Livebait Fishery of the Maldives

Fishing Grounds in the Central and Southern Atolls, Fisher Perception and Current Trends in Fishery

MNU Research Grant URG-2021-L-AS04

September 2023

THE MALDIVES NATIONAL UNIVERSITY

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About Maldives National University

One of the main goals of Maldives National University is fostering exemplary research and innovation. To encourage and promote research culture amongst the staff of MNU, research grants are awarded annually. The research grants are awarded to support and encourage national and international research and innovation on multi-disciplinary thematic areas. It also addresses the needs of the community and support to improve the socioeconomic and cultural development of the nation.

About IPNLF

The international Pole and Line Foundation (IPNLF) works to develop, support and promote socially and environmentally responsible pole-and-line and hand line and troll fisheries around the world. IPNLF's ambition is to contribute to thriving coastal fisheries including the people, communities and businesses and the seas connected with them. IPNLF is an international charity working across science, policy and the seafood sector that uses the influence of the market to develop and demonstrate the value of one-by-one caught tuna to thriving coastal fisheries and the people and seas they connect. IPNLF is officially registered as a charity in the UK in January 2012. IPNLF-Maldives is IPNLF's local chapter registered in the Maldives in October 2020.

About the REPORT

It is fair to assume livebait fishing takes place throughout the Maldives — on shallow reefs and slopes and in atoll lagoons. But it is different to ask fishers to mark them on a map of 0.025° x 0.025°- degree spatial resolution across the atolls of the Maldives. That was the main objective of this project – to identify livebait fishing grounds in the Maldives by fishers themselves, including what species they caught, how frequently they fish and in what seasons. Why? The answer is simple. Tourism development has been rapid and still ongoing. In the process, the authorities have been allocating uninhabited islands and, recently submerged reefs/shallow lagoons to reclaim islands. Depending on the geographic nature of the island, resorts have exclusive rights up to 500 – 1000 meters from the shoreline. This puts fishers at a disadvantaged position as more and more potential livebait fishing grounds are becoming out of bounds to them. It is hoped the identification of livebait fishing grounds on maps indicating their preference and use of those sites in the Maldives will be useful for spatial planning purposes and help improve environmental impact assessments of development projects, such as resorts, reclamations, and dredging. More importantly it is also believed that the work would contribute to conservation and management of livebait fishery, critical for pole-and-line and handling tuna fisheries of the Maldives.

The report also provides an analysis of fisher perceptions on topical issues of livebait fishery; their practice and views on how best to conserve and manage the resources including their willingness to pay for both wild caught and cultured livebait if they are readily available. The report also provides some interesting confirmation of results of the perception survey through an exploratory analysis of the fishery observer data on livebait (for years 2014-2021) reported here for the first time. Data preparation and mapping of bait fishing grounds were done by Mohamed Shimal. Dr. Ahmed Riyaz Jauharee helped in developing and trialing the survey for gathering information from fishers and compiled the first chapter on review of livebait fishery. The survery tool was developed in collaboration with the Maldives Marine Research Institute. Dr. Shiham Adam conducted observer data analysis, compiled and edited the report. Ibrahim Nadheeh and Ibrahim Saneeh spent numerous hours with fishers meticulously recording responses from fishers and marking fishing locations on maps.

The project is carried out by The Maldives National University under the research Grant URG-2021-L-AS04, awarded to Senior Lecturer Mrs. Mariyam Nashath at Faculty of Engineering, Science and Technology of MNU. Nashath, the principal investigator, oversaw the implementation of the project and supported in training Bachelor of Marine Science and Bachelor Environment Management students of 2021 and 2022 batches in developing survey tools and implementation of the tools throughout the project. IPNLF took the responsibility of executing the project.

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Executive Summary

Livebait fishing is vital to the tuna fisheries of the Maldives, where hook and line methods exclusively target tuna. Both pole-and-line and handline fisheries rely heavily on livebait, sourced from coral reefs and lagoons, to attract and sustain schools of feeding tuna within close proximity to fishing vessels. The practice of livebait fishing is nested within the tuna fishery, typically occurring at the outset of each fishing trip. Livebait varieties are found throughout the Maldives, inhabiting shallow reefs, slopes, and atoll lagoons. The rapid expansion of tourism has led to the allocation of uninhabited islands for resort development, restricting access to surrounding reefs. More recently, the issue has been exacerbated by designating shallow reefs for reclamation and resort island construction.

The primary objective of this project is to comprehensively map livebait fishing areas by conducting interviews with fishers, allowing them to pinpoint those areas and specify their use — including time of day, season, and target species. Identification took place on gridded maps featuring a spatial resolution of 0.025° x 0.025° degree grid cells spanning the Maldives' atolls. These grids, hierarchically linked at all aggregation levels presented on high-resolution maps categorized by fishery, time of day, season, and by species distinctly highlight significant areas at the atoll level. These findings can prove invaluable for the conservation and management of livebait resources in the Maldives.

Additionally, the survey encompasses a perception component, wherein fishers were invited to share their perspectives on pertinent issues within the livebait fishery. Topics of discussion included light bait fishing, the captivity of livebait, post-harvest mortality, the potential for livebait fishing to become an independent fishery, and the willingness of fishers to buy cultured and harvested bait. The initiation of this perception survey by the Maldives Marine Research Institute (MMRI) aligns with the government efforts to explore cultured livebait. The results from this perception survey substantiated the findings derived from the exploratory data analysis of observational data. This convergence of evidence bolsters the reliability and credibility of the report's conclusions.

In summary, the report, synthesizing mapping, data analysis, and perception surveys, provides an all-encompassing view of fishing locations, trends, and fisher perspectives. These insights will serve as a valuable resource for policymakers, conservationists, and stakeholders dedicated to the sustainable management of this vital fishery.

Background & Context

Livebait is essential for tuna fishing. Conducted on shallow reef areas, slopes and atoll lagoons, fishers had no restriction on where they could fish. That was around the 1980s and earlier. However, to accommodate the rapidly developing tourism sector and consequent socio-economic development of the country, large numbers of uninhabited islands and associated reefs and lagoons are being allocated for tourism, and other commercial activities making those house reefs and surrounding areas inaccessible to fishers for livebait fishing.

During the last 20 years or so, the tourism industry has expanded across the entire Maldives. The lease agreement of the resorts grants the developer rights to fully protect up to between 500 - 1,000 meters[1] from the mean tide level of the island. This has manifested resort management barring fishers access to their reef for livebait fishing or any other activities resulting conflicts between tourism and fisheries[2]. At the time of this writing in early 2023 there are 168 operational resort islands and further 197 islands designated for resort development[3] currently in various stages of development.

Tourist resort development projects require an environmental impact assessment (EIA) to obtain environmental clearance from the Environmental Protection Agency (EPA). A key question posed during the EIA process, especially in reclamation projects, is whether the proposed development area is a “popular” livebait fishing ground or not. Unless there is specific information on livebait fishing in area the authorities must state either there is no information or the area is a fishing ground, for any reef area of the Maldives could potentially be a livebait fishing ground.

The recent trend of reclaiming shallow reefs/lagoons for resort development, reclamations to expand land area on inhabited islands, and consequent sacrificing of large number of livebait fishing areas has been an issue for fishers. However, their voice and concerns are not heard. It is believed that part of the solution towards protection or at least sparring popular fishing grounds would be to identify and mark them on maps. It is with this objective in mind that we formulated this project and that MNU awarded the grant.

There were also objectives other than to simply the map the livebait fishing areas. It was

[1] Under Regulation 2023/R-90, unless stated otherwise in the Lease Agreement of the Resort, or for resorts having islands or lagoons within their home reef, the boundary for which resorts have exclusive rights is up to 500 meters from the mean tide mark of the island. For resort islands with lagoon / reef flat extending more than 500 meters from mean tide mark the boundary for which resorts have exclusive rights is up to 1,000 meters.

[2] Fisheries Forum Report 2019: https://www.gov.mv/en/files/report-fishermens-forum-2019-maldives.pdf

[3] President’s Office. (n.d.). Projects. Isles. Retrieved January 25, 2023, from https://isles.gov.mv/Home/en

also the aim to undertake a review of the livebait fishery of the Maldives to provide context of the fishery and state of scientific knowledge fishery. We also provide an exploratory analysis of fishery observer data at IPNLF-Maldives that provide status and trends in the fisheries. During the project we invited Maldives Marine Research Institute (MRRI) to help us co-create the questionnaire for the livebait survey. MMRI team also instigated having series of questions to understand fisher perceptions on topical issues of the day; how fishers maintain livebait, how they feel about the malpractices in the livebait fishery, including their willingness to pay for wild caught and the cultured lived bait if they are readily available.

The maps we have produced can be provided at several levels because each grid is associated with information on the locale (atoll), type of fishery (PL or HL) and species (12), and season (NE or SW) and whether the fishing is done during day or night. Thus, the maps can be provided at the entire country, by atoll, by fishery and season, by species and by day/night. However, we chose to present the maps only at the fishery level (pole-and-line and handline), by major species, and by atoll. There are plans to extend the survey and provide series maps to compile the livebait atlas of the Maldives.

Review of Information on Livebait Fishery of the Maldives

Introduction

Fishing in the Maldives has continued to be of significant importance to the Maldivians over several centuries. Tuna fishing was considered an important activity even before Maldives conversion to Islam in 1153-1154 AD (Lister, 2016). Thus, it is believed that people living in these atolls have caught and consumed tuna for over a millennium (Anderson et al., 1996). Tuna is the main species exploited across the Maldives even today. In 2020 recorded amounts of tuna and tuna like species accounted for about 95% of the marine produce in the Maldives. Catches are dominated by skipjack tuna (65-70%) followed by yellowfin tuna (15%). Other species of tuna caught in the Maldives included bigeye tuna, kawakawa, frigate tuna and dogtooth tuna (MNBS, 2020). Several other species of fish and invertebrates are also caught in the Maldives. These included billfishes, wahoo, several species of reef associated fish, sea cucumber and lobster (MNBS, 2020).

Unlike industrial and other major tuna fisheries, the Maldivian tuna fisheries catch fish with hook and line, literally catching one fish at a time. The time honored tradition and is an

important livelihood activity of the Maldivians, particularly of those living on the outer islands. The tuna harvesting sector employs the majority of the domestic workforce in the outer atolls supporting their families, providing food and employment opportunities (Edwards et al., 2019). Current catches are around 100,000 MT annually and over 85% of the catch is from pole-and-line methods using livebait.

In the past, with limited educational opportunities, transport and communication between the islands and the international communities, the percentage of the population engaged in fishing was much higher across all the atolls. With expansion of education, tourism and other business opportunities the tendency towards 'white collar' jobs became more popular among the youth. This led to a decline in the number of youths joining the fishing industry.

During the 2020 pandemic when the country went into a shutdown and when there was zero tourist arrival, many locals who were working in the tourist resorts became unemployed. These locals had to return to their local communities and several of them chose to join the tuna fishery. Thus, the tuna fishery helped them earn an income and food to sustain their families, highlighting the importance of the tuna fishery for the nation even during the pandemic.

The Livebait Fishery

Despite the importance of the livebait fishery, there has not been comprehensive studies of the fishery and its resource base. However, several smaller studies have been undertaken. A number of earlier descriptive accounts for the Maldives fishery includes some information on livebait, e.g., Munch-Petersen (1980). Accounts of livebait fishing methods are given by Anderson (1983 & 1995), and Waheed and Zahir (1990). The major livebait varieties used are described by Anderson and Hafiz (1984). A brief review of the Maldivian livebait was provided by Anderson and Hafiz (1988) and later reprinted in a revised form in Maniku et al. (1990). The biology of some of the livebait species, including information from studies of reproduction, growth and predation is discussed by Milton et al. (1990a) and Milton et. al (1990b). Seasonal and regional and inter-annual variations in the utilization of livebait within the Maldives are described by Anderson and Saleem (1994 & 1995). Estimates of the size of the Maldivian livebait fisheries are provided by Anderson and Hafiz (1988) and Anderson (1994). Management issues are discussed by Anderson and Hafiz (1988), and Wright (1992). To properly account for the livebait harvested by tuna fishery a section to collection information on bait caught was included in the logbook introduced in 2010. In 2013 Marine Research Centre (MRC) developed a livebait management plan (Gillett et al. 2013) but was never gazetted. In 2015, a review of the livebait fishery associated with the pole-and-line tuna fishery was conducted (Jauharee et al. 2015).

Livebait Species

Livebait used in the pole-and-line tuna fishery consists of small pelagic and reef-associated species (Table 1) that are sourced from the waters of the atoll lagoon. Most of the targeted species for livebait have short generation times and a high population turnover, although some livebait is likely to consist of juveniles (e.g., cardinal fish). The availability of livebait species varies greatly between seasons and regions throughout the Maldives (Anderson and Saleem, 1994) which combined with the large quantities required per fishing trip and year-round fishing have resulted in fishers complaining of shortages of livebait.

There are other fisheries that utilize livebait (Gillett, et al. 2013) creating additional demand on the resource: various forms of reef fishing and the yellowfin handline fishery require large quantities of livebait on a regular basis. In addition, some baitfish, particularly sprats and scads, are now routinely caught and landed as a food fish increasing total livebait catch. In the mid-2000s total estimated bait catch was at 15,000 Mt per year (Gillett, et al. 2013).

Table 1: Livebait fishes utilized in the Maldives – arranged in descending order of importance as observed in the study.

Local Name	English Name	Scientific Name	Fishery
Rehi	Silver sprat (SRH)	*Spratelloides gracilis*	PL
Boadhi	Cardinal fish (APD)	Apogonidae (fam) - various Sp	PL
Hondeli	Blue sprat (SPD)	*Spratelloides delicatulus*	PL
Miyaren	Shorthead Anchovy (ENR)	*Encrasicholina heteroloba*	PL
Mugraan	Fusiliers (CJX)	Caesionidae (Fam) - various sp	PL / HL
Nilamehi	Blue damsel (TNC)	*Chromis viridis*	PL/HL
Mushimas	Bigeye Scad (MSD)	*Selar crumenophthalmus*	HL
Rimmas	Round Scad (MSD)	*Decapterus macarellus*	HL
Kalhu Rondu	Redtooth niger (RTF)	*Odonus niger*	HL
Gumbalha	Bluestripe herring (CLP1)	*Herklotsichthys quadrimaculatus*	PL/HL
Thaavalaha	Hardy head (CLP2)	*Atherinomorus lacunosus*	PL/HL

Livebait Catch and Utilization

The bait fishery in the Maldives is well documented. Summaries of many aspects are given in Anderson (1997), Adam (2006), Anderson (2009), and Gillett (2012). Despite data collection methods for the tuna fishery being well developed as early as the 1960s (Anderson and Hafiz, 1988), there has been no data collection effort for the livebait fishery. In the past livebait fishing data was gathered opportunistically during field trips undertaken by MRC, now MMRI, Maldives Marine Research Institute. Such data collection activities to estimate annual livebait utilization in the pole-and-line fishery were conducted from 1978 to 1981; 1985 to 1987; 1993 to 1994 and in 2003 (Table 2).

During 1978 to 1981 the estimated livebait catches was 3,000 to 3,500 tons/year (Anderson and Hafiz, 1988; Anderson 1994) and for 1985 to 1987 it was estimated at 5,100 ± 2,800 tons/year (Anderson and Hafiz, 1988; Anderson 1994). For 1993 the livebait catches was estimated at 11,100 ± 2,800 tons/year. These estimates were based on the data collected by MRC staff. Some shortcomings in the methods of estimation for these periods included inadequate sampling activities (Anderson, 1994). In 2014 several field trips were conducted to gather data on livebait fishery. From this data the average livebait catch for a tuna fishing trip was 148 kg. The estimated livebait catch for 2014 was approximately 10,063 tons and based on the total tuna catches by pole and line vessels it was estimated that 11.8 kg of tuna was caught using 1 kg of livebait. Analysis of the IPNLF's observer data showed that roughly 12,100 tons of livebait were harvested annually during 2017-2022.

Table 2: Estimates of historic annual livebait utilization in the pole-and-line fishery. After Anderson and Hafiz (1988), Anderson (1994, 1997 & 2009) and Adam (2006) and for current study (last row).

