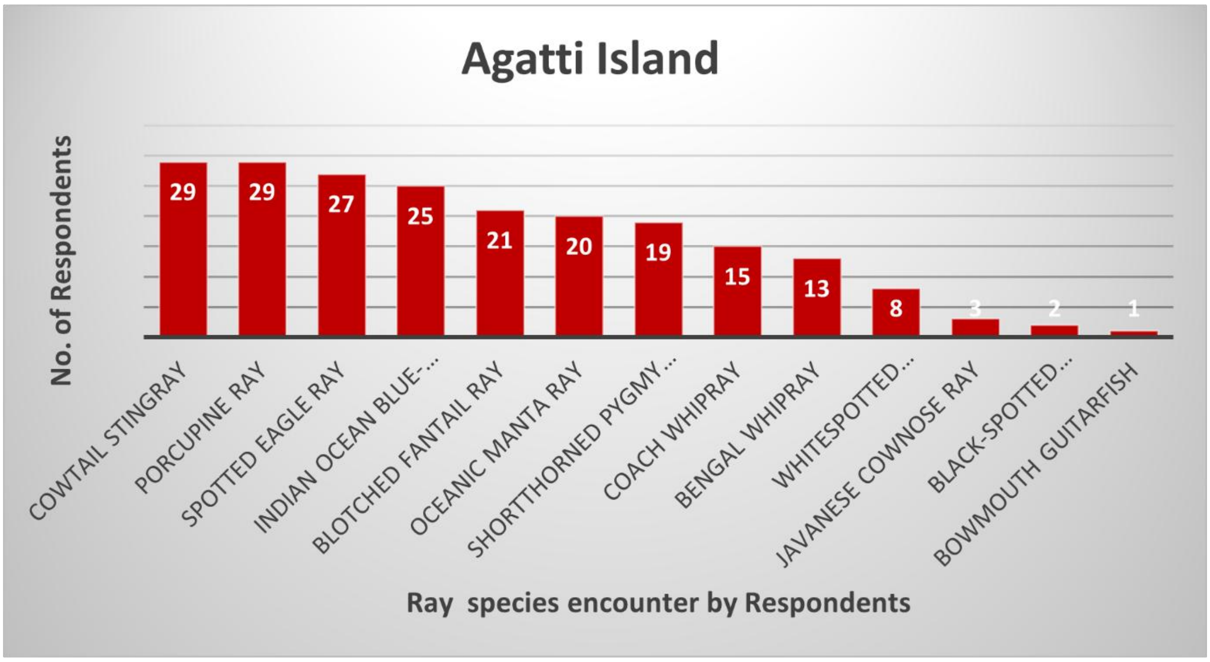

Figure 10 AGATTI ISLAND RAY SPECIES COMPOSITION

3. KADMAT ISLAND RAY SPECIES COMPOSITION

13 ray species around Kadmat Island were reported by respondents during the interviews. The spotted eagle ray and porcupine ray were each reported by 13.9% of respondents, followed closely by the Indian Ocean blue-spotted mask ray. Less frequently reported species included the black spotted torpedo ray and the bowmouth guitarfish, though specific percentages for these were not provided. (Figure 11)

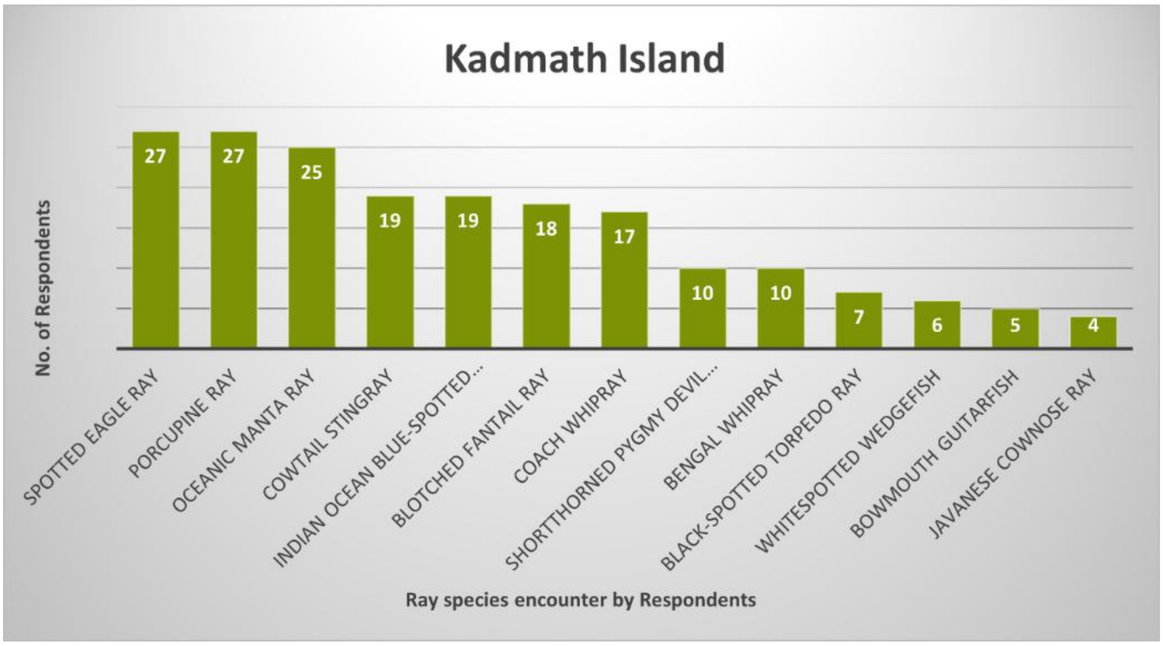

Figure 11 KADMATISLAND RAY SPECIES COMPOSITION

4. BITRA ISLAND RAY SPECIES COMPOSITION

A total of 12 ray species were reported by respondents. The spotted eagle ray and oceanic manta ray were each reported by 11.1% of respondents, followed closely by the porcupine ray (10.7%). The Bengal whipray was less frequently reported (2.2%). (Figure 12)

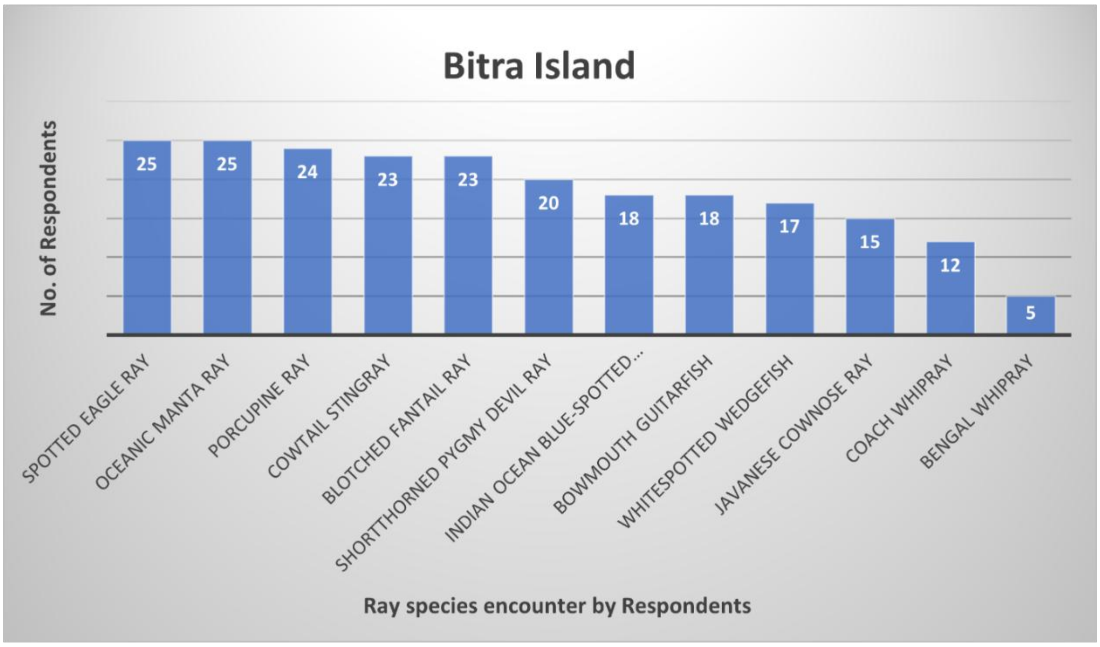

Figure 12 BITRA ISLAND RAY SPECIES COMPOSITION

5.6 MAP OF AGGREGATION SITES FOR SHARKS AND RAYS

Across the study area, 16 sites were identified as shark and ray aggregation points. (Figure 5). Interviews reported eight shark aggregation sites and nine ray aggregation sites. Notably, uninhabited islands Cheriyapani and Valiyapani were common aggregation sites for both sharks and rays. Bitra had two prominent shark sites (Bitra-Panjarakon and Bitra Tangi), reported by 19 and 8 respondents, respectively, and one key ray site (Bitra Lagoon) noted by 18 respondents. Valiyapani, with 25 respondents, and Cheriyapani, with 29 respondents, emerged as significant aggregation sites for both sharks and rays, highlighting their importance across the four islands (Figure 6). Kavaratti Island's southern tip and lagoon were cited by 10 and 4 respondents, respectively, for sharks and rays. Suheli Par was noted by 19 respondents for rays. Kadmat Island featured two major shark aggregation sites: the Shark Caves at the southern tip, with 9 respondents, and Kadmat-Amni for rays, with 5 respondents. In Agatti, 13 respondents identified the west side as an aggregation site, while Perumal Par was mentioned by 14 respondents, and 2 respondents reported Chetlat as an aggregation site (Figure 13).