Period	Estimated Catch	Bait Utilization	
	Mt / year	Kg of bait / day	Kg of tuna/ Kg of bait
1978 – 1981	3,250 ± 800	32	7.4
1985 – 1987	5,100 ± 1,300	32	10.0
1993 – 1994	11,000 ± 2,700	49	7.5
2003	15,000	72	9.6
2014	10,063	148	11.8
2017-2022	12,110	325	19.7

Using observer data on estimated livebait harvests and tuna caught in pole-and-line fishery (see Analysis of Observer Data), it was estimated that 325 kg livebait were required per

fishing trip. The livebait utilization ratio was much higher indicating more efficient utilization of livebait during the period. Part of the reason for this apparent increase in efficiency could be that these data were mainly from the south where pole-and-line is more prevalent and large catches are taken during periods of good fishing.

It is clear that the tuna catch-per-unit bait or "livebait utilization ratio[4]" is around 12 kg of tuna per kg of livebait (range 7.3 - 13.0 for estimates). This is much lower compared, for example, with the estimate from Pacific and Minicoy in Lakshadweep where some 20-30 kg of tuna are recorded to have been caught per kg of livebait (IPNLF, 2012). It is not entirely clear why the livebait utilization ratio is lower in the Maldives compared to other livebait pole-and-line fisheries. It may be the fishers are used to chumming large amounts of livebait to catch tuna. Or there is a high percentage of postharvest mortality of pelagic livebait species such as sprat which are used most frequently across the Maldives.

Systematic data collection in the livebait fishery across the Maldives began with the introduction of tuna fishery logbooks in 2010. It is mandatory for the fishers to report their catches using the logbook which gathered information on bait species, bait fishing ground, duration of bait fishing operation, amount of tuna caught using the bait. The bait catch was recorded in the logbook as an estimate of weight in kilograms. Based on the feedback from fishers and field work conducted by MRC a new logbook was introduced in 2013 in which fishers reported their bait catch as the number of scoops of bait. By then most fishers had started using scoops to transfer their catch from the bait net into the bait hold.

There was a problem with this measure of bait quantity, however; the size of the scoop used on different pole-and-line vessels varied. Initially the scoops used were very large (diameter approximately 50cm) and two people were required to handle these scoops. As the fishers realized scooping large quantities of small fish at once increased the mortality of livebait (from information disseminated by MRC), they gradually switched to smaller scoops (diameter approximately 35cm) which could be easily handled by one person. In 2014 and 2015 MRC staff conducted field work on board pole-and-line fishing vessels to estimate the average weight of livebait that was taken using the smaller scoops. For the pole-and-line fishery this average value (12kg) is now used to convert the number of scoops of bait catch reported in the logbook to weight.

The revised logbook introduced in 2013 gathered data on:

- Date of catch
- Position of bait catch (reported as a number on the grid in the position chart
- provided at the back of the logbook)

[4] In principle it may not be utilization, because the ratio is between the estimates of livebait **caught** (not utilized) on the trip for catching the tuna.

- Bait type (ten possible species)
- Duration of fishing (total amount of time spent on livebait fishing)
- Amount caught (bait scoops)
- Discarded catch (bait scoops)

Livebait Harvesting

Livebait fishing technique has basically remained the same over the centuries. However, the scale of the livebait fishery today has expanded and the efficiency has also increased very much. This has some consequences too. Livebait fishing is part of the daily tuna fishing operations. Unlike in many parts of the world where livebait is collected by separate vessels and then sold to tuna fishers, the livebait fishery in the Maldives is conducted at sea by tuna fishers using tuna fishing vessels and takes place prior to almost every tuna fishing trip.

In the past livebait fishing was undertaken during early morning hours (Adam et al., 2003) utilizing small rectangular lift-nets deployed from the sides of boat. This technique of livebait catching involved making use of snorkelers in the water who actively forced schools of fish on to the net. Even during daytime bait fishing, depending on the species targeted, the approach varies. If pelagic species such as sprats and anchovies are targeted the net is attached to two long poles and lowered into the water and lifted trapping the tiny fish inside the net. The vessel is usually not anchored. Demersal species such as cardinal fish and fusiliers are mainly caught after anchoring the vessel. Weighted nets are lowered into the water close to the sea floor and with the help of swimmers the net is spread open. Depending on the species chum is used to attract the bait onto the net or the bait are heard onto the net by varying techniques such as chasing with coconut frond, plastic pipes or making a sound with chains attached to the end of a rope.

Over the years with the introduction of technology several changes have taken place in the methods used for aggregating livebait. Now fish finders are widely used to identify and locate livebait aggregations. Powerful lights – 4 to 6 flood lights (2000W each) above the surface and 3000W submersible lights are simultaneously used to aggregate bait under the vessel. Divers with the help `of SCUBA spread huge nets (130 x 100 feet) on the sea floor and heard the bait onto the net using torch lights.

Once the bait net is pulled to the surface, the net is kept along the side of the vessel and the livebait are quickly transferred into the flooded bait tank using large scoop nets (kavaavashi). Wet scooping is practiced by several fishers as it enables the bait to survive longer in the bait tank. Seawater in the bait tank is circulated with the help of pumps.

Postharvest mortality in livebait fishery

There are several factors contributing to post harvest mortality of livebait in the pole and line tuna vessels. The main factors are poor handling and poor circulation of seawater in the bait tanks. During the harvesting of livebait sometimes the net is hauled rather quickly from depths of around 40m to 60m. When the small fish are raised quickly from such depths, they have decompression issues and many lay floating on the surface of the water unable to breath properly.

Once the bait is brought to the surface it is concentrated into a small area inside the net hence making it difficult for the fish to breath as the oxygen in the water is quickly depleted. Such concentration also makes the fish to rub against the walls of the net causing the loss of scales and mucus on the outside of the fish. Transferring of bait from the net to the bait tank using dry scoops also contribute to further injuries to the fish. Sometimes bait net is also hauled with large quantities of bait during transfer to the bait tank. This causes bait to be crushed and contribute to further injuries. To minimize these injuries some fishers, have sort to wet scooping of livebait.

Water circulation in the bait tank is maintained using pumps during the bait fishing period and while fishing from the tuna schools. While the vessel is travelling to the tuna fishing grounds the circulation in the bait tanks are maintained by seawater inlets and outlets from the hull of the vessel. As both the inlet and the outlet pipes are raised to the surface of the water level inside the bait tanks fresh seawater entering the bait tank also leaves the bait tank from the surface of the water column without reaching the bottom of the tank. This poor circulation of the water leads to depletion of oxygen at the bottom of the bait tank causing more bait to die.

Stock condition and structure

Anderson (1997) states there has been no stock assessment, so the status of livebait stocks is unknown. In general, it is believed to be rather difficult to overfish stocks of small, highly fecund pelagic fishes such as the sprats upon which the Maldivian livebait fishery heavily depends. There are no clear signs of overfishing so far, but given the enormous importance of the livebait fishery, it would be prudent to initiate stock assessment activities.

Anderson (2006), using an empirical relationship between primary productivity and small pelagic fish yield, makes an estimate of maximum sustainable yield for Maldivian baitfish of about 13,000 ± 2,000 tons per year.

Adam (2011) states that the MRC has undertaken a series of studies on the livebait fishery. Collaboration between CSIRO, Australia, and MRC, under ACIAR funding in the early mid-1980s, provided important biological information on major species. Surveys done by MRC in the 1980s and 1990s provided important insights on the fishery dynamics, its seasonal and regional variations and estimates of livebait utilization. Despite fishers reports of livebait shortages in recent years, livebait utilization has remained more or less constant (Jauharee, et al. 2015). Data shows that livebait utilization has linearly increased with the increase in tuna catches implying that there are no declines in availability of livebait.

Identifying livebait fishing grounds, identifying the ecosystem features of the habitats that livebait species occupy is an important step towards better understanding the livebait stocks. Hence this initiative towards mapping livebait fishing grounds is very important. It will not only help initiatives towards better evaluating the livebait resources, but it will also help preserve these fishing grounds for fishery purposes rather than non-fishery related activities.

Analysis of Observer Data

This section reports the results of an exploratory analysis of the livebait data collected during the IPNLF Observer Program. The program was a collaboration with MRC started in September 2014 and continued until Covid19 Pandemic lock-downs. While the data on bycatch and ETP interaction have been reported elsewhere (e.g., Miller et al., 2017 and Miller et al., 2019), the data on livebait has not been analyzed so far.

Livebait Data

The data was collected using a standardized protocol to ensure consistent recording. Livebait removals were recorded at event level. For bait fishing operations, a fishing event was defined as the catch from a single location. In most cases there would be more than one haul from the same location. If more than one location was used during a fishing trip, which may not be uncommon, a different fishing event was assigned. Livebait catch and its species composition for each event was recorded as estimated by fishers, but also corroborated, where possible with the number of scoops[5] transferred from the haul.
A total of 195 trips were conducted from September 2014 to February 2022. There were no trips in 2017 and 2018, but reasonable coverage in other years and months. Other than Jan, July and December, most months had a reasonable number of trips (Table 3).

[5] Scoops were used to transfer bait from the net (haul) to the bait well. The estimate of livebait is made by counting the number of hauls. Average weights of haul (small and large) were predetermined.

Table 3: Number of PL and HL fishing trips made in year and month.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2014	0	0	0	0	0	0	0	0	4	9	0	8	21
2015	6	5	8	16	10	3	0	14	0	15	8	0	85
2016	0	0	0	1	7	0	0	1	0	0	0	0	9
2019	0	3	8	6	9	11	5	4	4	3	6	0	59
2020	0	5	0	0	0	0	0	0	0	0	0	0	5
2021	0	0	0	0	0	0	0	0	0	1	6	0	7
2022	1	1	0	0	0	0	0	3	0	0	4	0	9
Total	7	14	16	23	26	14	5	22	8	28	24	8	195

These trips were conducted from 42 unique vessels operating mainly in the south, from Laamu, Gaafu Alifu and Gaafu Dhaalu where pole-and-line method of fishing dominates. Consequently, most of the trips were conducted on pole-and-line (PL) vessels (94% of the trips) but few were also on handline fishing trips (6%), in which case were from Malé area and in the north. Most of the vessel were >24m in length overall (69% of the vessels).

Methods of Catch

A variety of livebait catching techniques were used although there were three main modes of catch: daytime, nighttime, and using SCUBA. Operations conducted during night invariably used, either shone from the vessel or from underwater. Several variations of nighttime techniques were observed which essentially relate to how the net was deployed and how deep it was deployed. Over the course of the observer program, it is clear these techniques have been refined in various ways that improved efficiency. The livebait perception survey conducted under this project, and reported in Section 3, shows use of submersible lights to attract livebait - a totally new technique which was only recently introduced. Submersible lights were not reported in the Observer Program.

The following methods of livebait harvesting were recorded during the Observer Program.

- Long Pole (POL): A nighttime technique targeted for sprat and anchovies inhabiting near-surface, primarily at night when the bait is aggregated under the light. The net is rigged on long poles and fishers do not get in water.
- Deep Net (DPN): A nighttime bait fishing technique targeting bait species close to the bottom (cardinal fish) and some schooling fish (scads and mackerel scads) that are

attracted to light. The net is deployed by fishers in water with weights attached to corners. The depth could range from 20 to 50m.

- Pole (PLL): Nighttime fishing technique with lights using small poles with lines targeting aggregations of scads and mackerels. (Mainly for handling livebait)
- Using Scuba (SCB): Day time fishing technique targeting bottom species (cardinal fish). Depth ranges from 20 to 40m].
- Shallow Net (SHN): A daytime operation targeting schooling fish (fusiliers, cardinal fish, Chromis, scads and triggerfish) along the edge of the reef. The depth ranges from a few meters.
- Herding (HRD): Day time fishing technique targeting aggregations of small fish (silver sides and herring) in the shallow lagoons. The net is spread on the bottom of the shallow lagoon which is only about a meter deep.

During the sampling period, the most predominant live bait fishing technique was SCUBA (Figure 1). This method specifically targets deep-dwelling species, especially Boadhi (Apogonidae). It is often practiced over reef slopes or within the atoll lagoon on submerged reefs. Based on past experiences, fishers select a favorable location. Around midnight, lights are activated to attract live bait. However, the actual fishing takes place shortly before sunrise during which time the bait would be attracted. Fishers deploy a net beside the vessel, which divers then spread across the reef. These divers play an active role in guiding the bait above the net. Once in position, they signal for the net to be pulled up, ensuring all the while that the school of bait remains above the net during the haul.

There are instances where the fishers with floats in water assists in deploying the net (DPN method) or where the net is rigged on long poles in which case operates from the vessel (POL). A technique often used when hauling the bet is rapidly cutting off the light by covering a red cloth underneath making the swarm to tightly congregate under the light.

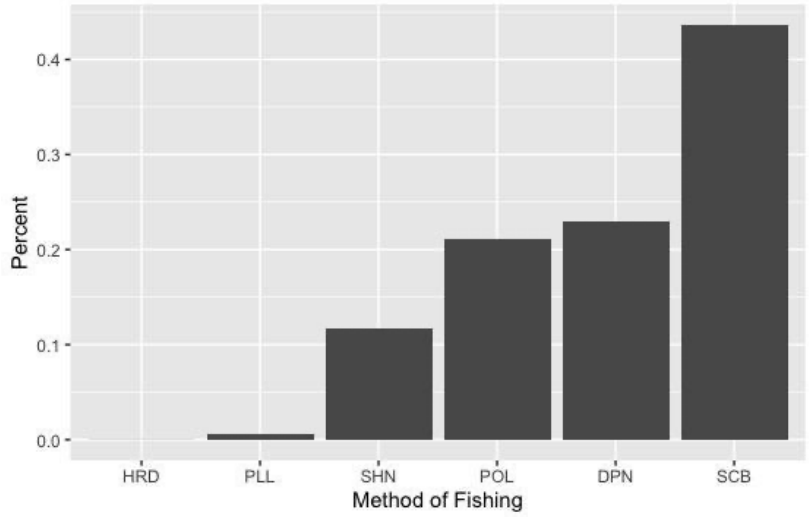

Figure 1: Methods of livebait fishing: HRD-Herding | PLL-Pole | SHN-Shallow Net | DPN-Deep Net | POL-Long Pole | SCB-SCUBA.

Species Composition

Most of the bait fishing takes place during nighttime (85% of the events, Figure 2, right). Eight main varieties are targeted (Table 1, see page 13): Five of them are exclusively for use in pole-and-line fishing (Figure 2), namely Apogonidae (APO), Silver sprat (SRH), Blue spart (SPD), Blue stripe herring (CLP), Anchovies (ENR). In handline fishery Scads (MSD), Trigger Fish (RTF) and Fusiliers (CJX) are commonly targeted. It is not uncommon; however, fusiliers are also used in pole-and-line, but only smaller sized ones whereas the sizes used in handline are larger.

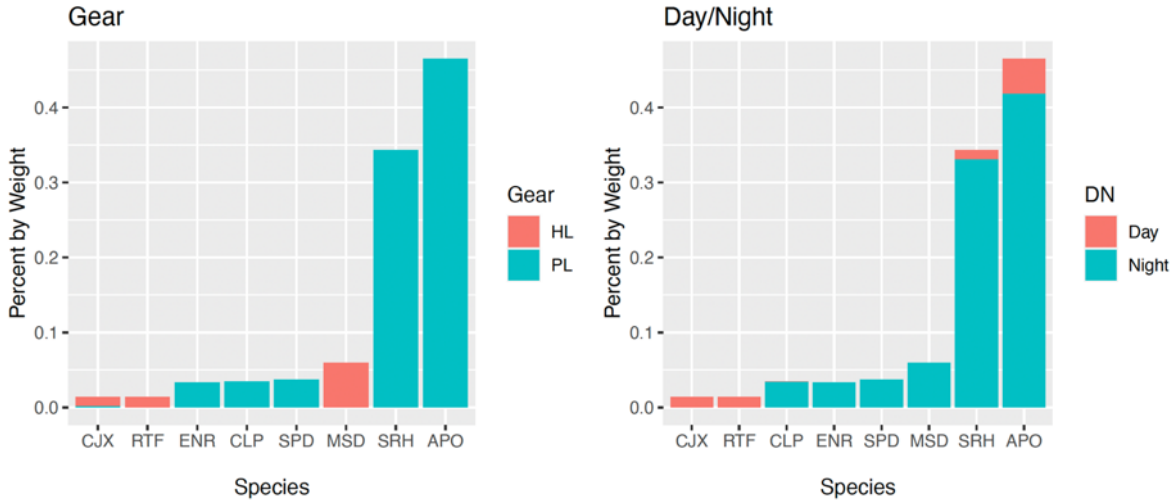

Figure 2 Target species by Gear and by Day/Night operations. ENR - Anchovies, CLP - Bluestripe Herring, SPD - Blue Sprat, CJX - Fusiliers, RTF - Red-Toother Trigger, APO - Cardinal Fish, SRH - Silver Sprat, MSD - Mackerel / Round Scads.

When it comes to the entire set of species recorded, the most common is Sprats (Rehi - *Spratelloides delicatulus*), common throughout the Maldives. This is followed by the Apogonidae (various species) and Scads (bigeye and round scads). Records show anchovies (*Encrasicholina heteroloba*) more common in the past, but occurs primarily in the south (Anderson, 1997).

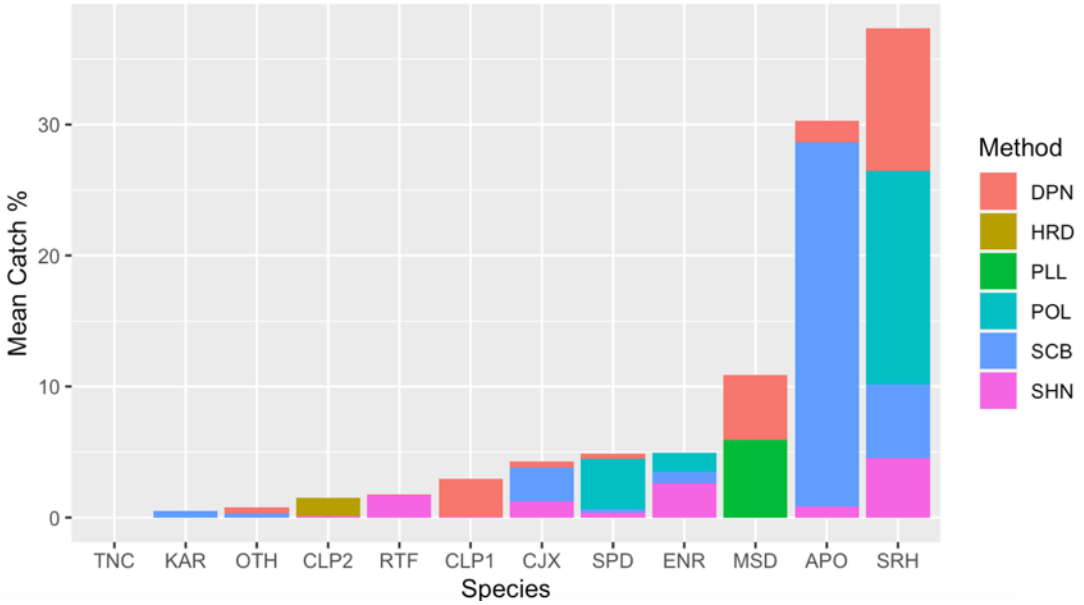

Figure 3: Relative catch of livebait species in the Maldives. Species: TNC – Nilamehi, KAR – Karavathi, OTH – Others, CLP2 – Thaavalha, CLP1 – Gumblalha, RTF – Rondu, CJX – Muguraan, SPD – Hondeli, ENR – Miyaren, MSD – Scads, APO – Boadhi, SRH – Rehi. Methods: DPN – Deep Net, HRD – Herding, PLL – Poles, POL – long pole, SCB – Scuba, SHN – Shallow Net

Location of Catch

Livebait fishing takes place throughout the Maldives. However, it is noted that the largest number of pole-and-line vessels these days operate in the south whereas handline's operations are in the north and center. It is, however, not uncommon for pole-and-line vessels to travel north or anywhere to stage fishing operations. This, in part, explains the widespread nature of livebait fishing. (Figure 4).

Triggerfish and fusiliers are fished during daylight hours. Tigger fish often occur on reef slopes and current swept channels, where fusiliers are very common on shallow reef slopes.

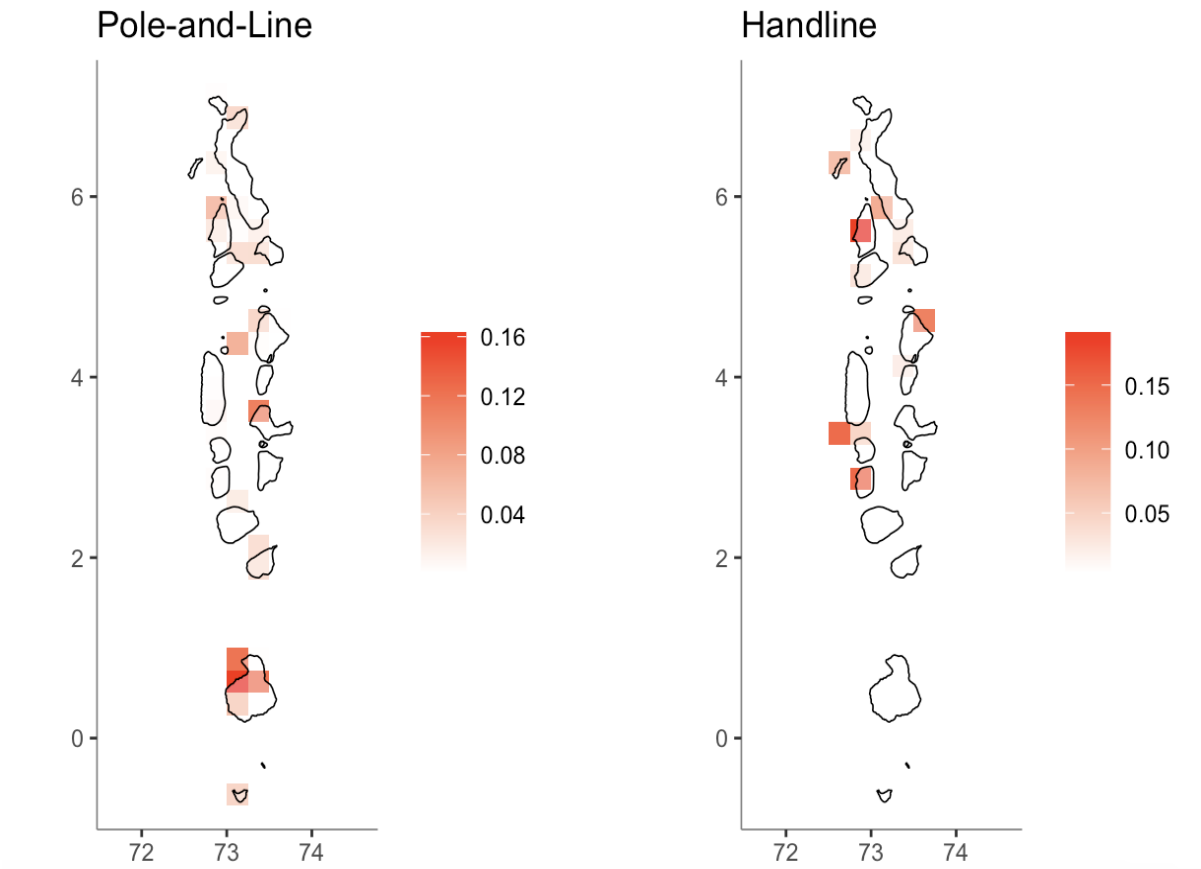

Figure 4: Location of the livebait catch by fishery. The catch is aggregated over ¼ of degree and plotted as relative catch.

Catch and Catch Rates

Accurate estimates of catch and catch rates are difficult to measure. Large quantities of bait are hauled and transferred quickly to baitwells and fishers normally do not allow them to weigh. The method followed was to estimate the number of scoops transferred (with a distinct large and a small) to come up with the total estimate. Similarly, species composition was also estimated in the same manner.

It is also difficult to estimate fishing effort or catch per unit of effort. Possible measure of fishing effort would be duration of lighting but may be poorly or not-at-all correlated with the catch. For a given abundance of livebait, there would be a maximum amount of livebait that can be attracted per lumen (or power). Without more controlled experiments it will be difficult to tease out the effect of duration of light on livebait catch.

A more practical unit of effort may be the number of hauls per fishing event, or indeed catch per trip. Now since, fishers would not go fishing unless a 'sufficient' amount of livebait is caught the latter may also be meaningless. A more plausible measure is the number of hauls. Amount caught in a haul, among other things, would be the amount of gear-

vulnerable livebait aggregated underneath the light. The less livebait, more hauls may be needed, or more fishing events per trip may be needed.

Average catch and catch per haul appear to increase from around 8 kg per haul to over 70 kg per haul during the sampling period (Table 4). Increasing total catch and decreasing number of hauls may indicate some gain in efficiency. A possible explanation would be diving which is introduced around the time. Diving makes livebait fishing very efficient. In addition to the lights being used to attract livebait, divers can lay the net more effectively and herd them into the net.

Table 4: Catch, number of hauls and catch per haul along with the number of fishing events over the years

Year	Catch	#Hauls	Catch/Haul	#Events
2014	73.4	8.94	8.2	18
2015	130.0	9.26	14.1	70
2016	77.1	4.57	16.9	19
2019	253.0	3.65	69.5	108
2020	415.0	8.38	49.6	8
2021	297.0	3.78	78.6	14
2022	310.0	4.87	63.6	18

Table 5: Frequency distribution of number of fishing events (n) during a fishing trip (left) and number of fishing events by method of fishing (right) over the sampling period.

Year	1	2-5	>= 6
2014	14	2	0
2015	50	9	0
2016	3	1	1
2019	46	14	4
2020	3	2	0
2021	6	0	1
2022	6	1	1

Year	DPN	SCB	SHN	HRD	POL	PLL
2014	4	3	11	0	0	0
2015	20	1	18	1	30	0
2016	0	0	14	0	0	5
2019	22	51	19	0	16	0
2020	0	3	0	0	5	0
2021	7	3	0	0	3	1
2022	12	4	0	0	2	0

SCUBA diving and Deep Net (DPN) methods also increased around the time (Table 5 right). However, there is no indication is that number of fishing events fished during the any trip increased significantly (Table 5, left)

Livebait Catch per trip for the whole period is at 208 kg per trip (SD = 322) for pole-and-line and for HL is it 347 kg (SD 526). The number of data points for the handline is much smaller and therefore it should not be taken seriously.

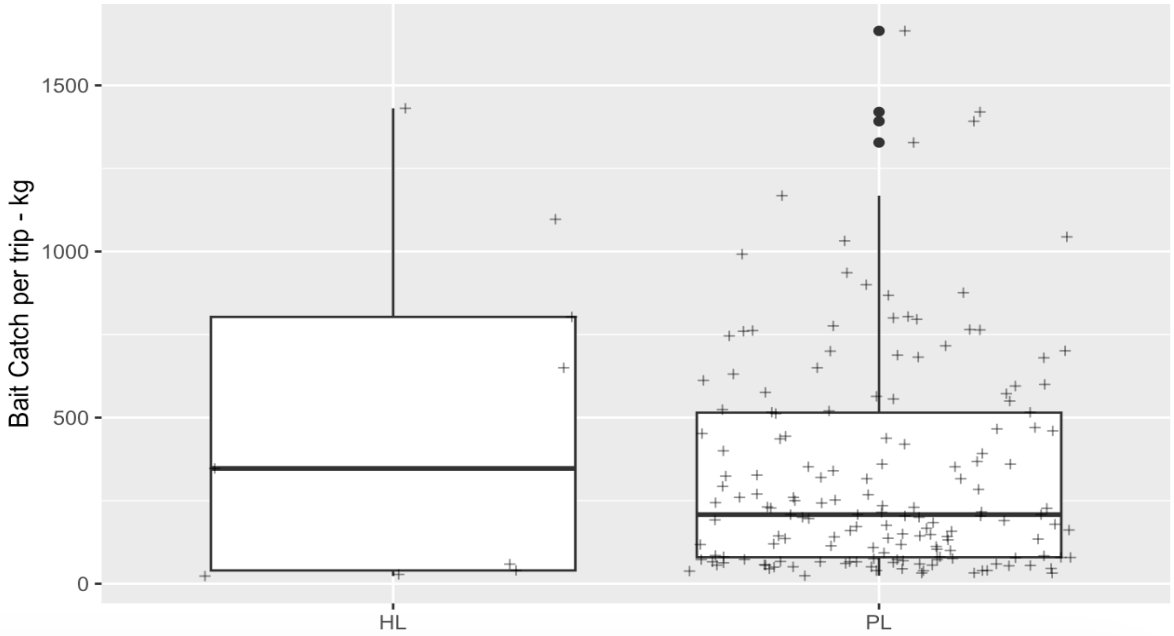

Figure 5: Box and whiskers plot of livebait catch per trip during the survey period. The boxplot compactly displays the distribution of a continuous variable. It visualises five summary statistics (the median, two hinges and two whiskers), and all "outlying" points individually. The points give the degree of scatter for each fishery.

Livebait Perception Survey

Along with the survey on identification of livebait fishing areas, a perception survey on livebait fishery was also conducted. These include light bait fishing, bait holding in captivity, post-harvest mortality and whether livebait fishing may be carried out as an independent fishery and if fishers are willing to utilize cultured bait. These questionnaires were instigated by the Maldives Marine Research Institute

Some 20 questions were formulated which require a response or multiple responses to be ticked and few of them open to their views. Since the questionnaire is in Dhivehi, the questions and multiple-choice responses are given in Table 6.

Table 6: Survey questions and the and multiple-choice responses

Num	Question	Method of response
0	General information about the interviewee; year/month, atoll/island, type of fishery, vessel registry, etc. Also, on experience - duration of years interviewee actively worked in tuna fishing /fisheries	General information to be filled by the interviewer. For the duration of the fishing experience five different ranges were presented.
1	List the type (modes & techniques) of livebait fishing	To tick 4 options and to rank in the order of importance, 1 being most important.
2	Number of lights used in fishing and their wattage	Type / brand of the light, number of lights used in fishing and their total wattage
3	Availability of livebait and seasonality	Responses framed in a table, with names of livebait in rows and calendar months on the columns. Fishers found it difficult to complete the seasonality of livebait availability by species. The question was eventually dropped in the survey.
4	Listing of important observations in marine environment and livebait fishing - 4 observations were stated	1: Demise of reefs and shallows where reef fishing was carried out 2: Lack of access to livebait fishing areas due to area/reef been allocated for resort development 3: Lack of access to the area due to the declaration of MPAs 4: Other observations
5	From a set of list of 7 issues, fishers were asked tick areas they think were important <note they can tick more than on>	1: Decrease in availability of livebait 2: Increase in availability of livebait 3: Increase in harvesting of livebait 4: Decrease in harvesting of livebait 5: Non-traditional varieties of livebait are being used 6: New techniques of livebait fishing are being used 7: Other
6:	Roughly how many days did you not go fishing **in the last year due** to lack of livebait	Six option were available to tick - only one box may be ticked i) 0-5 days, ii) 6-10 days iii) 11-15 days iv) 16-20 days, v) 21-25 days, vi) 26-30 days, vii) > 30 days
7	If livebait fishing was very good, do you take more than	Two options Yes or no

	what you need	
8	What do you do with any excess livebait after the day's fishing is over?	Six options: i) throw to open ocean ii) throw to atoll lagoon or closer to a reef iii) keep for the following days' fishing iv) consume at home v) sell them at the market vi) other
9	Name and rank two types of livebait that perform well in captivity	List two - two lines are provided
10	List and rank two varieties of livebait that die most quickly in captivity	List two - in the order of difficulty to maintain
11	Design of livebait well (To be ticked on all descriptions that fits)	Five descriptors 1: Water pumped and poured into the well from above. 2: Water pumped from below the well - through pipes inserted at an angle into the hull or otherwise. 3: Aerated through an air-diffuser system - air coming from tiny holes in pipes laid on the hull on the transverse and longitudinal frame. 4: Maintain a light in the bait well 5 Raised mouths of bait well and water level maintained above deck to minimize slosh effect
12	Ways of transferring the haul	Four different options to tick (can tick more than one) 1: Entire haul flicked into the well (Dry scooping) 2: Dry scooping using handled netted scoop (Dry scooping) 3: Wet scooping - using handled canvas/netted scoop 4: Other
13:	Tick the activities that may damage the livebait fishery	Five options - can tick more than one 1: SCUBA diving for livebait 2: Night livebait fishing using lights 3: Use of underwater lights 4: Taking more than what system can produce 5: other
14:	What do you think one can do to "improve/ manage" livebait fishery	Open for written answer
15:	Would you buy livebait, if it was available (like in Japan)	Yes/No
16:	If the response was Yes to Question 15 how much you would be willing to pay	Expect a response from in one sentence

17:	Do you think livebait fishing can be done as totally separate fishery	Yes /No
18	Do you believe that milk fish can be effectively used on pole-and-line fishing	Yes/no
19:	If milkfish may not be used what are the reasons	Only one line - their response may be noted
20	If milkfish can be used in PL fishing, would you buy cultured milkfish	Yes/No
21	How much would you be willing to pay (amount that can be used for a day's fishing)	Single line to give an amount

The perception component of the survey had 106 respondents; 67 from pole-and-line fishery (PL), 38 from handline fishery (HL) and one individual who identified as operating in both fisheries. This individual was removed from analysis as his responses cannot be linked to a separate fishery. The respondents are distributed across 8 atolls of the Maldives with respondents from HL fishery mostly from central atolls and respondents from southern atolls coming from PL fishery as also observed in the livebait observer data (Figure 4). Since the type of livebait fishing is different in HL and PL, results have been presented separately by fishery.