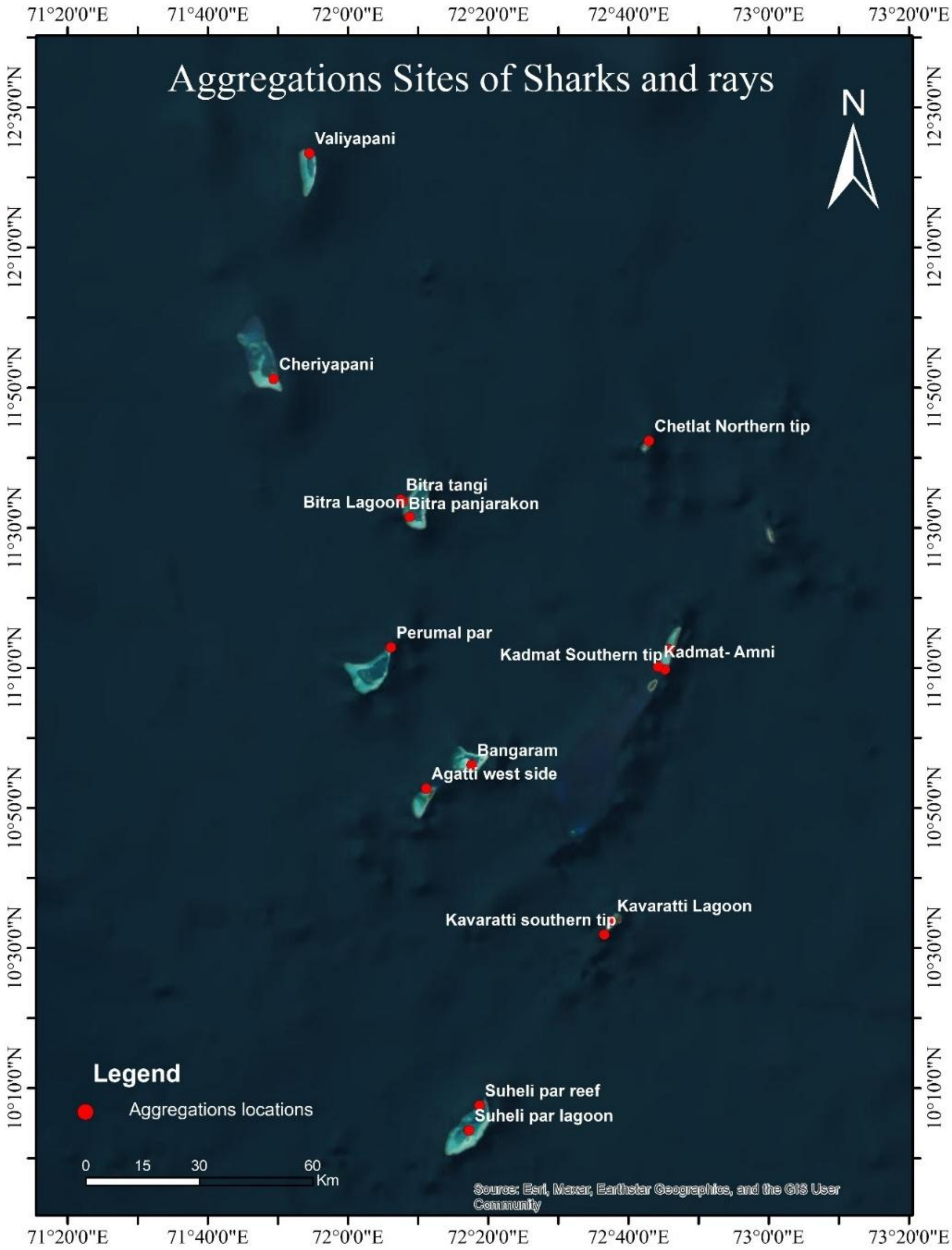

Figure 13 MAP OF AGGREGATION SITES FOR SHARKS AND RAYS

Aggregations Sites of Shark

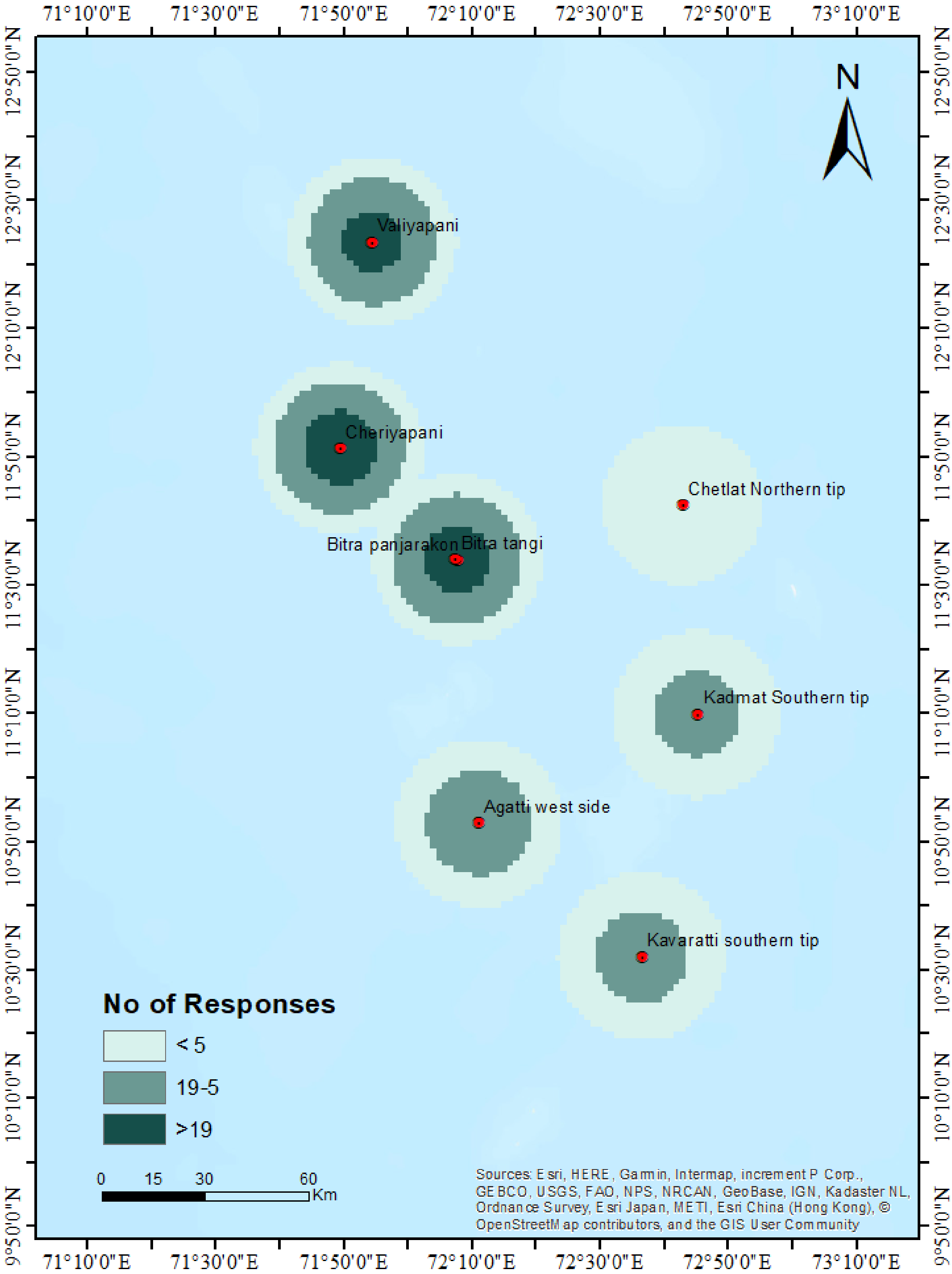

Figure 14 Shark aggregation sites Map

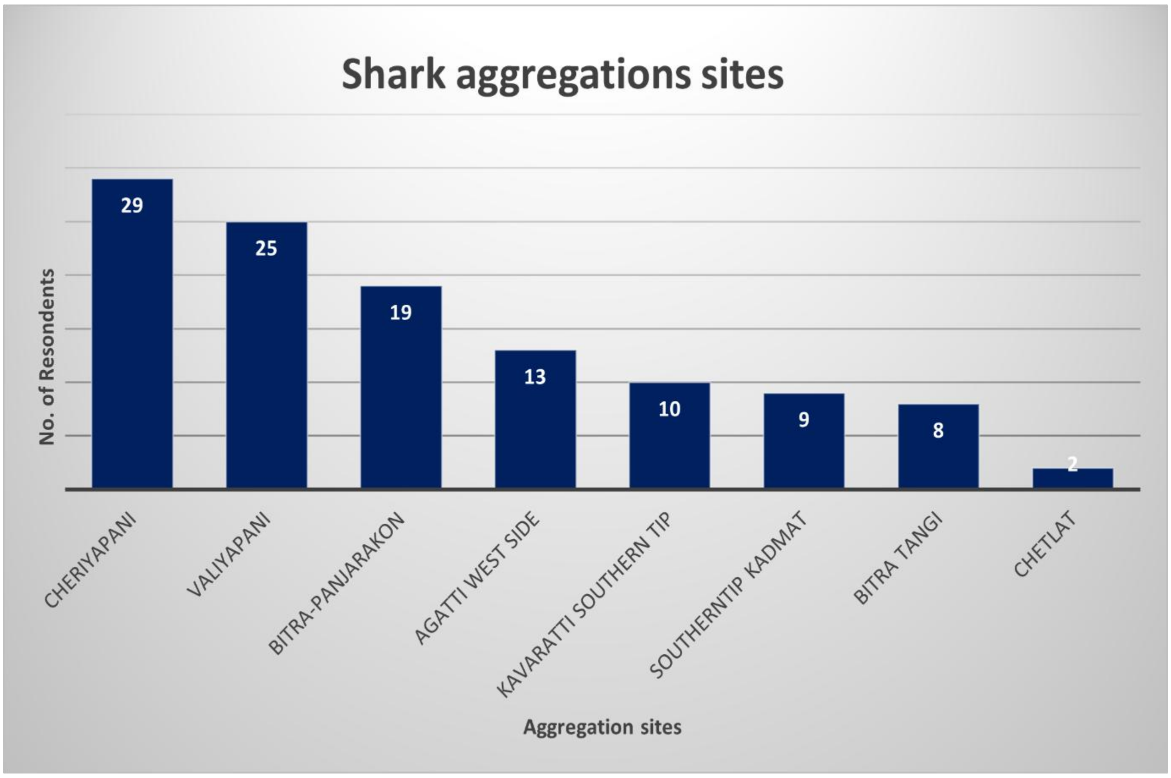

Figure 15 Shark Aggregation graph

The southern tip of Kavaratti, along with the Kavaratti lagoon, constitutes the two primary regions reported by respondents as sites of shark and ray aggregations. 69.56% of respondents indicated the southern tip of Kavaratti as a shark aggregation, while 30.43% of respondents identified the Kavaratti lagoon as a site for ray aggregation. Regarding Agatti, a notable 72% of fishermen reported shark aggregation sites, with the western side of Agatti and Bangaram Island comprising 28% of the reported key aggregation areas. In the context of Bitra, it is noteworthy that this island has the most expansive lagoon in comparison to its edge, with its aggregation site located within the lagoon, specifically in the Panjarakon and Tangi regions of Bitra. Additionally, fishermen have documented the presence of shark and ray aggregations in the uninhabited islands of Cheriyapani and Valiyapani Reef. For Kadmat, the southern tip of the island, and the reef between Kadmat and Amni have been identified as a site of sharks (Figure 14).

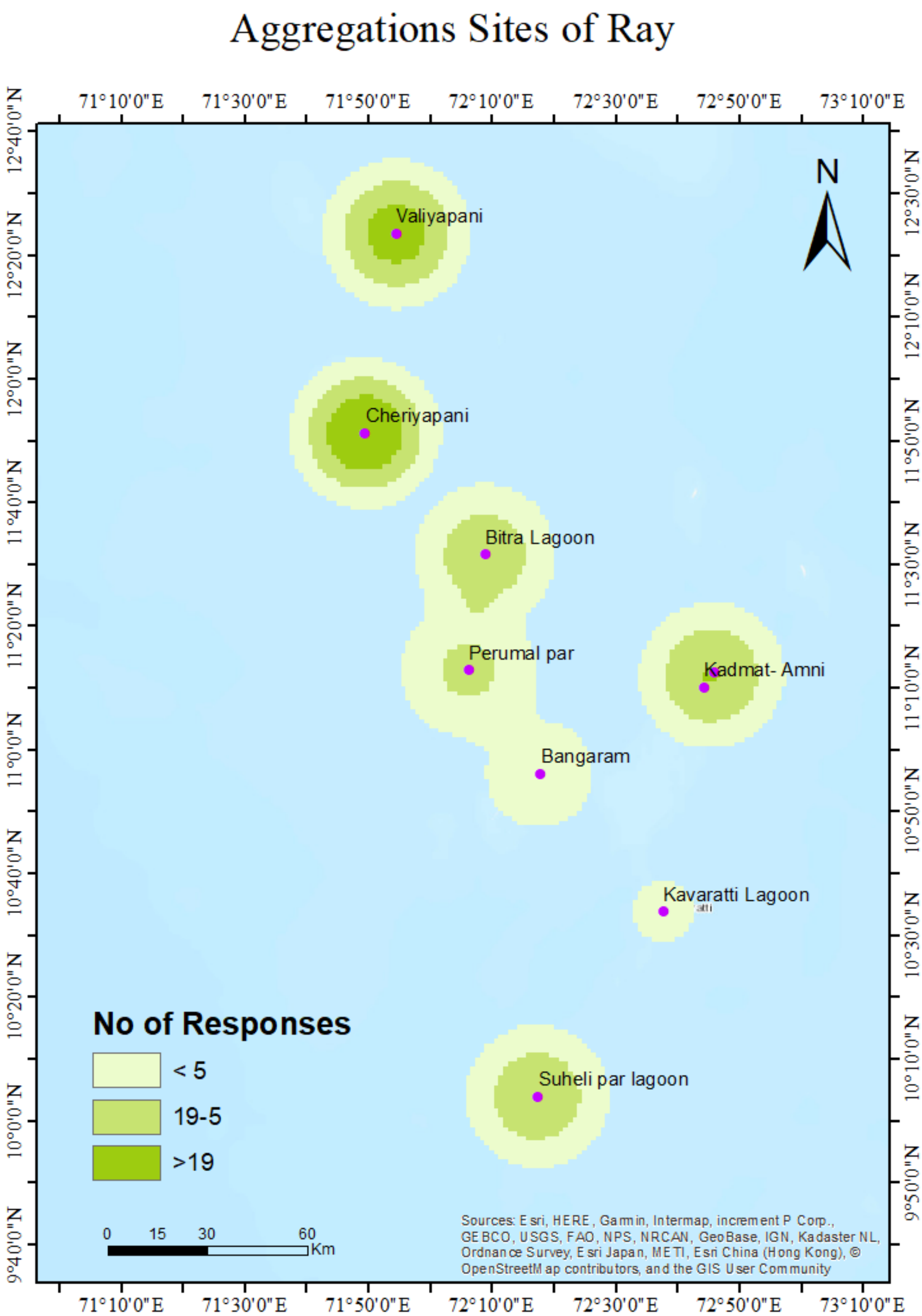

Figure 16 Ray Aggregation Sites Map

Ray aggregation locations. The most reported mentioned sites were Cheriyapani, 29 respondents and Valiyapani, 25 respondents. In Bitra, the ray aggregation sites include Bitra. 18 respondents reported in Bitra Lagoon. For Kadmat, the most reported aggregation site is Kadmat Lagoon, particularly near the jetty area, which is reported by 16 respondents. In Agatti, the Perumal Par site was reported by 14 respondents it's an uninhabited island adjacent to Agatti. In Kavaratti, 16 respondents reported in Kavaratti Lagoon and 19 respondents reported observations at Suheli. (Figure 17)