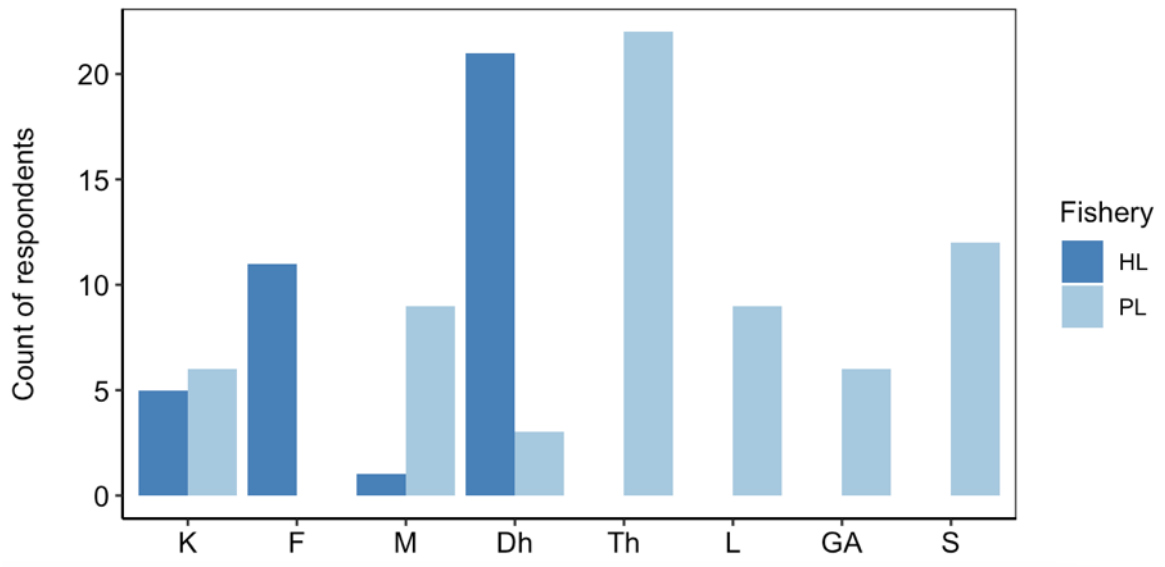

Figure 6: Number of respondents by Atoll. X-axis, Atolls: Kaafu (K), Faafu (F), Meemu (M), Dhaalu (Dh), Thaa (Th), Lamu (L), Gaafu Alifu (GA) and Seenu (S) atolls.

Most of the respondents were highly experienced, measured in the number of years they have been working as a member of the crew (53% in PL and 39% in HL had more 21 years of experience). There was a stepwise increase in the proportion of crew with different duration of experience in HL fishery. Th PL fishery however, the proportion of respondents were >21 years of experience and lowest between 6-10 years. The difference in pattern is difficult to understand but may be related to the continuous new recruitment happening in the more recently established HL fishery.

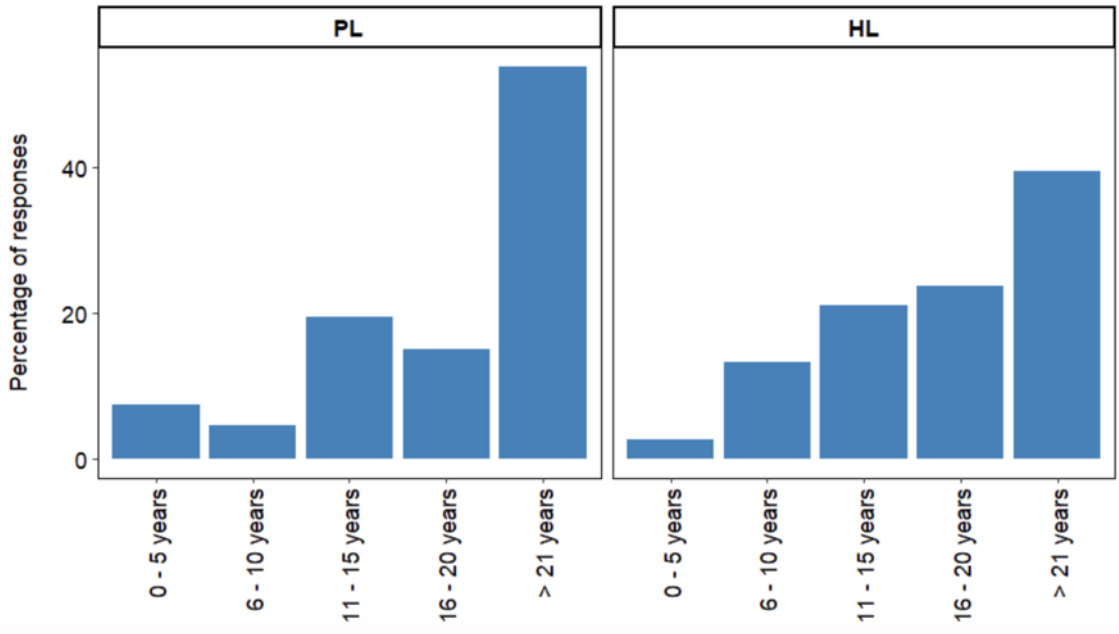

Figure 7: Percentage of response by the years of 'experience' working in the fishery – PL pole-and-line and HL handline.

Method of Fishing

Question #1 asks to indicate and rank the methods used for bait fishing from 1 to 4, with 1 being most common and 4 being the least common. On some forms the most common method is chosen as 1, and a second method chosen 4 to indicate rare use, but without indicating a method for rank 2 and 3. In these cases, it is assumed that the vessel only uses two methods, with the first method being very common, and the one with rank 4 being rarely used. In these cases, a new rank is given with the method with rank 1 kept the same, and the method chosen as 4 re-ranked at 2, since there are only two methods chosen for the vessel. Summaries are calculated after this new ranking. The data is presented as percentages and since more than 1 person indicating same methods, the total would be more than 100.

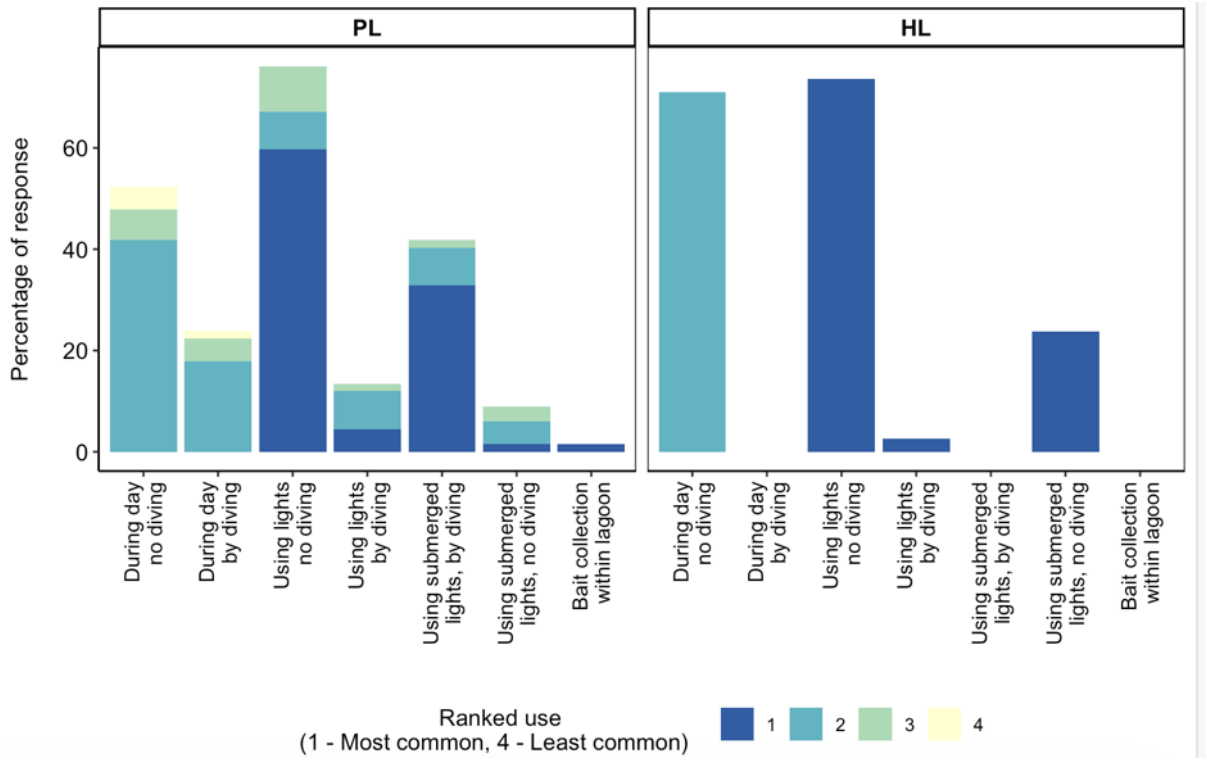

Figure 8: Percentage of responses and their rank about the type (or mode) of livebait fishing.

The two most common methods of bait fishing in PL fishery are (i) bait fishing at night using lights but without diving (59.7%), and (ii) bait fishing at night using submerged lights and diving (32.8%). The second most common preferred bait fishing methods in PL fishery are (i) bait fishing during day without diving (41.8%) and (ii) bait fishing during day by diving (17.9%). The two most common methods of bait fishing in HL fishery are (i) bait fishing at night using lights but without diving (73.7%), and (ii) bait fishing at night using submerged lights and but without diving (23.7%). The second most common preferred bait fishing method in HL fishery is (i) bait fishing during the day without diving (71.1%). It is worth noting that one respondent indicated a method that includes diving for bait fishing in HL fishery (i.e., Night bait fishing with lights and diving).

On the question of type of light and wattage, It was clear that at the present most use mercury lights of 2,000 - 6,000 total Watts and submerged lights from 1,000 - 3000 Watts. More than 40% of vessels used submerged lights.

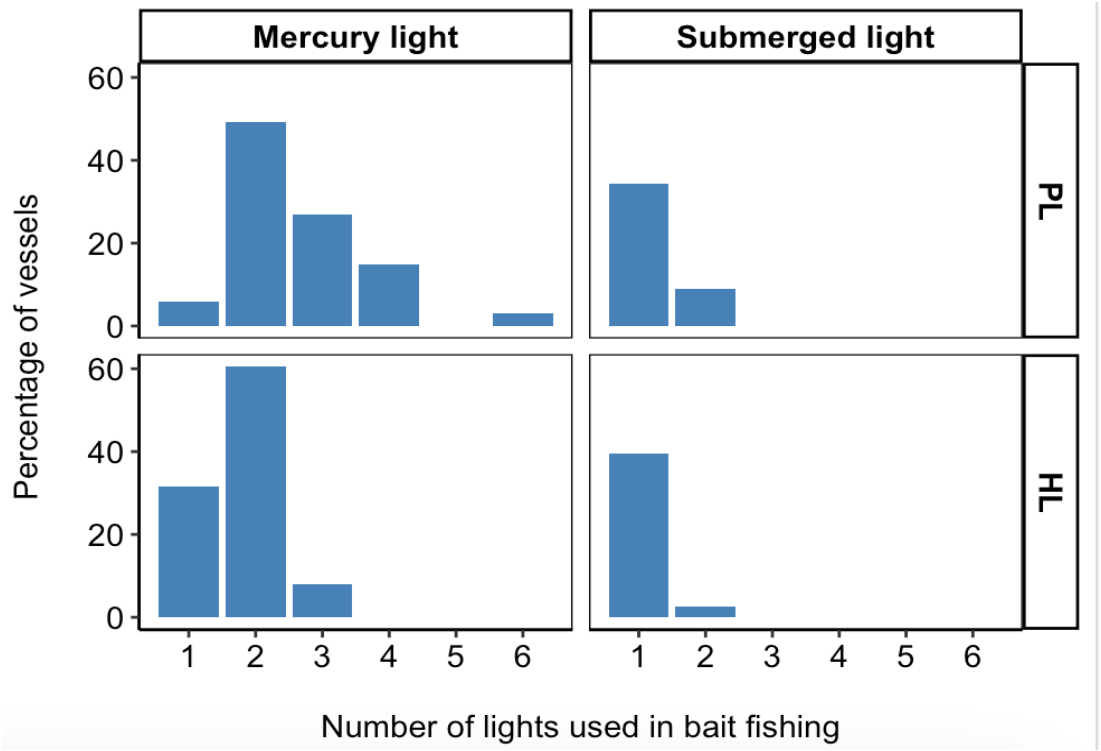

Figure 9: Percentage of vessels using lights (mercury – from above water) and submersible, by fishery.

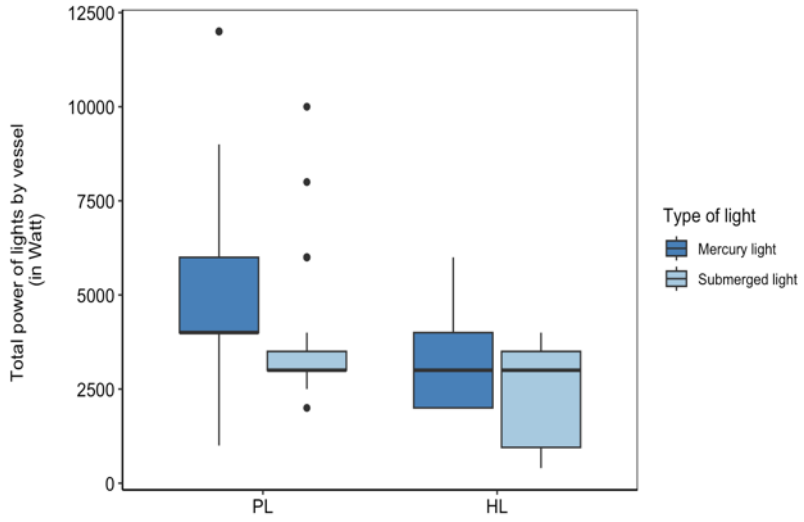

Figure 10: Box plot to show mean and distribution total power used by the vessel during livebait fishing.

Observation of the Fishery

Question #4 addresses the fisher observation of loss of bait fishing grounds in the past 10 years (Figure 11). As the most common observation respondents indicated loss of access to bait fishing grounds were due to resort development (PL: 83.6%, HL: 44.7%). While PL respondents indicated loss of bait fishing grounds due to coral bleaching, disease etc. (25.4%) as their second most common observation. The same came third in HL fishery

(15.8%). HL respondents indicated loss of bait fishing grounds due to dredging and reclamation (21.1%) as their second most common observation compared to only 4.5% from PL fishery. From the survey, only one respondent (HL) indicated loss of access to bait fishing grounds due to designation of MPAs.