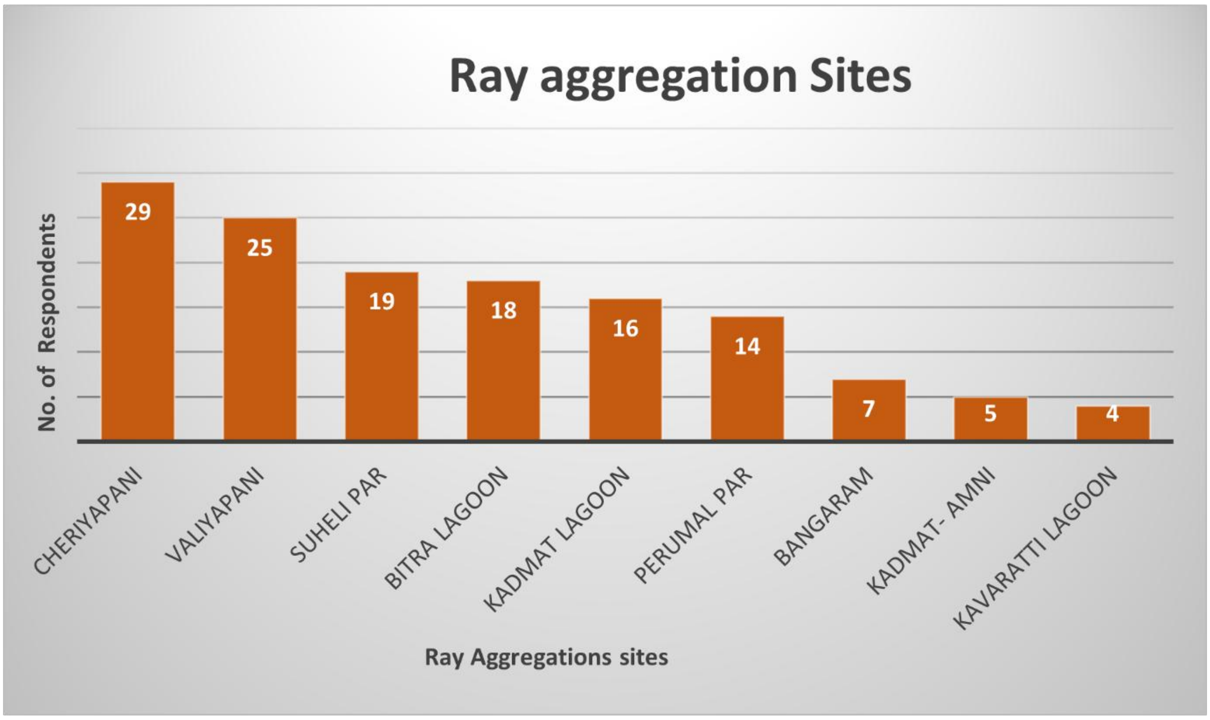

Figure 17 Ray aggregation graph

5.7 SHARK AGGREGATING SPECIES

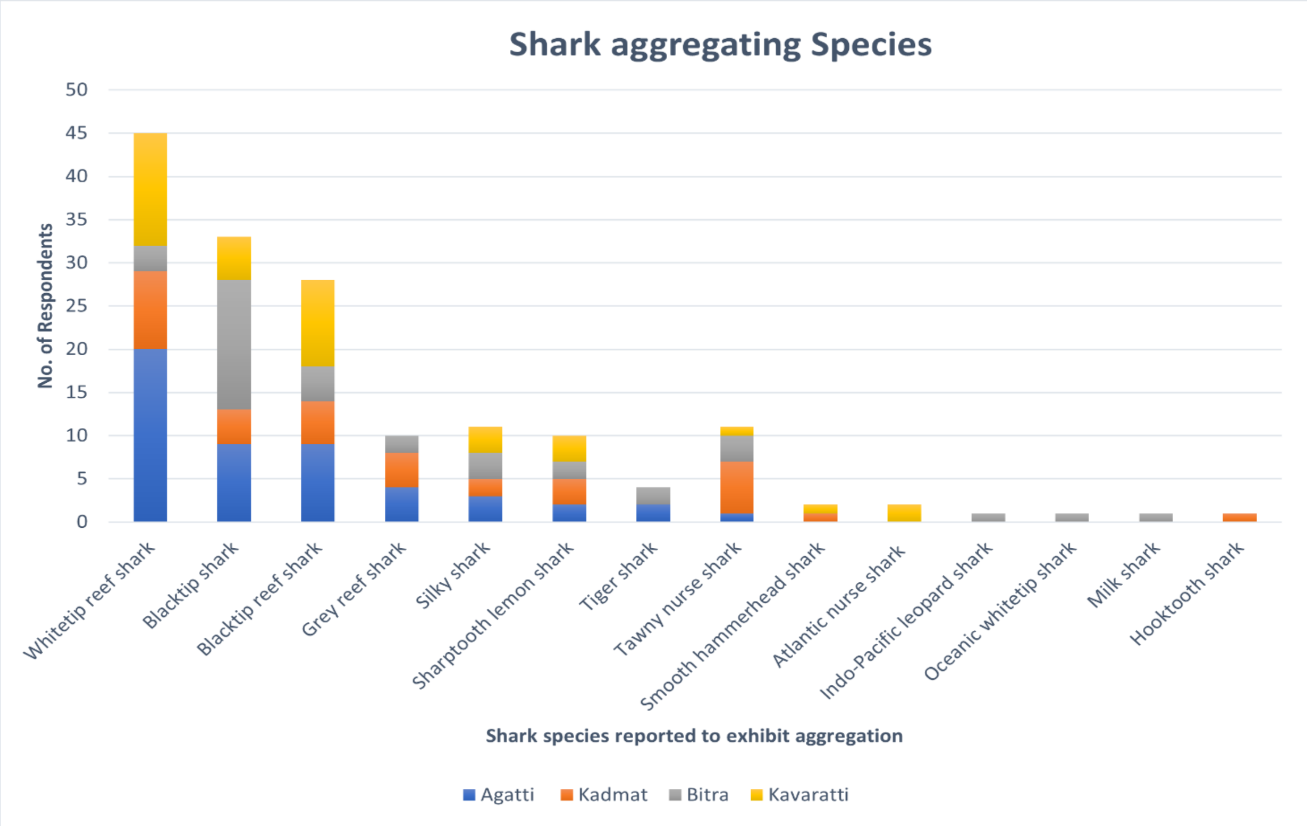

Figure 18 Shark aggregating species

1. KAVARATTI ISLAND SHARK AGGREGATION SPECIES

From the 23 species reported, 8 species were observed in aggregations by respondents. The most commonly reported species was the Whitetip Reef Shark *(Triaenodon obesus)*, mentioned by 34.2% of respondents. This was followed by the Blacktip Reef Shark *(Carcharhinus melanopterus)* at 26.3%, and the Blacktip Shark *(Carcharhinus limbatus*) at 13.2%. Aggregations of the Silky Shark (*Carcharhinus falciformis)* and the Sharp-Tooth Lemon Shark *(Negaprion acutidens)* were each reported by 7.9% of participants. Additionally, 5.3% mentioned the Atlantic Nurse Shark *(Ginglymostoma cirratum),* while both the Tawny Nurse

Shark *(Nebrius ferrugineus)* and the Smooth Hammerhead Shark *(Sphyrna zygaena)* were cited by 2.6% of respondents.

2. AGATTI ISLAND SHARK AGGREGATION SPECIES

From the 22 species reported, 8 species were specifically noted at aggregation sites by respondents. The whitetip reef shark was the most frequently observed aggregating species, with 40% of respondents reporting its presence. The blacktip shark and blacktip reef shark were each reported by 18% of respondents as aggregating near Agatti. Aggregations of the tawny nurse shark were infrequently reported, with only about 2% of respondents noting their presence. (Figure 18)

5. KADMAT ISLAND SHARK AGGREGATION SPECIES

Among the 24 species reported, 8 shark species were observed aggregating near Kadmat. The blacktip reef shark was the most commonly reported aggregating species, with 34.8% of respondents noting its presence in groups. The whitetip reef shark was reported aggregating by 19.6% of respondents, followed by the tawny nurse shark at 13%. A small percentage (2.2%) of respondents reported aggregations of smooth hammerhead sharks. (Figure 18)

6. BITRA ISLAND SHARK AGGREGATION SPECIES

Out of the 22 shark species reported, 11 species were observed in aggregations. The blacktip shark was most frequently reported as aggregating (40.5%), followed by the blacktip reef shark (10.8%). Aggregations of the milk shark were rarely reported (2.7%). (Figure 18)

5.7 RAY AGGREGATING SPECIES

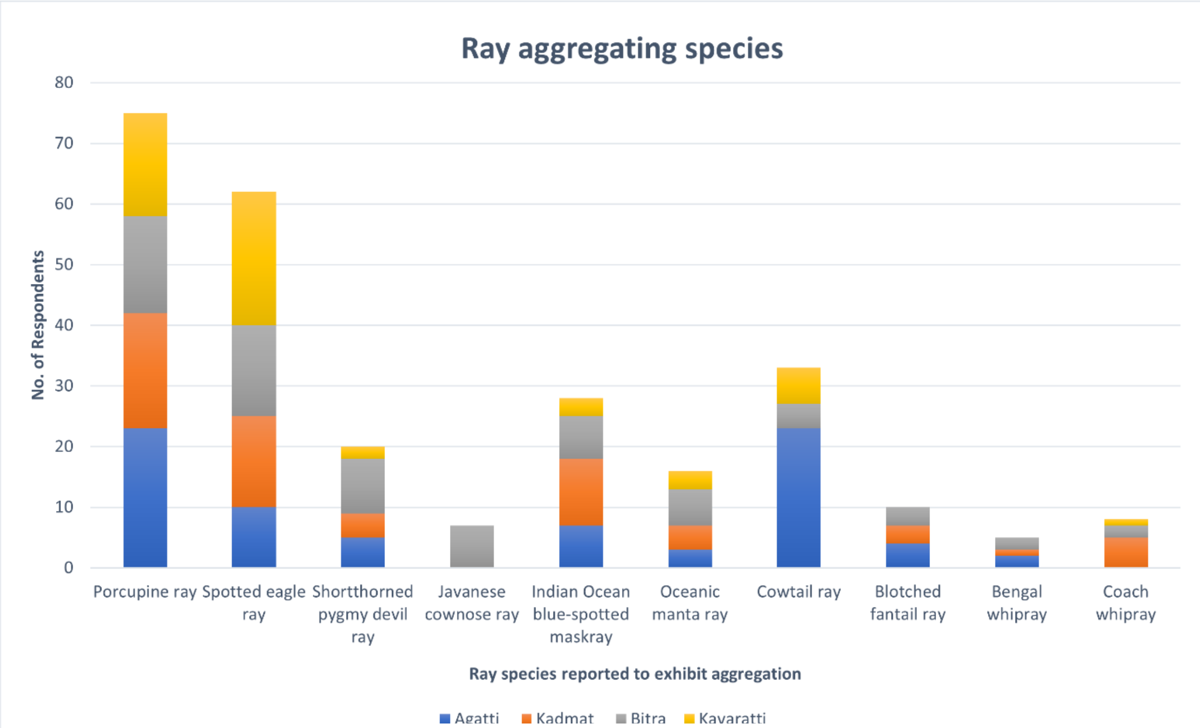

Figure 19 Ray aggregation species

1. KAVARATTI ISLAND RAY AGGREGATION SPECIES

Out of the 13 ray species reported, 7species were reported by respondents in aggregations near Kavaratti. The spotted eagle ray was most frequently cited as aggregating (40.7%), followed by the Porcupine ray (31.5%) and the Cowtail ray (11.1%). (Figure 19)

2 AGATTI ISLAND RAY AGGREGATION SPECIES

Out of the 13 ray species reported, 8 species were observed in aggregations by respondents. The cowtail ray was the most frequently reported aggregating species, with 31.5% of respondents having seen groups of this ray. This was followed by the porcupine ray (26%) and the spotted eagle ray (13.7%). Aggregations of the blotched fantail ray were reported by only 5.5% of respondents. (Figure 19)

3. KADMAT ISLAND, RAY AGGREGATION SPECIES

Out of the 13 species of rays reported, 8 species were reported in aggregations by respondents. Porcupine rays were most frequently reported, with 25.7% of respondents observing groups. The spotted eagle ray was reported aggregating by 20.3% of respondents, and the Indian Ocean blue-spotted mask ray by 14.9%. A small proportion (1.4%) of respondents reported aggregations of the Bengal whipray. (Figure 19)

7. BITRA ISLAND RAY AGGREGATION SPECIES

Among the 12 ray species reported, 10 species were reported in aggregations by respondents in this porcupine ray was most frequently reported in aggregations (22.5%), followed by the spotted eagle ray (21.1%) and the shorthorned pygmy devil ray (12.7%), a species not commonly seen aggregating in the other three islands. Aggregations of the coach whipray were rarely reported (2.8%). (Figure 19)

5.8 AGGREGATION TYPE:-

Respondents were asked about the species aggregation of sharks and rays around Kavartti Island. Among the 20 respondents, some reported single-species aggregation for both rays and sharks, while 16 respondents from Kavartti noted multi-species aggregation of sharks and rays. In Bitra, 27 respondents observed single-species aggregation, and none observed multi-species aggregation. In Kadmat, 27 respondents reported single-species observation, while 9 respondents noted multi-species aggregation. In Agtti, 27 responses indicated single-species aggregation, and 1 respondent observed multi-species aggregation. (Figure 20)