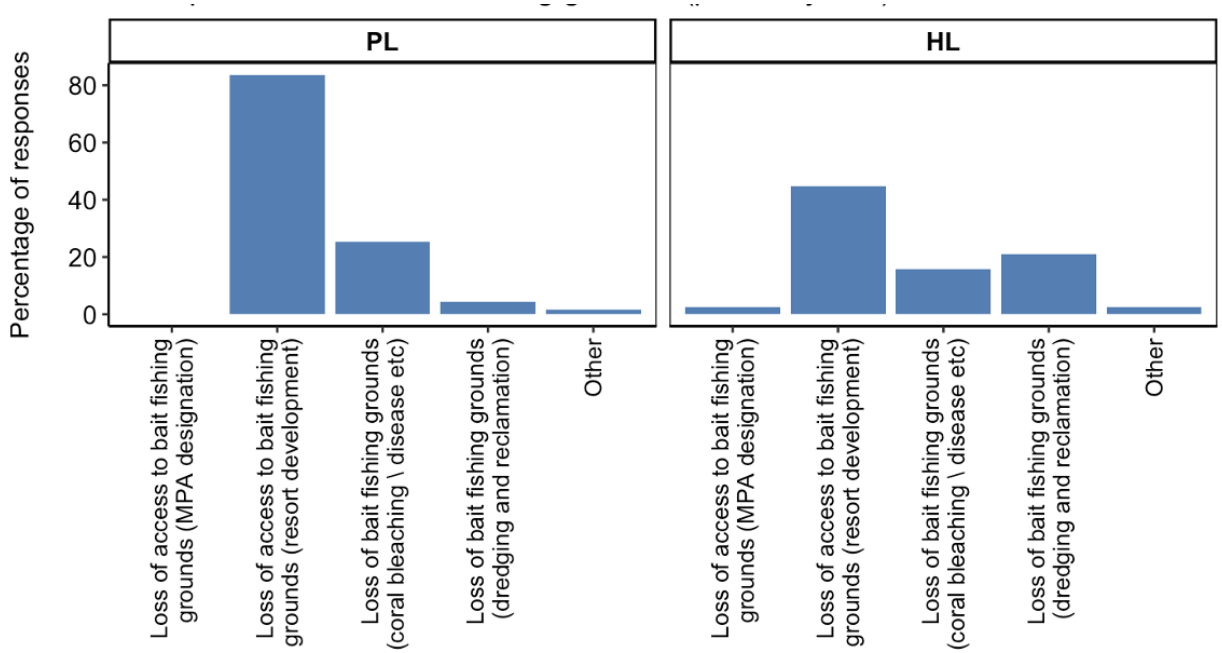

Figure 11: Fisher's perception for reasons of loss of livebait fishing grounds.

Question #5 is on fisher observation of bait fishery in the past 10 years. Most respondents observed an increasing overall harvest of bait (PL: 98.5%, HL: 94.7%). Use of new bait fishing techniques (PL: 82.1%, HL: 76.3%) and low availability of bait (PL: 55.2%, HL: 65.8%) are the other two most common observations about the fishery in the past 10 years, for both PL and HL respondents.

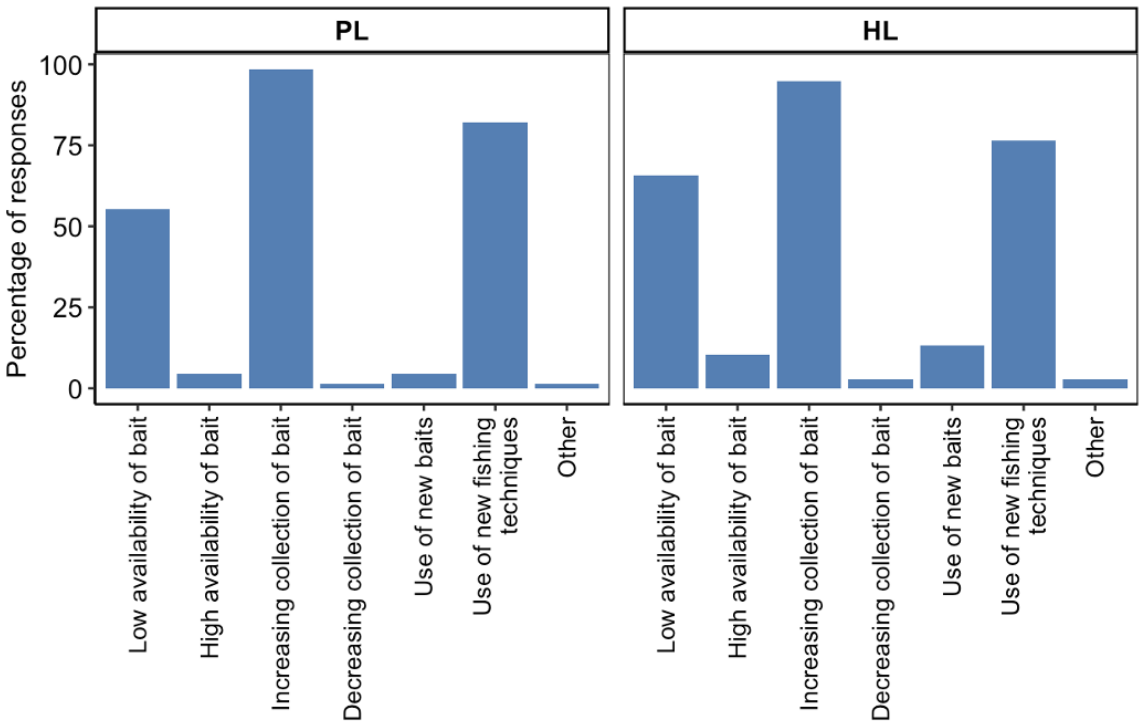

Figure 12; Fishers's observation about the livebait fishery in the past 10 years.

Days Lost Fishing.

Days without fishing (Question #6) due to unavailability of bait in the past year ranged from just a few days (0-5 days) to 4 months (Figure 8). More than half of respondents in both fisheries (PL: 88.1%, HL: 71.1%) indicated they had more than 15 days without fishing due to unavailability of bait. Most respondents indicated missing about 26 to 30 days of fishing in the past year due to unavailability of bait (PL: 40.3%, 26.3%).

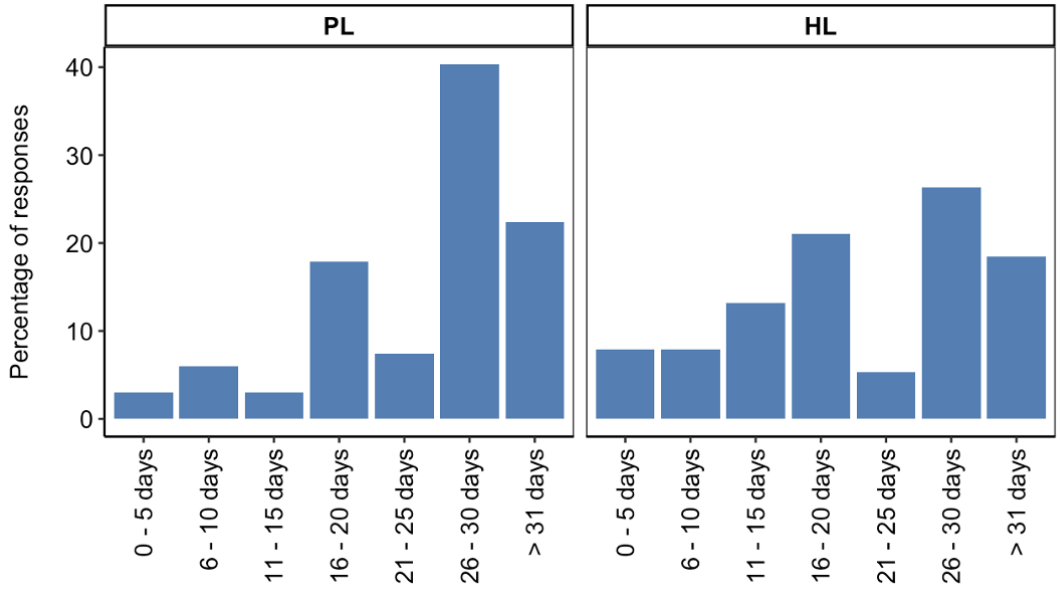

Figure 13: Day lost fishing due to lack of livebait.

A similar analysis was conducted from logbook data of 1993-1995, mainly form Ga Dhaalu Atoll where fishers indicated the days, they did not go fishing. Of the 11 reasons recorded, lack of livebait as a reason for not going fishing ranked lowest (Anderson, 1997) indicating lack of livebait was not an issue at the time.

Over-catch and Discards

The question #7 addresses on the fisher's decision to harvest livebait in excess of what is required for the trip. Most of the respondents indicated that they do not harvest excess bait (more than needed) when bait fishery is productive (PL: 88.1%, HL: 84.2%).

On the question #8 of what happens to excess livebait after the end of fishing most respondents in both PL and HL fishery indicated that any excess bait after a day's fishing is kept for another day (PL: 80.6%, HL: 97.4%). Amongst PL respondents, 28.4% indicated that they also discard the excess bait into sea, reef/inner atoll, while this number is lower for HL with 15.8%. More HL respondents indicated selling excess bait after fishing trips (39.5%) compared to PL respondents (6.0%).

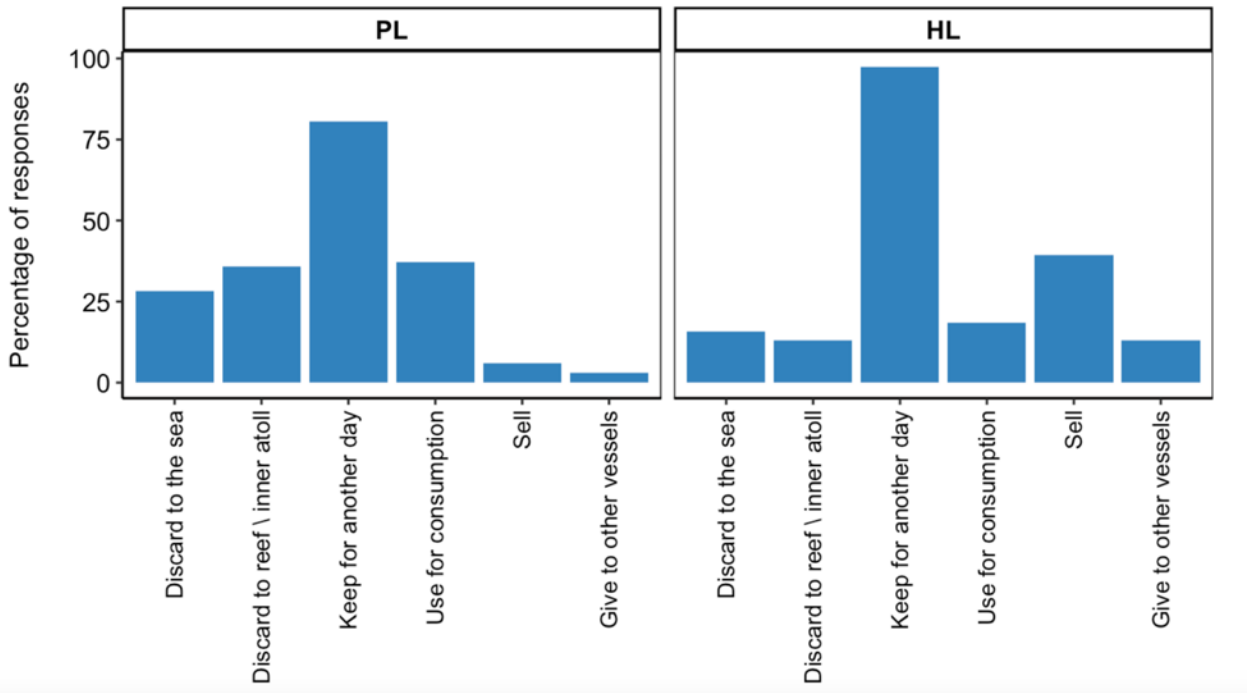

Figure 14: What is done to excess livebait at the end of day's fishing.

Best Bait for Captivity

On what is the most hardy livebait (Question #9) most PL respondents (88.1%) indicated that Boadhi (Apogonidae) as the bait that can be best kept in the bait hold, followed by Miyaren (anchovies), as the second best (52.2%). For PL respondents, Muguraan (Fussliers)

is also commonly considered as a second-best bait to keep (34.3%). The responses of best and second-best bait to keep in bait hold is split between Gunbalha, Thaavalha and Muguraan among HL respondents. Most respondents indicated that Thaavalha is the best bait to keep (55.3%), followed by Muguraan (23.7%), and Gunbalha (15.8%). Gunbalha (44.7%) is chosen by most as the second-best bait to keep, followed by Thaavalha (31.6%) and Muguraan (13.2%).

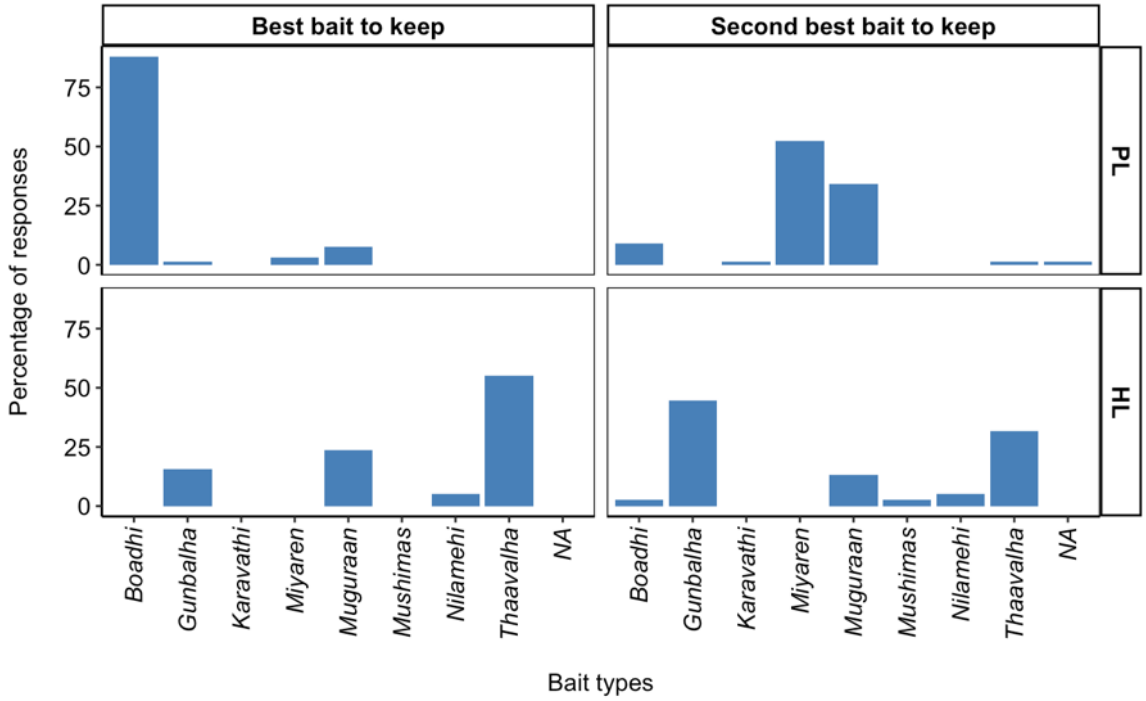

Figure 15: Best bait for captivity for long periods

Bait well Design & Water Circulation

Bait holds of most PL fishery vessels are very similar in design (Question #11), with most providing water input from above to the bait hold using a pump (100%) while also having water intake / outlet through openings on the hull (88.1%). Most of the respondents indicated that the bait hold mouth is elevated (to reduce the slosh effect in the bait well) (79.1%) and has lights switched on at the bait hold (92.5%). Only one PL respondent indicated having oxygen for aeration supplied to the bait hold.

Most of the HL respondents indicated having bait holds with water intake through openings on the hull (92.1%) and lights on at the bait hold (78.9%). Unlike PL fishery vessels, fewer respondents indicated providing water input from above to the bait hold using a pump (42.1%) and having elevated bait hold mouths (23.7%). Like PL, only one respondent indicated having oxygen supplied to the bait hold.