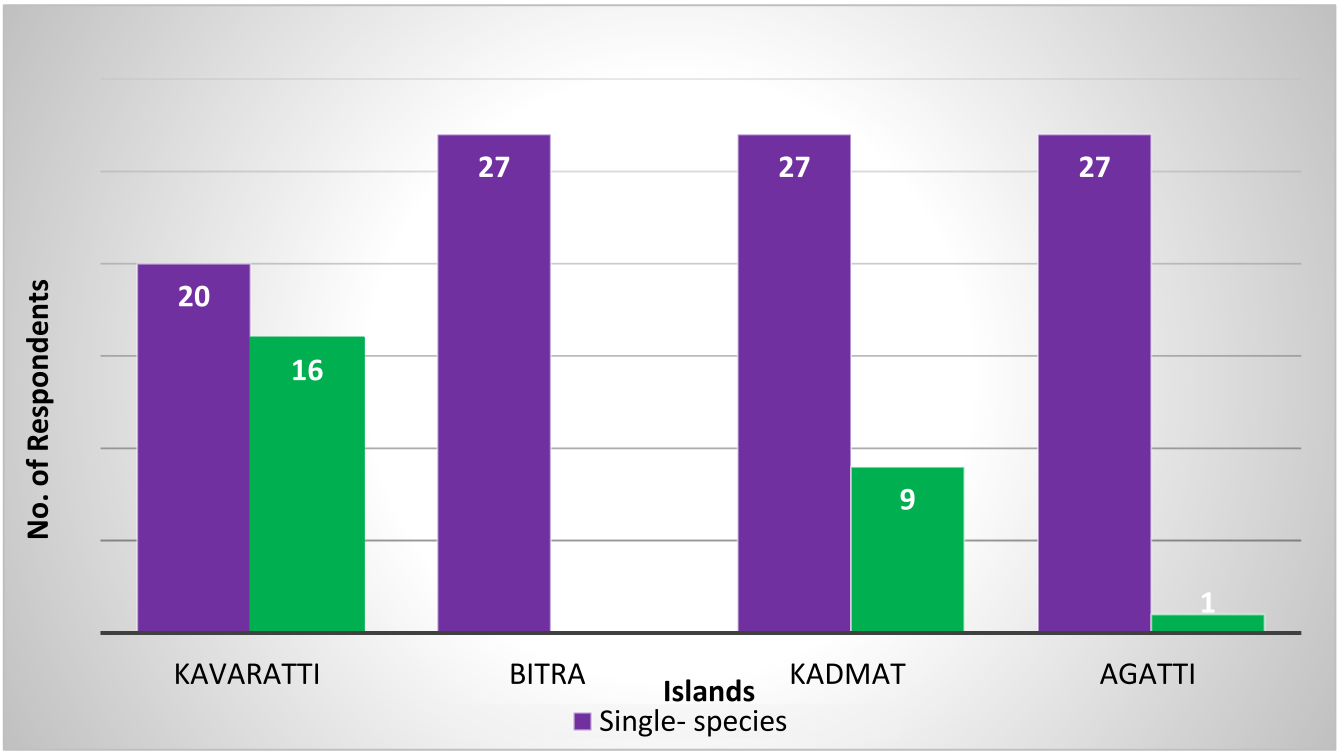

Figure 20 Aggregation type

5.9 SEASONS FOR SHARKS AND RAY AGGREGATION

When asked about the season of elasmobranch aggregation, around 63% of respondents reported sightings during the post-monsoon period (October to January). About 35% mentioned observing aggregations during the pre-monsoon months (February to May), while only 2% noted sightings during the monsoon season (June to September). (Figure 21)

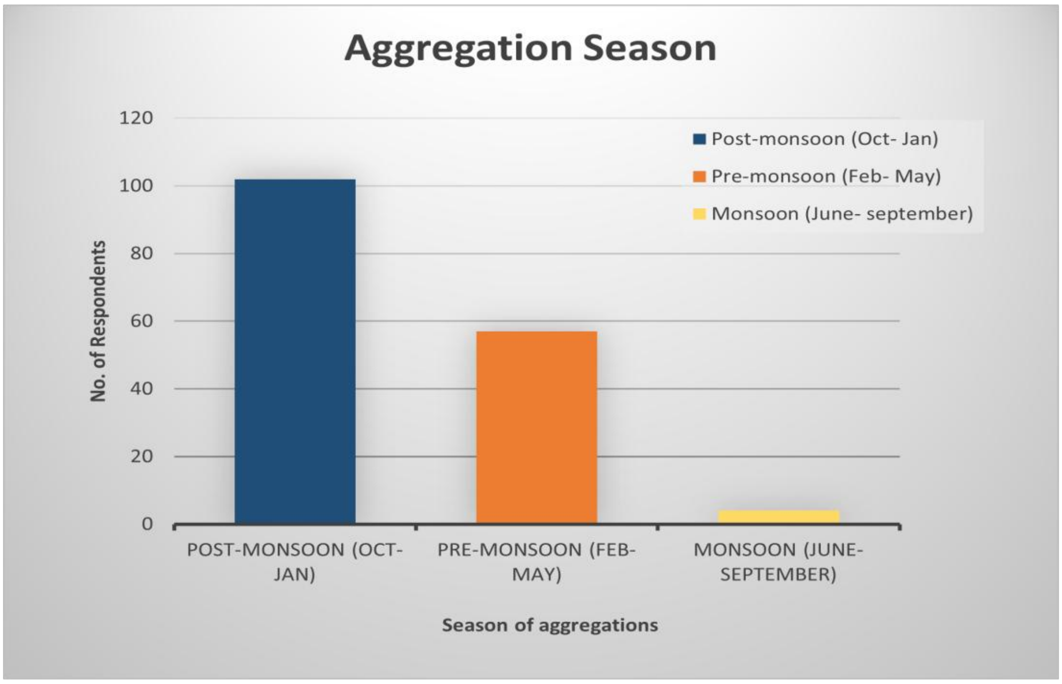

Figure 21 Aggregation seasons

5.10 TIDAL STATE FOR AGGREGATIONS

73% of respondents reported observing elasmobranch aggregations during high tide, whereas 27% indicated sightings occurred during low tide. (Figure 22)

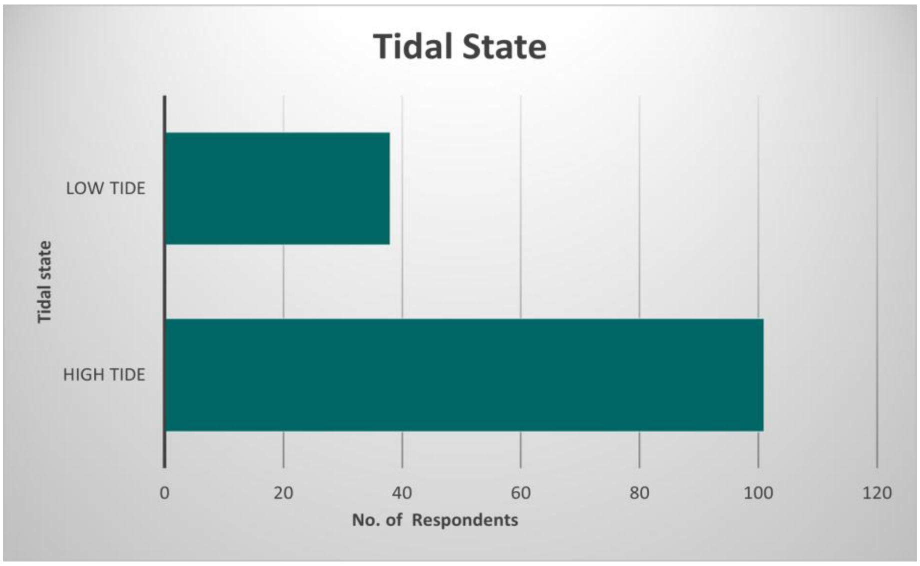

Figure 22 Tidal state

5.11 TIMING OF AGGREGATIONS

Most of the respondents talked about the tidal state. Around 68% of respondents mentioned morning aggregation behaviour, and20% of respondents saw the aggregation in the evening, and 6% of respondents saw the aggregation in the afternoon. Most of the aggregation has been seen by all the respondents in the morning. Morning time, the activity for the Sharks and Ray is more as compared to the evening at night as per the observations of respondents. (Figure 23)

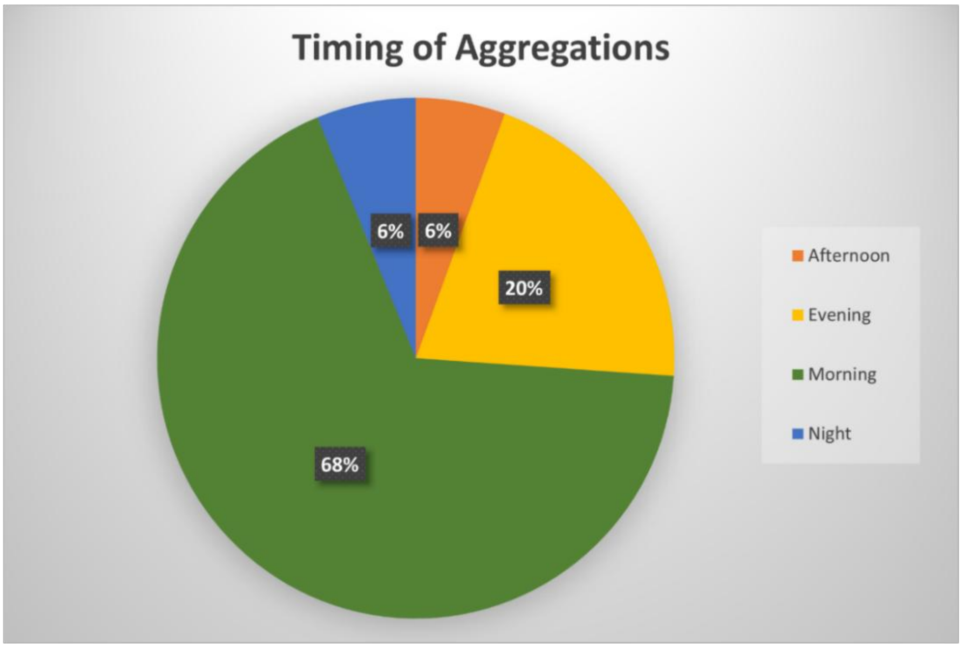

Figure 23 Time of aggregation

5.12 PROBABLE DRIVERS FOR RAY AGGREGATIONS

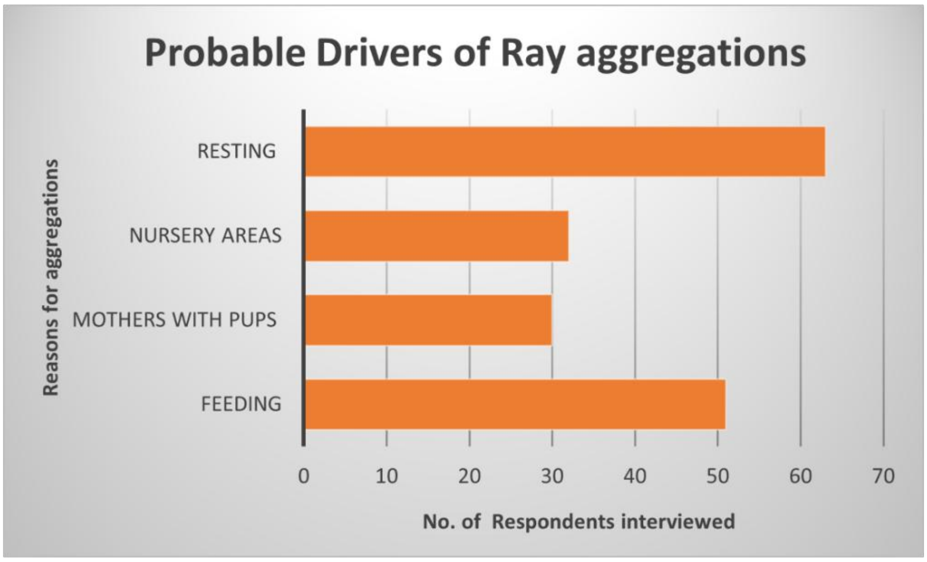

Figure 24 Probable drivers of Ray aggregations

The most probable drivers were resting, with 36 % of respondents reporting that they had seen rays gathered while resting, often on benthic sand substrates. Feeding was mentioned by 29 % of respondents. Nursery areas 18%, Mothers with pups 16% of respondents, the majority of respondents from Kadmat Island reported seeing cowtail stingray and porcupine ray aggregations specifically in the lagoon region, highlighting the ecological importance of these habitats for ray species in the Lakshadweep archipelago. (Figure 24)

5.13 PROBABLE DRIVERS FOR SHARK AGGREGATIONS

Shark aggregations, the most probable drivers reported by respondents, were feeding, cited by 48% of those who had observed shark groups. Resting 31% Mothers with pups 10% Nursery areas were mentioned by 11 % of respondents as sites where shark aggregations were observed. (Figure 25)