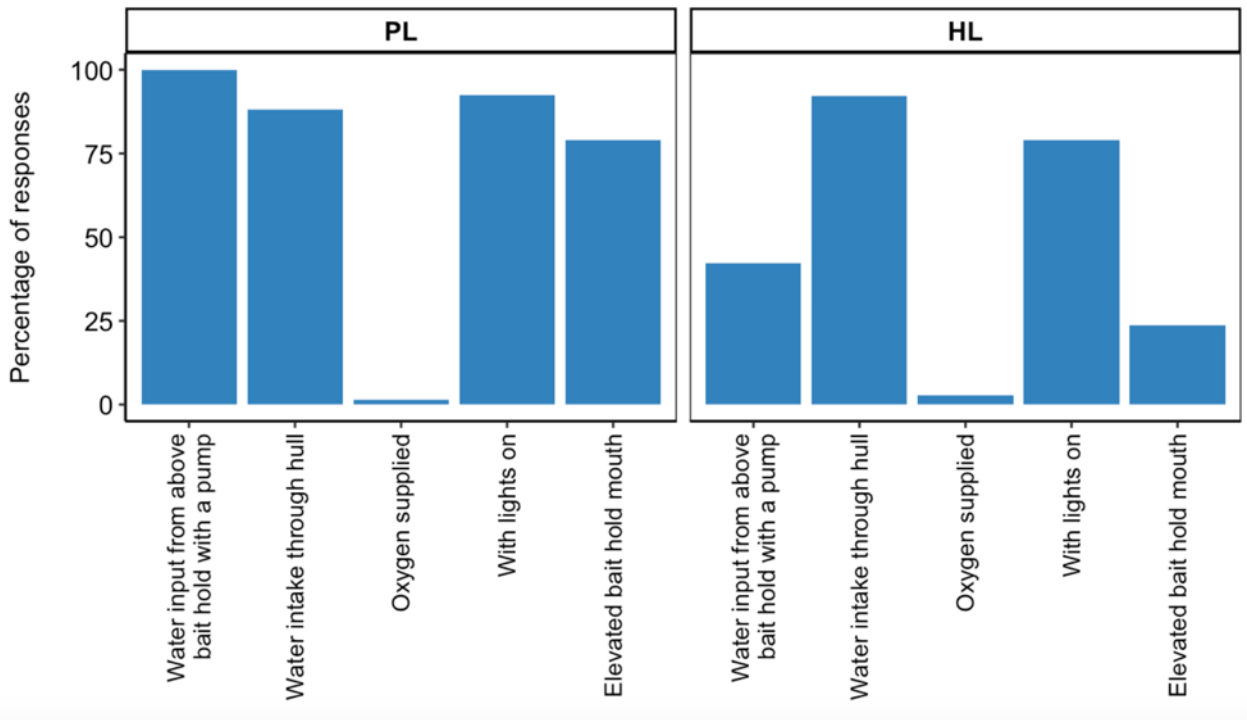

Figure 16: Existing livebait design and water circulation

Transfer of Bait

Question #12 considers on ways of transferring livebait from the haul. The question was motivated to understand the extent of fishers using wet-scooping as opposed to dry-scooping (transfer without water). Based on the response, there appears to be some confusion of the use of scoop with/without water, since entire haul in one go and dry scooping are the same, where scoping with water and use of cloth or tarpaulin would be wet scooping. It is clear that wet scooping is becoming the norm in both PL and HL fisheries.

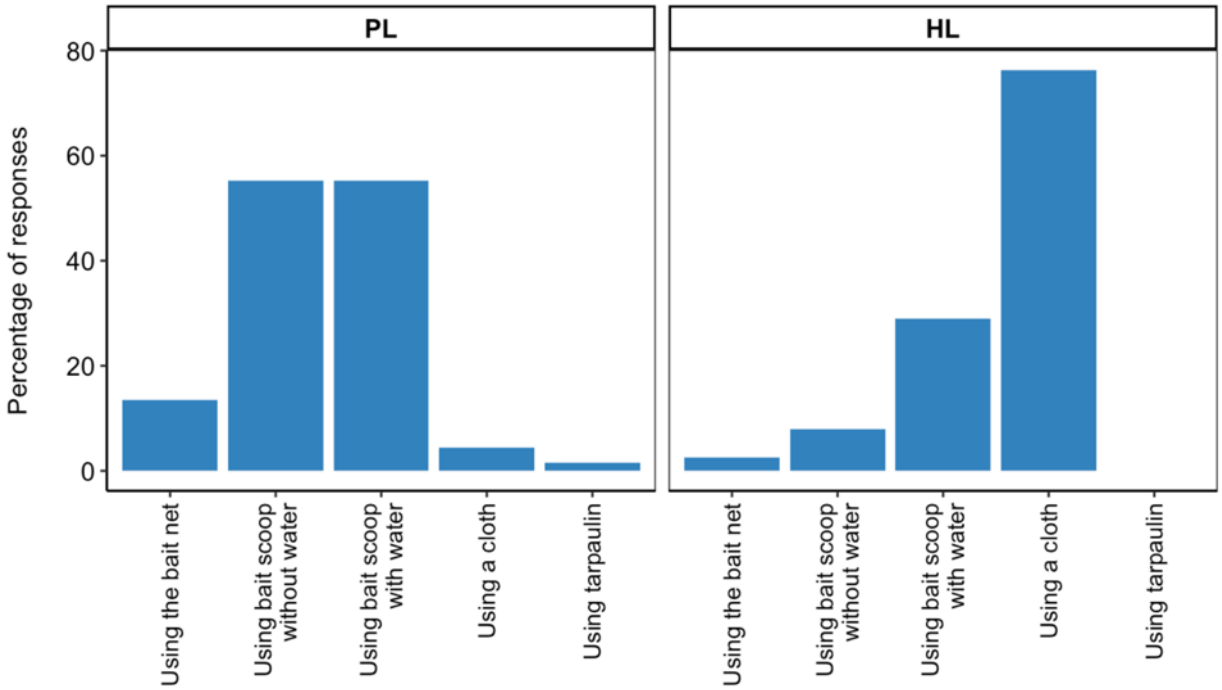

Figure 17: Bait transfer methods as provided by fishers.

Impacts to Fishery

Question #13 relates to identifying the type of fishing activities that are negatively affecting the fishery. As **Table *6*** indicates there are five methods including the option "other' to choose. Response in "other" has been re-corded into identifiable unique methods and presented here and keeping mind when divided by number respondents, the sum would not be 100%.

With the above caveats, the three most common bait fishing related activities that negatively impact the bait fishery, according to PL respondents are: Overexploitation (44.8%), diving (41.8%) and use of submerged lights (40.3%). Use of lights (13.4%) is also indicated as an activity that negatively impacts bait fishing, but some also indicate use of excess (or overuse) lights (23.8%) also harming the fishery.

The HL respondents indicated use of submerged lights (60.5%) as the most common activity that negatively impacts the bait fishery, followed by diving (52.6%).

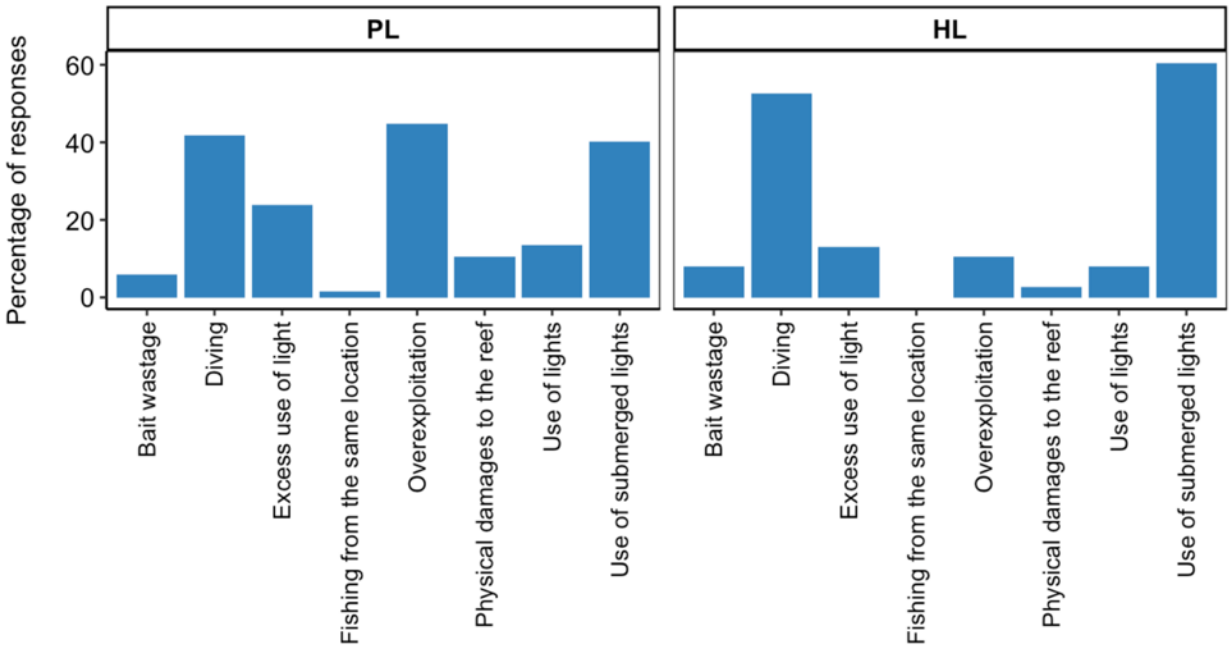

Figure 18: Fishers's perception of activities negatively affecting livebait fishery.

Improvements to Livebait Fishery

Question #14 was on fishers's perception of what could be done to improve the livebait fishery (i.e., manage the fishery sustainably). Given responses to this question are opinions, classification has been done to put the opinions into different themes.

On ways to improve bait fishery, most PL respondents indicated limiting use of lights (25.4%), while most HL respondents indicated stopping use of submerged lights in bait fishery (28.9%). Other key themes of suggestions are managing bait fishery, stopping diving for bait, reducing bait wastage and damages to reefs and stopping-limiting impacts from dredging and reclamation.

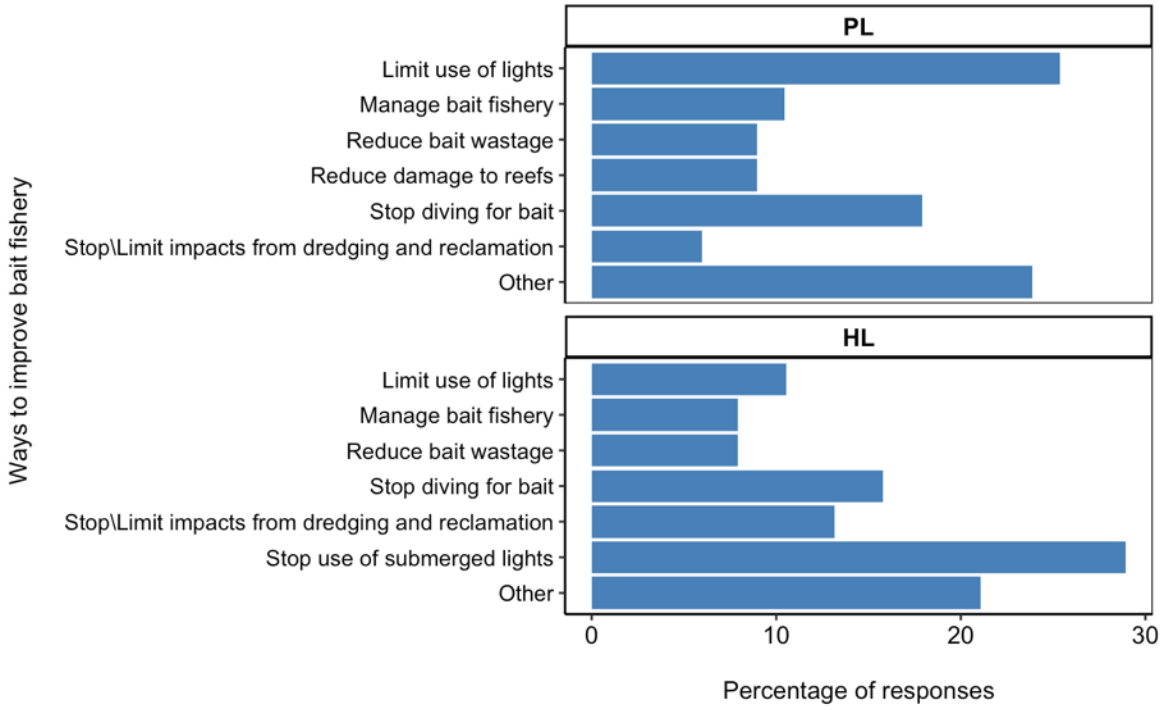

Figure 19: Fisher's perception on ways of improving the fishery.

Question #15 is about eliciting their response whether they would buy livebait if they are readily available for sale. Most respondents from PL (80.6%) and HL (60.5%) indicated willingness to buy currently used bait, although fewer people believe a separate bait fishery can be established (PL: 41.8%, HL: 21.1%).

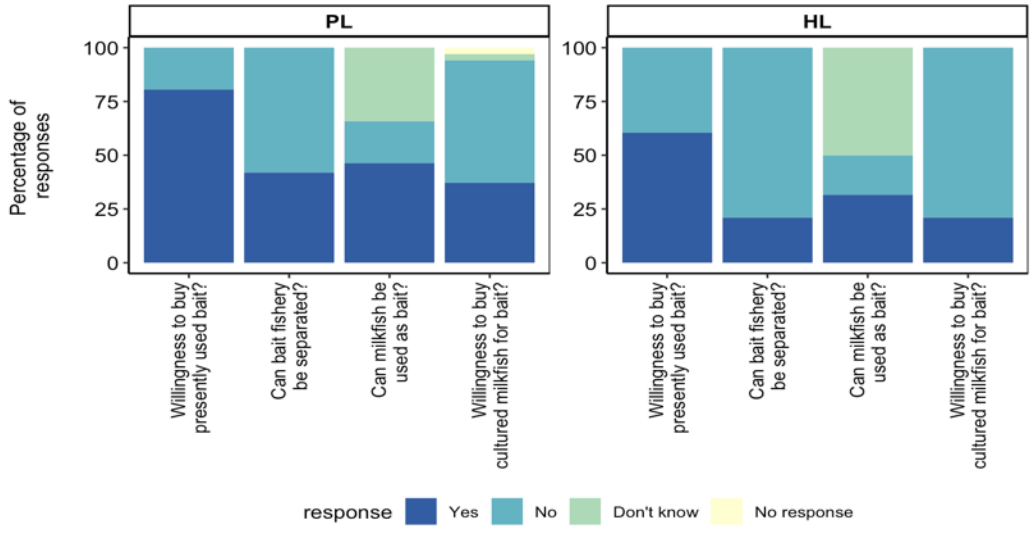

Figure 20: Perception about a establishing a livebait as a separate fishery.

Among those who indicated willingness to buy currently used wild caught bait, PL respondents indicated a median price of MVR 7,500 (mean ± SD: 7975 ± 4805) per bait hold

compared to a median price of MVR 5,000 (mean ± SD: 7797 ± 5606) per bait hold from HL respondents (Question #16).

Among those who indicated willingness to buy cultured milkfish as bait (except 4 PL respondents who didn't provide a price but indicated willingness to buy), PL respondents indicated a median price of MVR 5,000 (mean ± SD: 6547 ± 4209) per bait hold compared to a median price of MVR 6,000 (mean ± SD: 7656 ± 5780) per bait hold from HL respondents.

Some Conclusions

Some interesting conclusions can be drawn from the survey.

1. The most common method of livebait fishing is using lights at night. It is also clear there is increasing use of powerful submersible lights for which a substantial proportion of fishers feels the practice may be detrimental to livebait fishery and availability in the future.

2. A large proportion of the fishers believe there is substantial loss or access to fishing grounds because reefs and islands are being allocated for tourism and other developments. There is also feeling among the fishers that coral bleaching and dredging may also affect the livebait fishery through degradation of the environment.

3. Unlike what many of us believe, fishers are aware of importance of reducing post-harvest mortality and techniques for reducing loss following capture and holding. Fishers do not catch more than what is required (>80% of respondents) and most have measures in place in the bait well to deal with the issues; elevated mouth to reduce slosh effect (79% of respondents), lights to reduce stress (92% of respondents), generous water circulation (88% of respondents). However, very few have aeration through air bubbles (1% of respondents)

4. Both handline and pole-and-line fishers loose fishing days due to lack, or unavailability of livebait (71-88% consider >15 days was lost in a year). This result is totally different compared with the earlier survey (1993/1994, see Anderson, 1997) where fishers ranked lack of availability of livebait as least important for reasons (among 11) not going fishing.

5. There is high degree of willingness to purchase livebait if they are readily available (for about MVR 7,500 – 8,000 per full load per day's fishing). However, some believe it may be difficult to start livebait as a separate fishery. Less than half of the fishers believe cultured milk fish can be used as live bait, slightly lower than wild caught live-bait (5,000 – 6,000 per full load of day's fishing).

Mapping of Livebait Fishing Areas

The Survey

The survey targeted fishers operating from vessels in the central, south central and the southern atolls of the Maldives. This was because of the limitation of funds and the need to capture sufficient information where fishing is most developed, namely in the south which was the priority of the project. However, this does not mean information provided by fisheries would be restricted to only central and south. Mobility of vessel means fishers have the experience of fishing not only from their home-port atolls, but even from other atolls, and therefore some data were collected for the northern atolls.

Number of interviews were limited to one per vessel. Although rarely, if more than one was to be interviewed from the same vessel, it was done on separate days. This was to ensure independence of the responses.

It should be noted the exact same survey was conducted by the same IPNLF staff in Gaafu Alifu and Gaafu Dhaalu Atolls for MMRI under contract with IUCN. Per arrangement with MMRI this report does not include those data (50 interviews from the area). Inclusion of them would provide more complete maps of the central and southern regions.

Also due to limited data for the northern atoll, the maps here are produced only for atolls from Kaafu and south.

Data Description & Mapping

The bait fishing ground mapping exercise was carried out through a questionnaire-based survey that allows respondents (captains/fishers) to identify areas where they fish for bait. Their bait fishing locations were recorded at a spatial resolution of 0.025° x 0.025°– degree grid cells across the atolls of the Maldives. Gridded maps by atolls or groups of atolls were prepared prior to survey to record the data consistently.

Each respondent was asked to identify their bait fishing locations across the Maldives, with a hierarchical differentiation based on season (Northeast – NE and Southwest - SW), bait fishing time of the day (Day or Night) and bait types (12 different bait types). Each respondent may identify as many locations as they fish for bait at any atoll in the Maldives. The fishery to which the respondent belongs is identified initially at the perception component of the survey. Hence, the resultant bait fishing locations dataset has four hierarchical levels: fishery, season, fishing time of the day and bait types. As a result of this hierarchical data recording, a single record of fishing location (a grid cell) for a specific bait (lowest level of hierarchy) will have associated information about the fishery from which that location data point came from, the

season during which that bait is usually fished and the time of the day when it is usually fished. All the data points in the survey were recorded to this level of hierarchical differentiation.

There were 120 respondents to the mapping survey with 78 respondents identified as working in the Pole-and-line fishery (PL) and 36 identified as working in the Handline fishery (HL). There were an additional 6 respondents who identified as operating in both PL and HL fishery. For the mapping, their bait fishing location responses were hence taken in both the fisheries.

Bait Fishing ground maps

The hierarchical nature of the dataset allows producing bait fishing ground maps at any of the hierarchical levels or any combinations of levels. However, the main maps produced here are for the (i) overall survey depicting preferred or commonly used bait fishing grounds and with both fisheries combined and (ii) preferred or commonly used bait fishing grounds by fishery (iii) preferred or commonly used bait fishing grounds by season and (iv) preferred or commonly used bait fishing grounds for specific baits, and (v) preferred or commonly used bait fishing grounds by bait fishing time of the day.

The bait fishing ground data are summarized and mapped to show preference/use of the grid cells. For the overall (both fisheries combined) bait fishing ground map, firstly, unique occurrences of bait fishing locations (i.e., grid cells) by respondents were computed, resulting in only one count for each bait fishing location chosen by the respondent. This was necessary, as the dataset holds several records for one bait fishing location by the same respondent due to the hierarchical nature of data recording. For example, a bait fishing location may have been represented twice in the dataset by the same respondent, i.e., for the two seasons, with information in all other levels being the same. Therefore, computing one count per bait fishing location per respondent indicates that location is used, regardless of how many hierarchical differentiations of the data exists in that grid cell.

Secondly, unique counts by respondents were summed up for each grid cell and, a preference and use score for each grid cell was calculated by dividing the sum of count of each grid cell by the maximum summed grid cell count within the full dataset. This results in a score of 1 for the grid cell(s) chosen by most of the respondents as one of their fishing grounds, and the rest scaled to this maximum grid cell. Hence, for demonstrating usage of bait fishing grounds, 1 is indicated as ‘highly preferred / used’ grounds and the fishing grounds with lowest score as ‘preferred / used’.

The preferred or used bait fishing grounds by fishery, season and time fishing was also produced following the same methodology as above but differentiated to the respective

hierarchical level. The unique occurrence of bait fishing locations by respondents were summed up separately by each level for each grid cell and scaled to the maximum of summed grid cell count. The grid cell with score of 1 therefore indicates the bait fishing location 'highly preferred / used' at the differentiated categories in each hierarchical level.

The data summarization as above at the preferred level of hierarchy was achieved through analysis in statistical programming language R, ver 4.2.3 (R Core Team ,2023). Given many possible hierarchical combinations of maps that can be produced from the dataset, a data summarization function specific to the dataset was written in R (R Core Team, 2023), mainly reliant on in core tidyverse packages, ver 2.0.0 (Wickham et al., 2019). Additionally, two other convenient functions specific to the dataset were also written to visualize summarized data as maps at broader country scale and focused on atoll scale. While these functions are very useful to produce quick summary maps, hence insights, at any hierarchical level or combinations of levels, final maps are produced in QGIS ver 3.28.6 (QGIS.org, 2023) to incorporate more context around usage of bait fishing ground, based on available spatial datasets for the Maldives.

The country scale summary maps indicating the preferred/used bait fishing grounds for overall survey, by fishery, by season, for specific baits and by fishing time of the day are mapped in QGIS using geographic atoll boundary and administrative divisions of the atoll as additional spatial layers. To show the spatial context at atoll scale, an additional set of zoomed-in maps for each atoll were then prepared for full survey and by fishery bait fishing grounds. These show detailed reef, lagoon and island boundaries, local council's jurisdiction around inhabited islands, protected areas and islands used or designated for resorts (layers from – MLSA, 2023). Five protected grouper spawning aggregation sites across the Maldives (MoFMA, 2020) are also shown on the atoll scale maps. The atoll scale maps with more detail are useful to understand the spatial context around preferred/used bait fishing grounds.

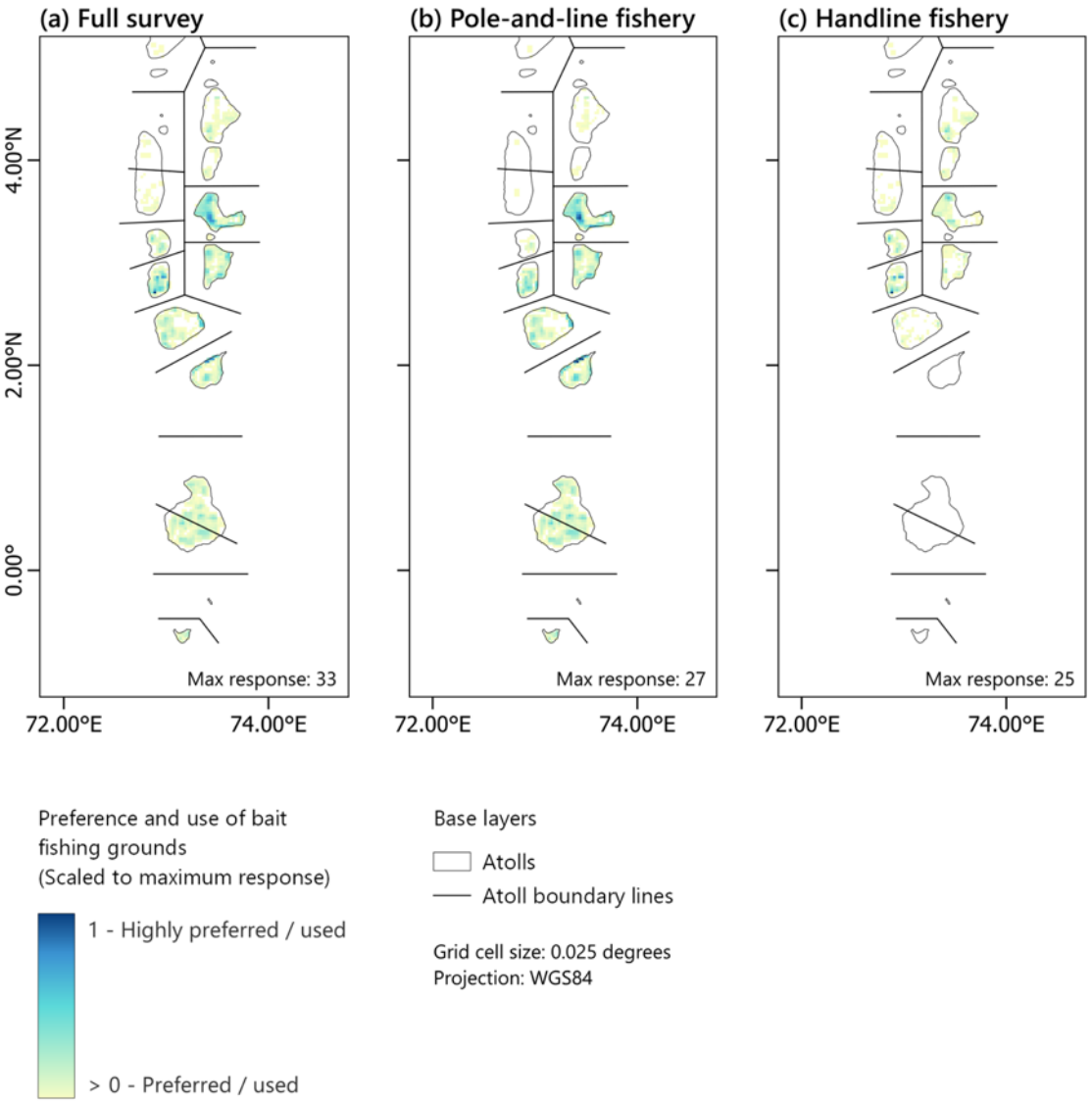

Figure 21: Livebait fishing grounds for the entire country and separated by two fisheries (PL and HL) separated.

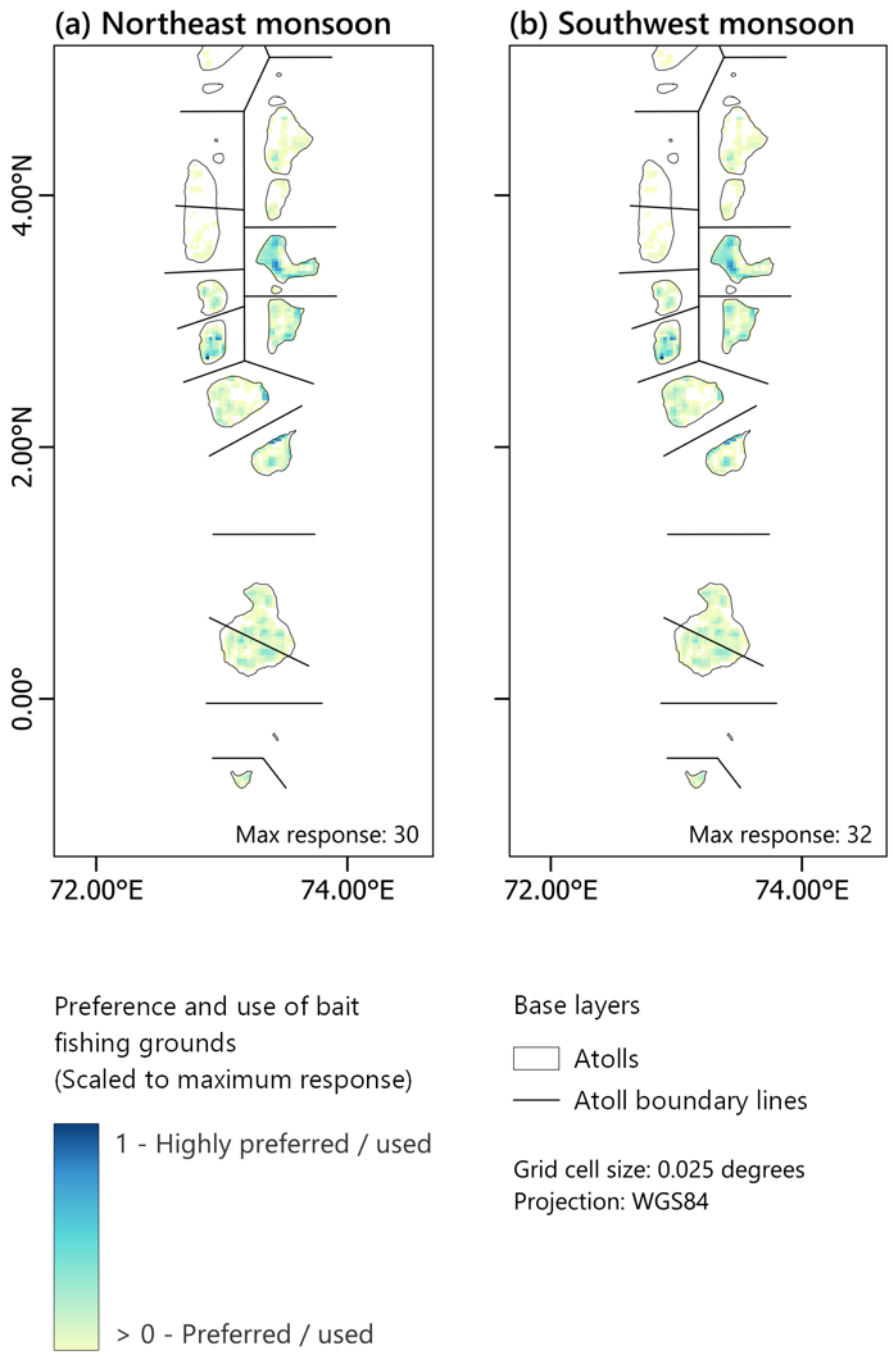

Figure 22: Livebait fishing grounds separated by seasons: southwest and northeast monsoon season.

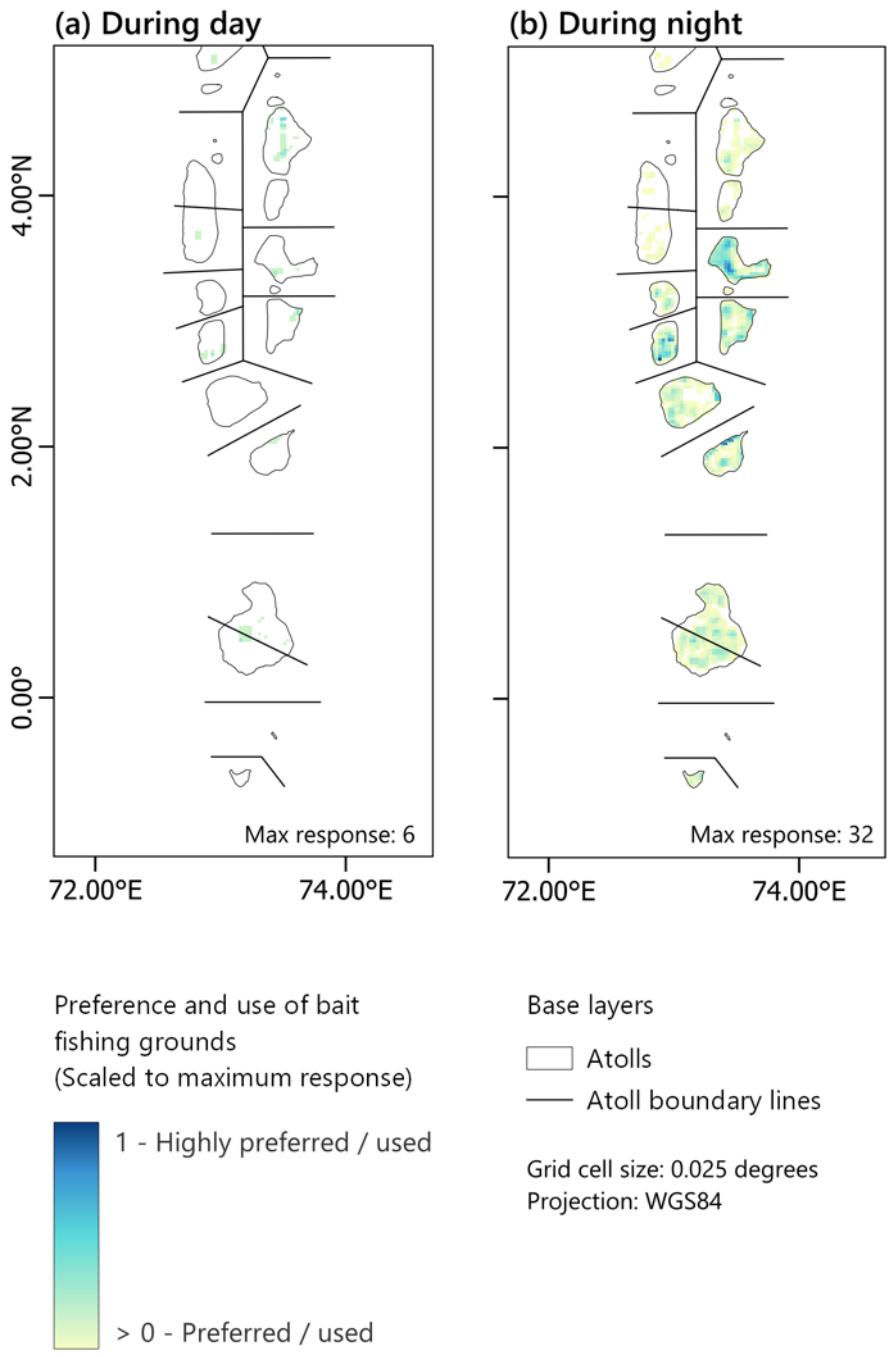

Figure 23: Livebait fishing grounds as indicated for day and night.