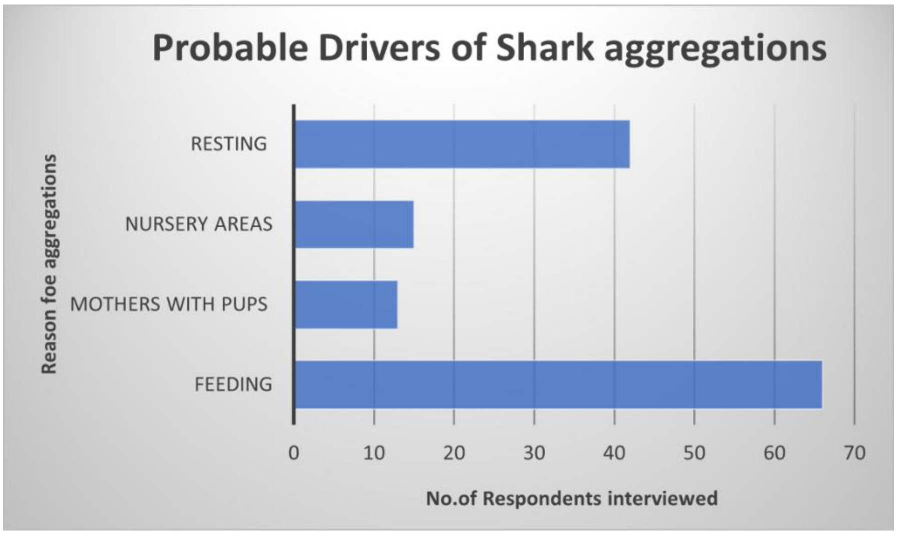

Figure 25 Probable Drivers of Ray aggregation

5.14 DETECTION IN BAITED UNDERWATER VIDEO DEPLOYMENT SURVEY (BRUVS)

I found no species of sharks or rays in the BRUVs. Several factors influence the observation of shark and ray species, including sampling strategies and the deployment of Baited Remote Underwater Video Surveys (BRUVs) within a limited timeframe from February to April. Low detection rates for sharks and rays in BRUVs can stem from various reasons, such as environmental conditions and seasonality, including sea currents. Often, when placing the camera underwater, I ensure it is weighed down to prevent drifting. However, underwater currents can still cause the camera to drift deeper; for instance, I placed a camera at a depth of 30 meters, but it ended up drifting to 40-50 meters. Through a semi-structured questionnaire survey of local fishers and scuba divers, I learned that the peak aggregation season for sharks occurs post-monsoon, primarily in November, December, and January. Studies have indicated that there are technological limitations as well, emphasising the need for modifications to the BRUV's camera structure based on local conditions. Understanding these factors is essential to enhance monitoring efforts. Additionally, short survey durations—like the mere two months I had in the field may not adequately capture the full diversity of individuals present. Research indicates that extending deployment periods can significantly increase the number of observed sharks (Gore et al., 2020)

5.15 OPPORTUNISTIC DRONE SURVEYS:-

As for the marine mammal transect survey in Lakshadweep, aggregations of rays are observed using drones in six locations. Also, it is very close to the aggregation sites where respondents said they have seen the rays in that location. (Table1)

Sr. no	Location	Island	Ray species	No. of individuals
1	Kavaratti Lagoon	Kavaratti	Cowtail Ray	8
2	Kavaratti entrance	Kavaratti	Spotted Eagle Ray	5
3	Kavaratti entrance	Kavaratti	Shorthorned pygmy devil ray	8
4	Kadmat lagoon	Kadmat	Cowtail Ray	8
5	Cheriyapani reef	Cheriyapani reef	Pelagic sting ray	6
6	Suheli par	Suheli par reef	Cowtail Ray	12

Table 1 OPPORTUNISTIC DRONE SURVEYS

5.16 HABITAT CHARACTERISATION OF AGGREGATION SITES:-

Out of 16 aggregation sites on 11 sites were conducted for the Habitat characterisation by the drop-down quadrant method. The percentage of the bottom cover of the aggregation site habitat is calculated. To know the habitat, quadrate percentage is calculated we dividing it into seven categories: Live coral, sand, coral boulders, algae and coral rubble. Open pelagic, calm/mussels, Live corals consist of coral species like *Acropora sp, Favia sp*. Sand benthic, coral boulders are rocky corals, produced in the lagoons or reefs, a type of stony coral, coral rubbles, which include the dead corals, bottom debris, and open pelagic. The depth was measured at more than 90m.

1. KAVARATTII ISLAND AGGREGATION HABITAT - LAGOON AND THE SOUTHERN TIP

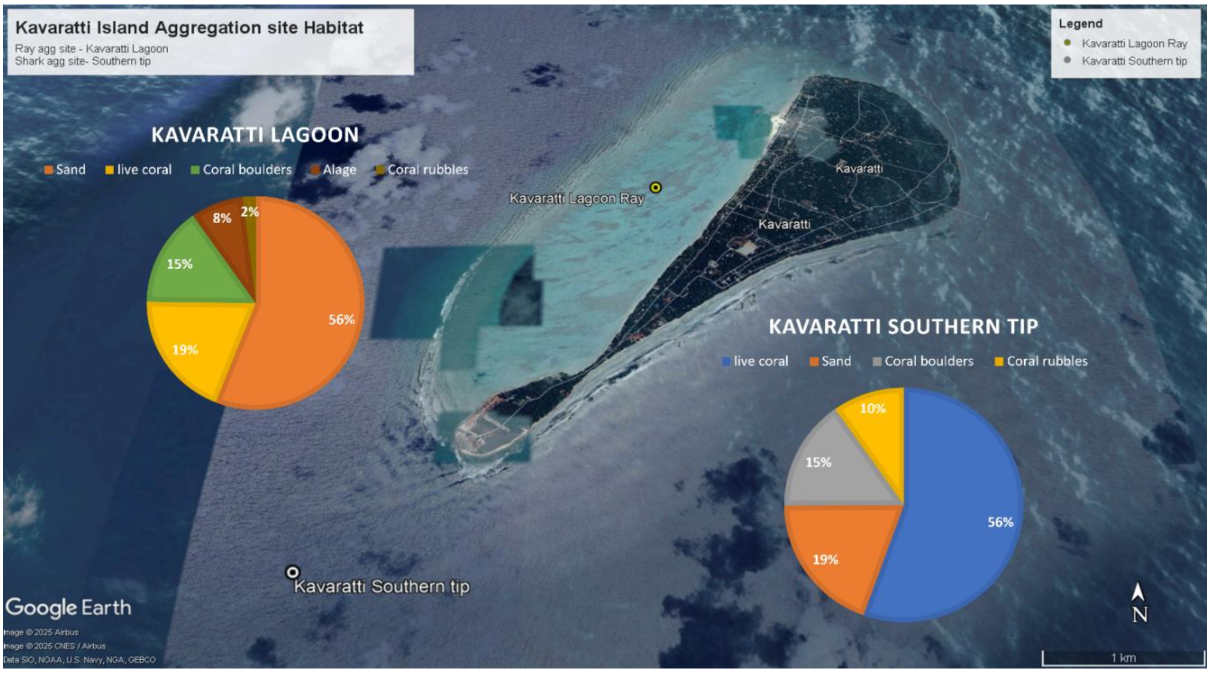

Figure 26 . KAVARATTII ISLAND AGGREGATION HABITAT - LAGOON AND THE SOUTHERN TIP

Kavaratti lagoon is the ray aggregation location, as indicated by the number of responses from fishermen and scuba divers. Kavarratti lagoon habitat comprises 56% sand, followed by 19% live corals, with the least coral rubble, 2%. Kavaratti Southern tip is a shark aggregation site, which comprises 56% live corals, 19% sand, 15% coral boulders and 10% coral rubble. (Figure 26)

2. KADMAT ISLAND AGGREGATION HABITAT - LAGOON AND SOUTHERN TIP

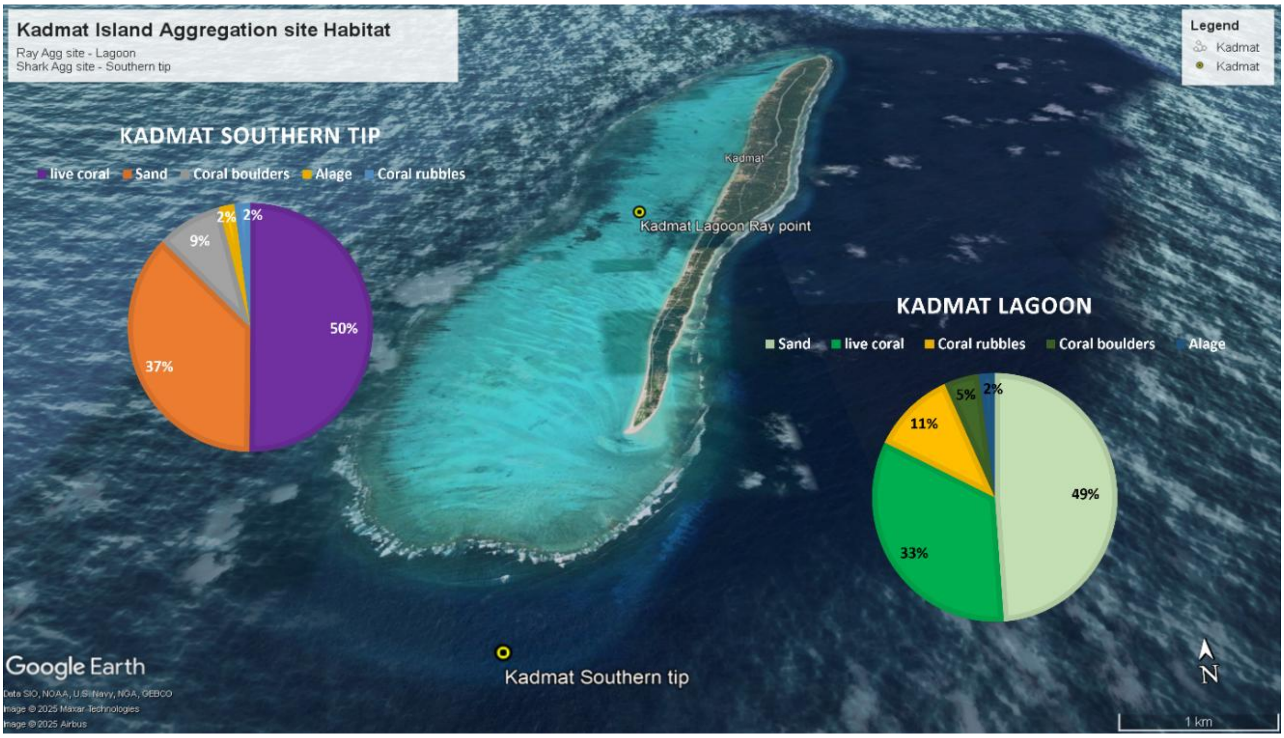

Figure 27 . KADMAT ISLAND AGGREGATION HABITAT - LAGOON AND SOUTHERN TIP

Kadmat lagoon is a ray aggregation site bottom substrate that consists of 49% bottom substrate ground cover. It is sand and 33% live corals. Kadmat has a very shallow depth in the lagoon, and the corals are dominated by *Acropora sp.* Kavaratti's Southern tip is a Shark aggregation site. The habitat comprises 50% of live corals, 37% of sand, 9% of coral boulders, 2% of algae and coral rubble. (Figure 27)

3. BITRA ISLAND AGGREGATION HABITAT – PANJARAKON AND LAGOON

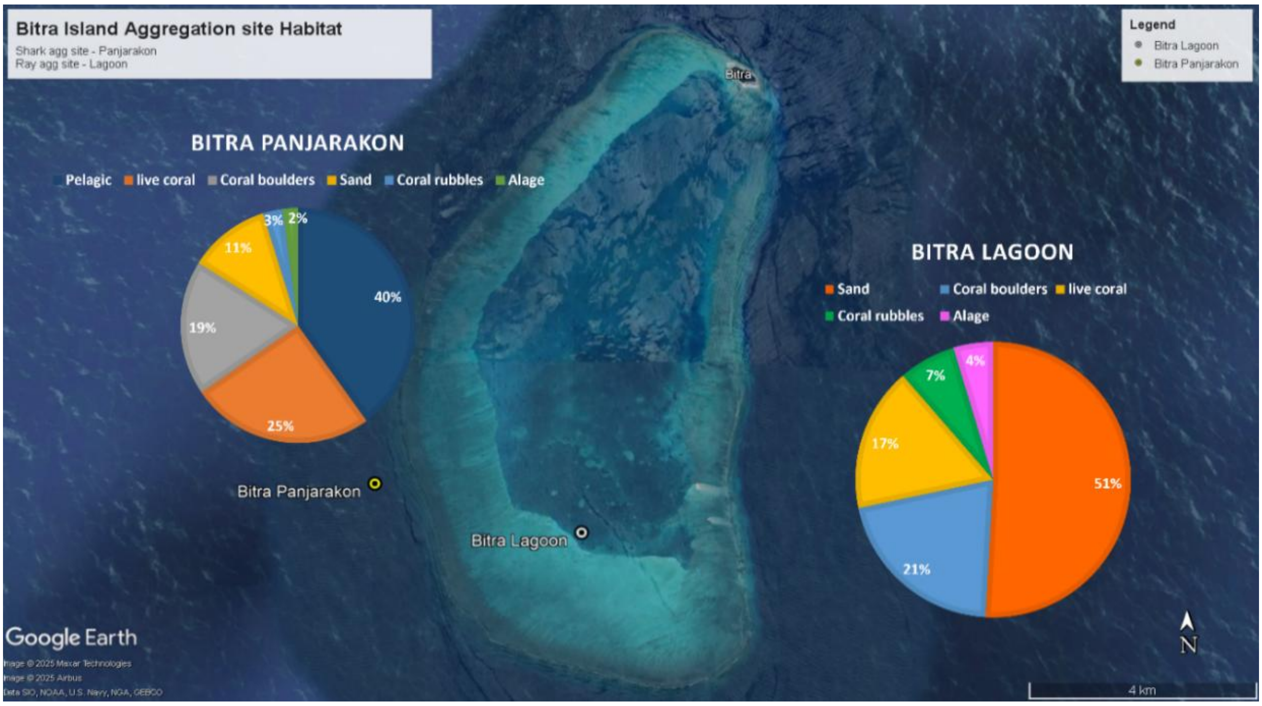

Figure 28 BITRA ISLAND AGGREGATION HABITAT – PANJARAKON AND LAGOON

Bitra Lagoon is the largest lagoon among all the islands of the Lakshadweep archipelago. It is a ray aggregation site. 51% bottom substrate is sand, 21% coral boulders, 17% live corals, 7% coral rubbles, and 4 % comprises of Alage. Panjarokon is a shark aggregation site is a curve just after the lagoon, most of the habitat is covered, 40% open pelagic, 25% live corals, 19% coral boulders, 11% sand, 3% coral rubble, 2% algae. This aggregation site comprises multiple microhabitats. (Figure 28)

4. SUHELI PAR AGGREGATION HABITAT – SUHELI NORTH AND LAGOON

Suheli Par is an uninhabited island. Suheli North Island, called Valiyakara it is a shark aggregation site. The habitat comprises 52% open pelagic, 27% live corals, 10% coral boulders, 9% sand and 2% coral rubble. Suheli Par Lagoon is the ray aggregation site which comprises 57% of sand, 25% of live corals, 6% coral rubble and coral boulders. (Figure 29)

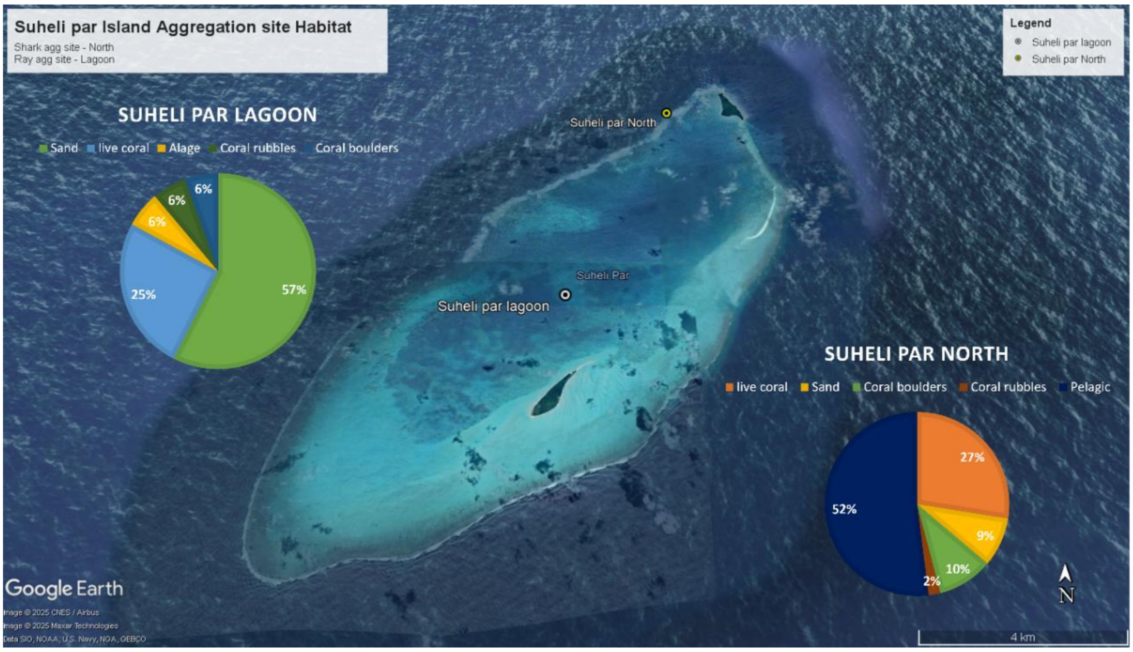

Figure 29 SUHELI PAR AGGREGATION HABITAT – SUHELI NORTH AND LAGOON

5. AGATTI WEST SIDE AGGREGATION HABITAT

On Agatti west side the habitat is mostly comprised of 48% pelagic, 26% live coral, 14% sand, 9% coral rubble and 3% rubble. Due to diverse habitat types, it's an important aggregation site for the whitetip reef shark. (Figure 30)

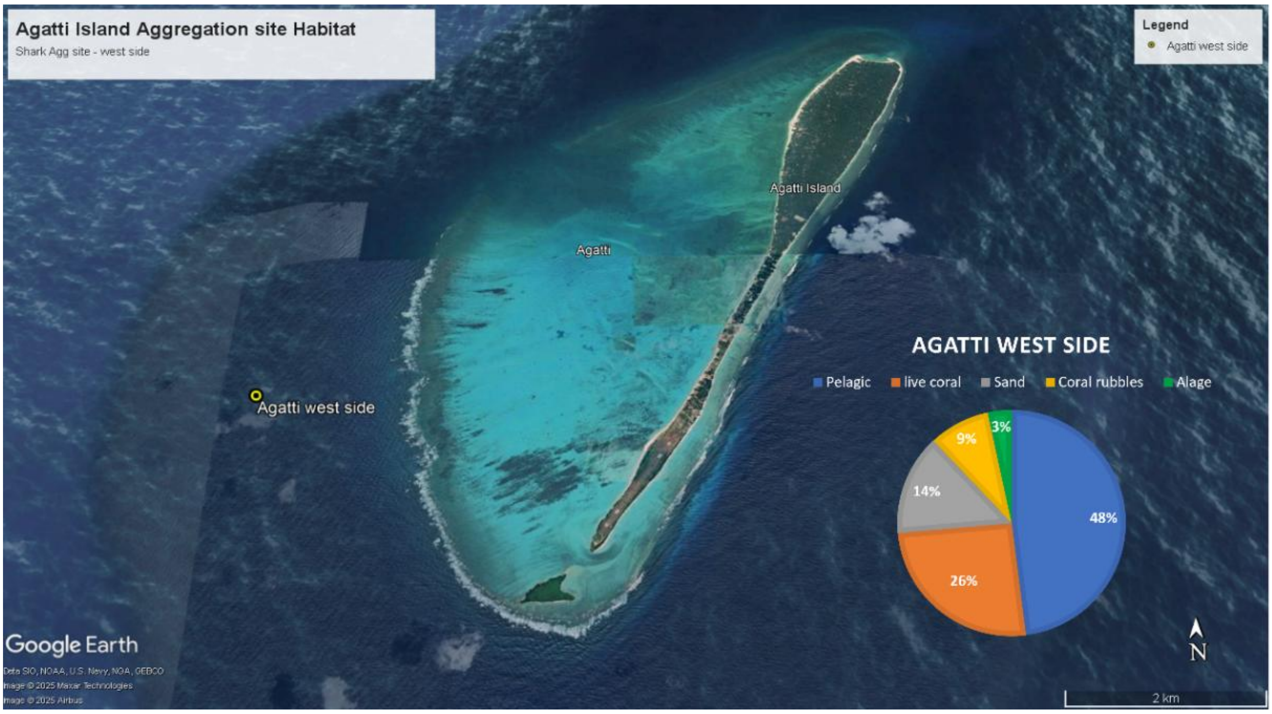

Figure 30 AGATTI WEST SIDE AGGREGATION HABITAT

6. VALIYAPANI REEF AGGREGATION HABITAT

Valiyapani is the aggregation site of an uninhabited island further north of Bitra. Here, 47 % of the bottom substrate is sand, followed by coral boulders, and 6% of the area is composed of calms. Which is not found in sampling on another island. (Figure 31)

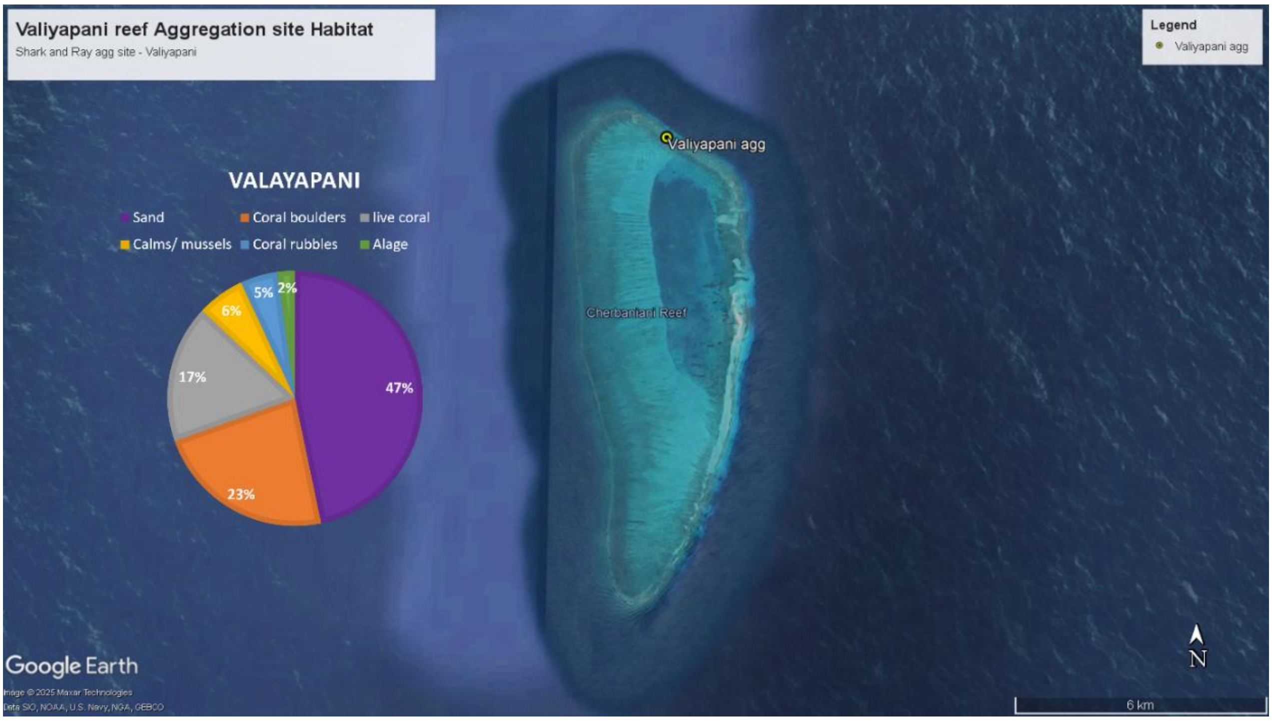

Figure 31 VALIYAPANI REEF AGGREGATION HABITAT

7. CHERIYAPANI REEF AGGREGATION HABITAT

Cheriyapani reef aggregation site of sharks and rays reported by fishermen is an uninhabited island where we recorded the habitat characteristics. 50 % of the habitat is live corals, 40% of sand50 % of coral boulders and coral rubble. (Figure 32)

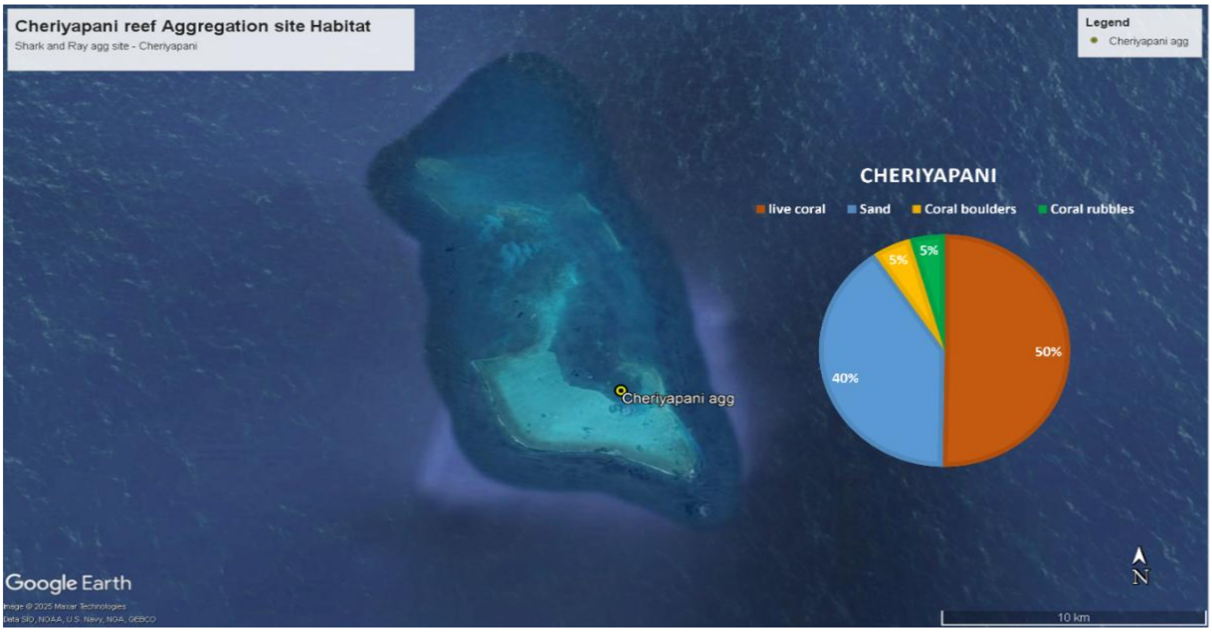

Figure 32 . CHERIYAPANI REEF AGGREGATION HABITAT

5.17 DEPTH OF AGGREGATION SITES:-

As with the drop-down quadrant method, depth is also recorded at every point in the transect. The average depth of shark aggregation sites is 31.5 m (Figure 33), which is in the reefs adjoining the lagoon area. Ray average depth is 6.7 m, which is a habitat in the lagoon region. (Figure 34)

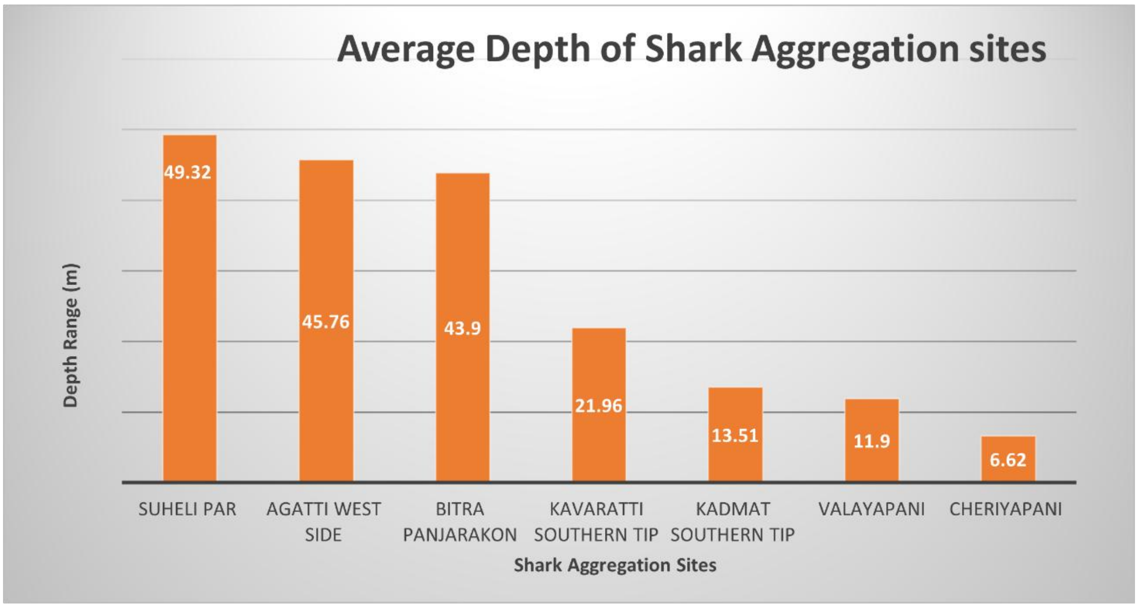

Figure 33 AVERAGE DEPTH OF SHARK AGGREGATION SITES

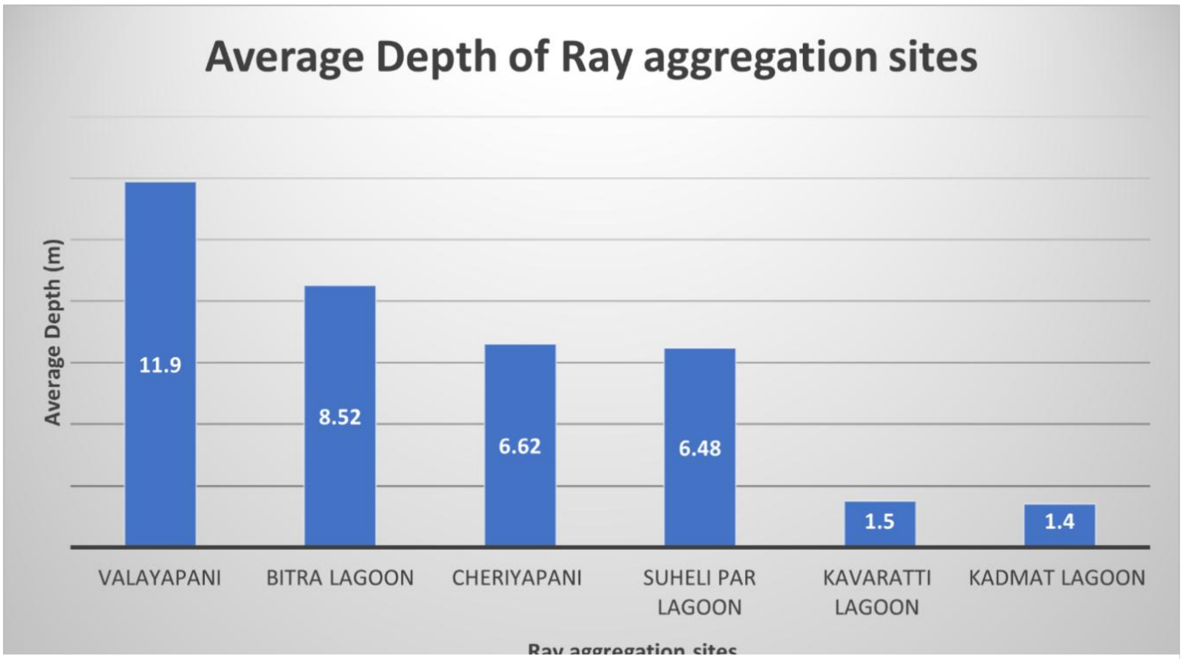

Figure 34 AVERAGE DEPTH OF RAY AGGREGATION SITES

CHAPTER 3

6. DISCUSSION

The aggregation sites of elasmobranch sharks and rays play a vital role in their lives, as these species are highly ecologically specialised (Makwana et al., 2024). Understanding the species composition of elasmobranchs in selected islands of Lakshadweep is crucial for gaining insights into their aggregation sites. Through a semi-structured interview survey, it was found that most islanders are engaged in fishing practices. They use traditional methods such as pole and line fishing, primarily targeting tuna. Other fishing techniques include beach seine and gill net fishing. Bitra is particularly significant due to its minimal use of hook-and-line fishing, a method often associated with shark targeting. This reliance on less intense fishing technology might explain the higher concentrations of sharks and rays observed there, as fishing pressure remains relatively low compared to islands where long-line fishing dominates. The study by Kumar et al., 2015) highlights the correlation between elasmobranch abundance and fishing gear.

Respondents reported twenty-four shark species and thirteen ray species. This research provided insights into local ecological and traditional knowledge regarding species, aggregation sites, habitats, and fishery methods practised across the four major islands: Bitra, Kavaratti, Kadmat, and Agatti.

Sixteen aggregation sites were identified from the survey, with Cheriyapani, Valiyapani, and Bitra being key regions. Blacktip reef sharks and whitetip reef sharks are observed aggregating in these areas, as confirmed by habitat characteristics observed during regional surveys. It was found that lagoon regions are highly important for ray aggregations, especially cowtail rays and mask rays. The reef areas of Kavaratti, Kadmat, and Suheli are dominated by live coral and coral boulders, whereas Valiyapani is a primary aggregation site for sharks and rays. Local fishermen from Bitra noted that rays aggregate to feed on *"Muchroli*," a calm species also observed in habitat surveys. During peak post-monsoon seasons, targeted shark and ray fishing occurs during aggregation periods, primarily in the morning hours.

Elasmobranch aggregations are distributed across the islands, with certain key sites. Sharks tend to aggregate mostly in open pelagic zones with depths over 60m and reef areas with depths ranging from 15-40m, while rays are more commonly found in shallow lagoon areas, less than 20m deep. An opportunistic drone survey detected high aggregations of rays. Remote regions such as Cheriyapani, Valiyapani, and offshore submerged banks like Suheli Par and Perumal Par highlight critical habitats that support large aggregations. These areas likely serve as refuges from disturbance and fishing pressure.

In undisturbed conditions, these habitats may promote group behaviours such as foraging, resting, or reproduction. According to local fishing knowledge, rays are frequently seen in benthic sandy bottom habitats that are crucial in supporting benthic elasmobranch species. Rays like the Indian Ocean blue-spotted mask ray and porcupine ray are associated with resting and nursery grounds in Kadmat and Bitra. While the sandy lagoon areas are vital, they are difficult to observe due to ray cryptic behaviour and challenges in visualising turbid or sandy-bottom habitats. Shark aggregations are most often linked to feeding activities, suggesting these are and possibly seasonal aggregations showing site fidelity. Long-term studies require multiple methodologies, such as drone-based surveys and modifications of the BRUVs methodology, are necessary to accurately determine the abundance of sharks and rays in the aggregation sites.

7. CONCLUSION:-

A study of sharks and rays requires very detailed, long-term research to understand their occurrence, habitat, and drivers of aggregation patterns. In Lakshadweep, I have learned from traditional ecological knowledge shared by fisherfolk and scuba divers that aggregation sites are crucial for the conservation of these species. For long-term studies, these social and non-social aggregations help us explore the ecological features essential for their protection. Elasmobranchs are sensitive and ecologically adapted species. Species like the whitetip reef shark, blacktip shark, and tawny nurse shark are adapted to the coral reef habitat, while the cowtail ray, Indian Ocean blue-spotted masked ray, and porcupine ray are observed in the benthic sandy lagoon region. The transition zone between the lagoon and open pelagic zone provides a suitable habitat for reef sharks and rays, which are mostly benthic organisms that prefer shallow coastal lagoon waters for potential breeding and nursery areas. This study highlights the first comprehensive traditional ecological knowledge of sharks and rays in Lakshadweep by identifying key aggregation sites. These sites play vital roles in their life history, biology, ecology, and behaviour.

To better understand the diverse behaviours and patterns of aggregation, long-term studies could incorporate UAVs (Unmanned Aerial Vehicles), such as drone surveys, for species that aggregate seasonally. Integrating drone technology into elasmobranch research has significantly advanced knowledge of sharks and rays' behaviour, movement, and social interactions at aggregation sites (Butcher, Paul A., et al, 2021). Future efforts should focus on expanding the use of underwater drones (ROVs and AUVs) and refining drone-based methodologies to identify confirmed feeding and breeding grounds, which will aid in the conservation and management of elasmobranchs in the coral islands of Lakshadweep.

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9. ANNEXURES

Checklist of Sharks and Ray species Reported by Respondents from Bitra, Agatti, Kavartti, and Kadmat in Lakshadweep

Table 2 CHECKLIST OF SHARK SPECIES

Sr. No	Shark species	Scientific name	IUCN Status
1	Whale Shark	*Rhincodon typus*	Endangered
2	Smooth hammerhead shark	*Sphyrna zygaena*	Vulnerable
3	Oceanic whitetip shark	*Carcharhinus longimanus*	Critically Endangered
4	Winghead shark	*Eusphyra blochii*	Endangered
5	Tiger shark	*Galeocerdo cuvier*	Near Threatened
6	Grey reef shark	*Carcharhinus amblyrhynchos*	Endangered
7	Blacktip reef shark	*Carcharhinus melanopterus*	Vulnerable
8	Silky shark	*Carcharhinus falciformis*	Vulnerable
9	Blacktip shark	*Carcharhinus limbatus*	Vulnerable
10	Shortfin mako shark	*Isurus oxyrinchus*	Endangered
11	Longfin mako shark	*Isurus paucus*	Endangered
12	Lemon shark	*Negaprion brevirostris*	Vulnerable
13	Sharptooth lemon shark	*Negaprion acutidens*	Endangered
14	Common thresher shark	*Alopias vulpinus*	Vulnerable

15	Pelagic thresher shark	*Alopias pelagicus*	Endangered
16	Bigeye thresher shark	*Alopias superciliosus*	Vulnerable
17	Whitetip reef shark	*Triaenodon obsesus*	Vulnerable
18	Atlantic nurse shark	*Ginglymostoma cirratum*	Vulnerable
19	Indo-Pacific leopard shark	*Stegostoma trigrinum*	Endangered
20	Tawny nurse shark	*Nebrius ferrugineus*	Vulnerable
21	Hooktooth shark	*Chaenogaleus macrostoma*	Vulnerable
22	Milk shark	*Rhizoprionodon acutus*	Vulnerable
23	Scalloped hammerhead shark	*Sphyrna lewini*	Critically Endangered
24	Bramble shark	*Echinorhinus brucus*	Endangered

Table 3 CHECKLIST OF RAY SPECIES

Sr. No	**Ray species**	**Scientific name**	**IUCN Status**
1	Spotted eagle ray	*Aetobatus ocellatus*	Endangered
2	Bengal whipray	*Brevitrygon imbricata*	Vulnerable
3	Coach whipray	*Himantura uarnak*	Endangered
4	Oceanic manta ray	*Mobula birostris*	Endangered
5	Shorthorned pygmy devil ray	*Mobuka kuhlii*	Endangered
6	Indian Ocean blue-spotted maskray	*Neotrygon indica*	Data deficient
7	Cowtail ray	*Pastinachus sephen*	Near Threatened

8	Bowmouth guitarfish	*Rhina ancylostomus*	Critically endangered
9	Javanese cownose ray	*Rhinoptera javanica*	Endangered
10	Whitespotted wedgefish	*Rhynchobatus djiddensis*	Critically endangered
11	Blotched fantail ray	*Taeniura meyeni*	Vulnerable
12	Black- spotted torpedo ray	*Torpedo fuscomaculata*	Data deficient
13	Porcupine ray	*Urogymnus asperrimus*	Vulnerable

1. List of Shark Aggregation species

Table 4 CHECKLIST OF SHARK AGGREGATION SPECIES

Sr. No	Shark species	Scientific name
1	Smooth hammerhead shark	*Sphyrna zygaena*
2	Oceanic whitetip shark	*Carcharhinus longimanus*
3	Tiger shark	*Galeocerdo cuvier*
4	Grey reef shark	*Carcharhinus amblyrhynchos*
5	Blacktip reef shark	*Carcharhinus melanopterus*
6	Silky shark	*Carcharhinus falciformis*
7	Blacktip shark	*Carcharhinus limbatus*
8	Sharptooth lemon shark	*Negaprion acutidens*
9	Whitetip reef shark	*Triaenodon obsesus*

10	Atlantic nurse shark	*Ginglymostoma cirratum*
11	Indo-Pacific leopard shark	*Stegostoma trigrinum*
12	Tawny nurse shark	*Nebrius ferrugineus*
13	Hooktooth shark	*Chaenogaleus macrostoma*
14	Milk shark	*Rhizoprionodon acutus*

2. List of Ray aggregation species

Table 5 CHECKLIST OF RAY AGGREGATION SPECIES

Sr. No	Ray species	Scientific name
1	Spotted eagle ray	*Aetobatus ocellatus*
2	Bengal whipray	*Brevitrygon imbricata*
3	Coach whipray	*Himantura uarnak*
4	Oceanic manta ray	*Mobula birostris*
5	Shorthorned pygmy devil ray	*Mobuka kuhlii*
6	Indian Ocean blue-spotted maskray	*Neotrygon indica*
7	Cowtail ray	*Pastinachus sephen*
8	Javanese cownose ray	*Rhinoptera javanica*
9	Blotched fantail ray	*Taeniura meyeni*
10	Porcupine ray	*Urogymnus asperrimus*

PLATE 1 :- Drone footage - Shorthorned pygmy devil ray

PLATE 2:- Drone footage – Pelagic Sting ray

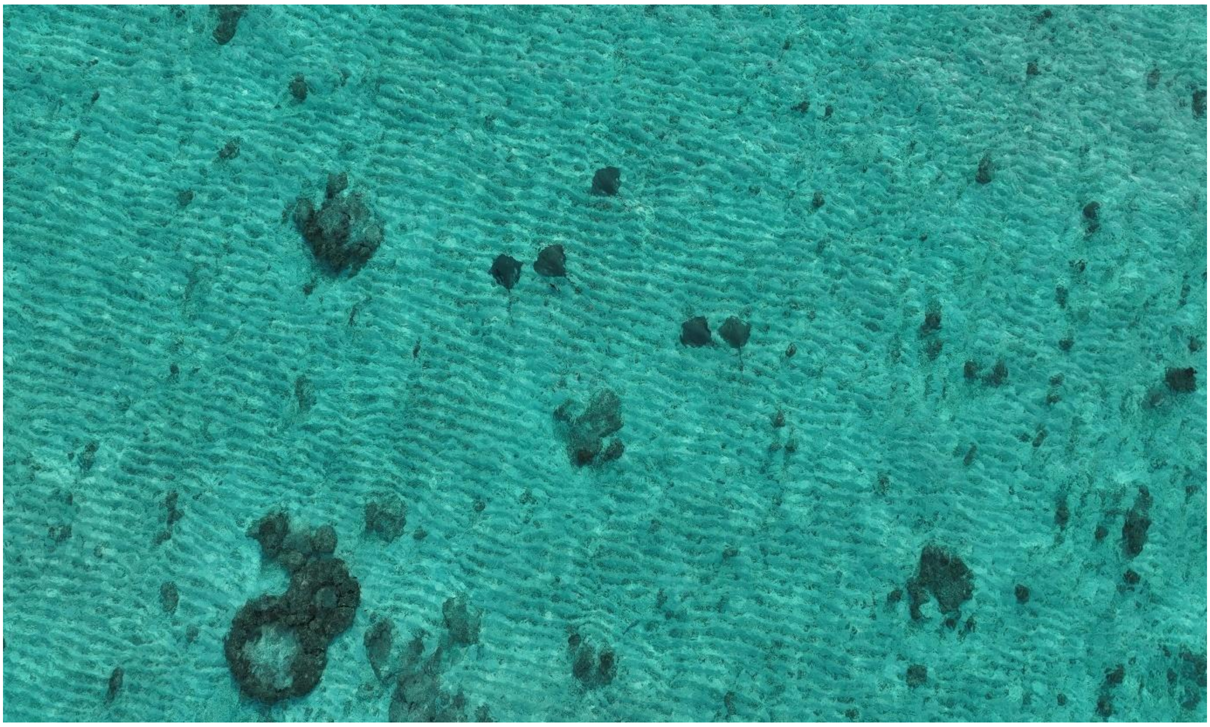

PLATE 3:-Cheriyapani reef

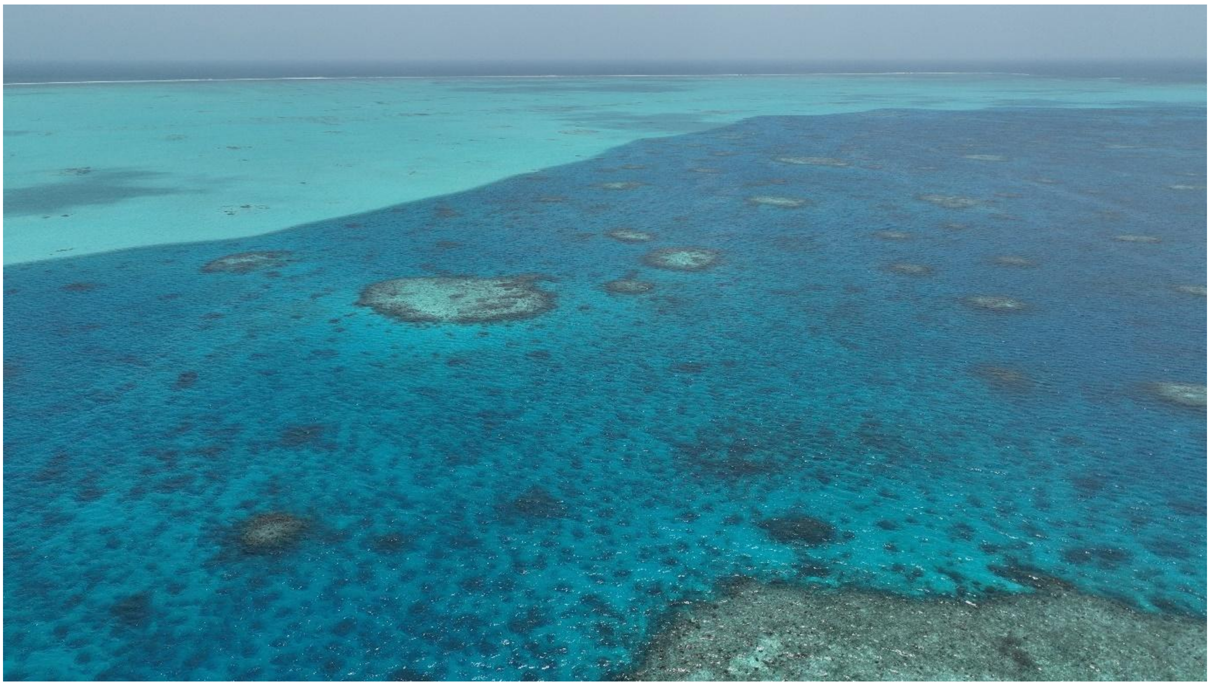

PLATE 4:- BRUVs Footage – Giant trevally

PLATE 5:- Baited Remote Underwater Video Surveys Structure

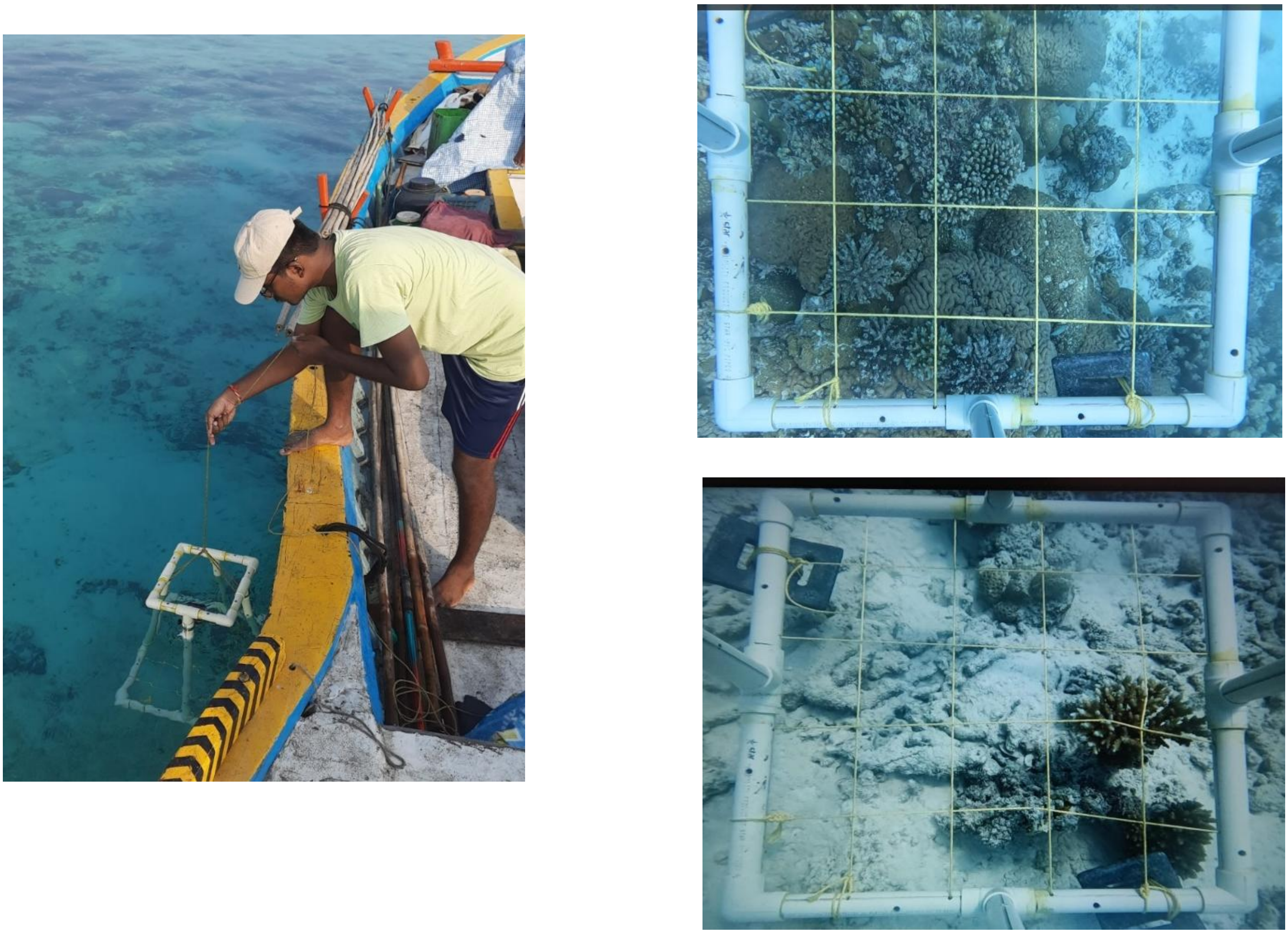

PLATE 6:- Drop down quadrant (left), Bottom substrate while sampling (Right)