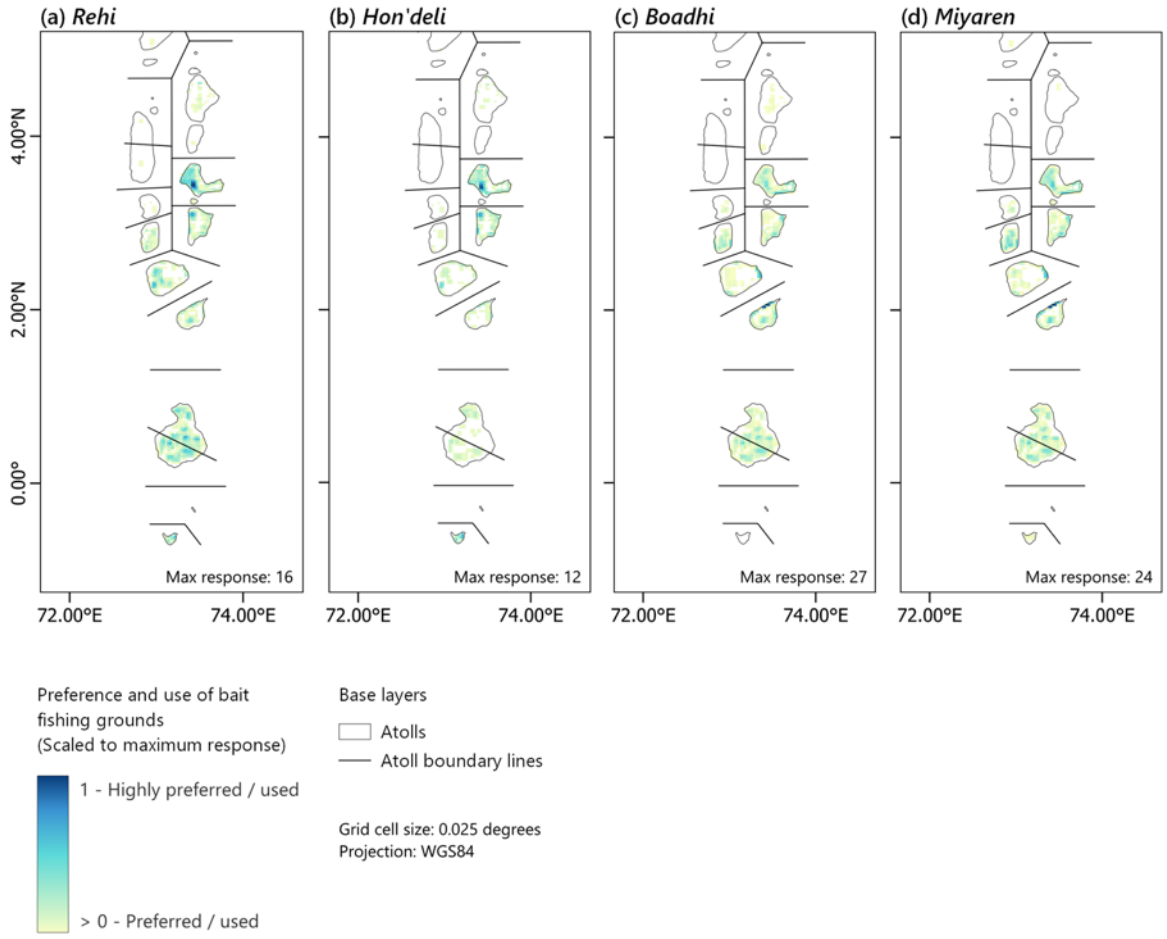

Figure 24: Livebait fishing grounds for species: Rehi, Hondeli, Boadhi & Miyaren.

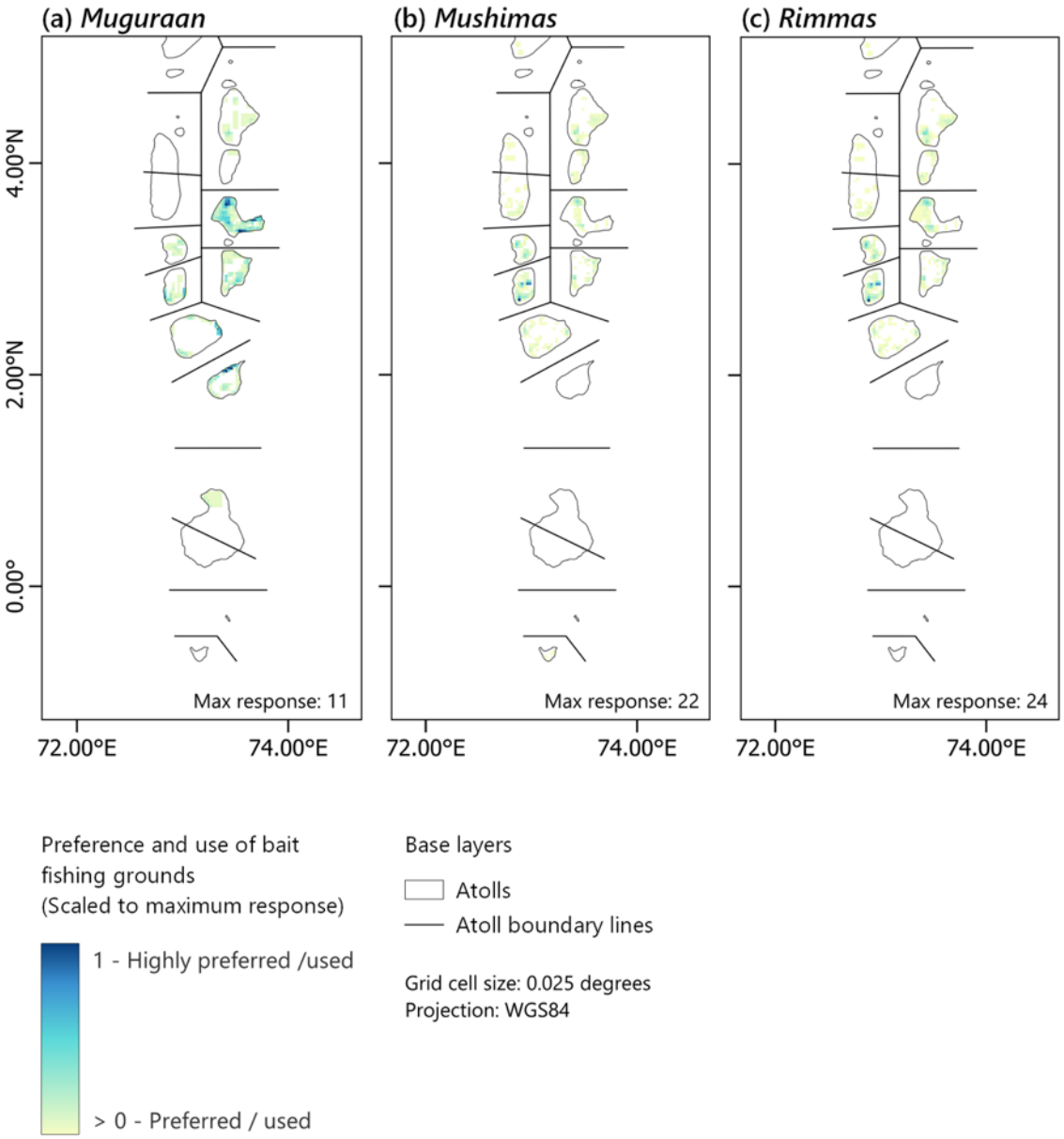

Figure 25: Livebait fishing grounds by species: Muguraan, Mushimas, Rimmas..

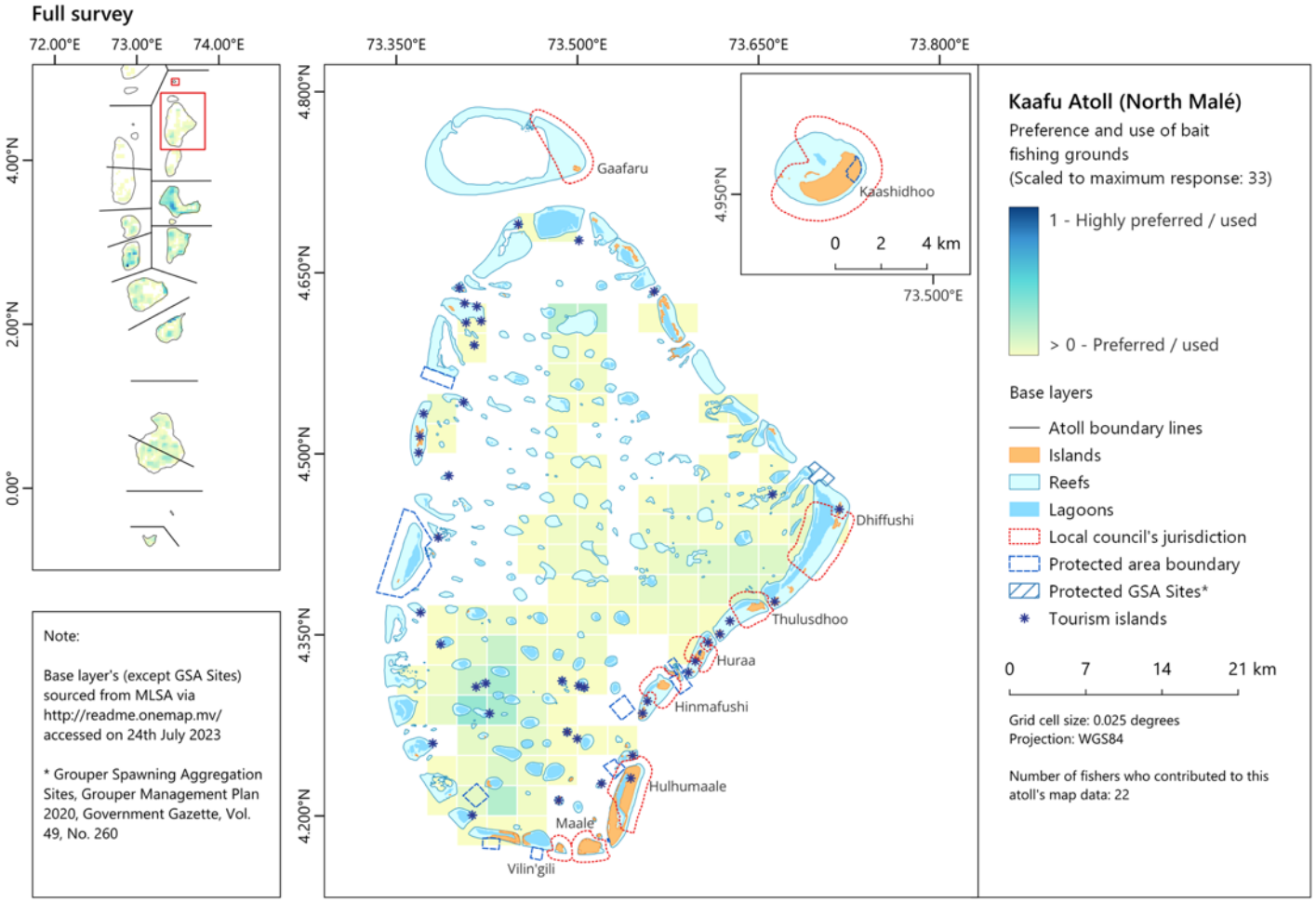

Figure 26: Livebait fishing ground for North Malé Atoll.

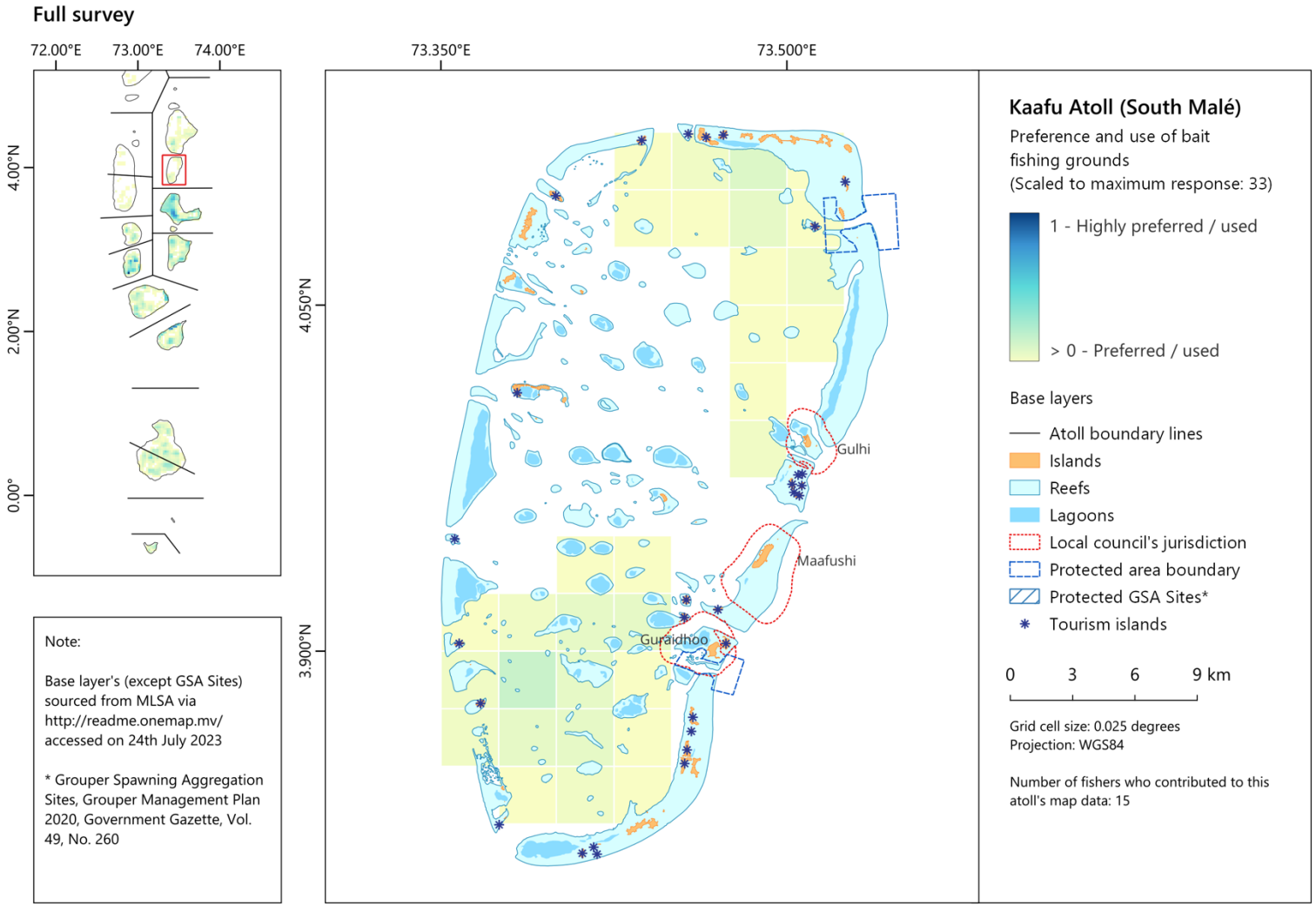

Figure 27: Livebait fishing ground for South Malé Atoll.

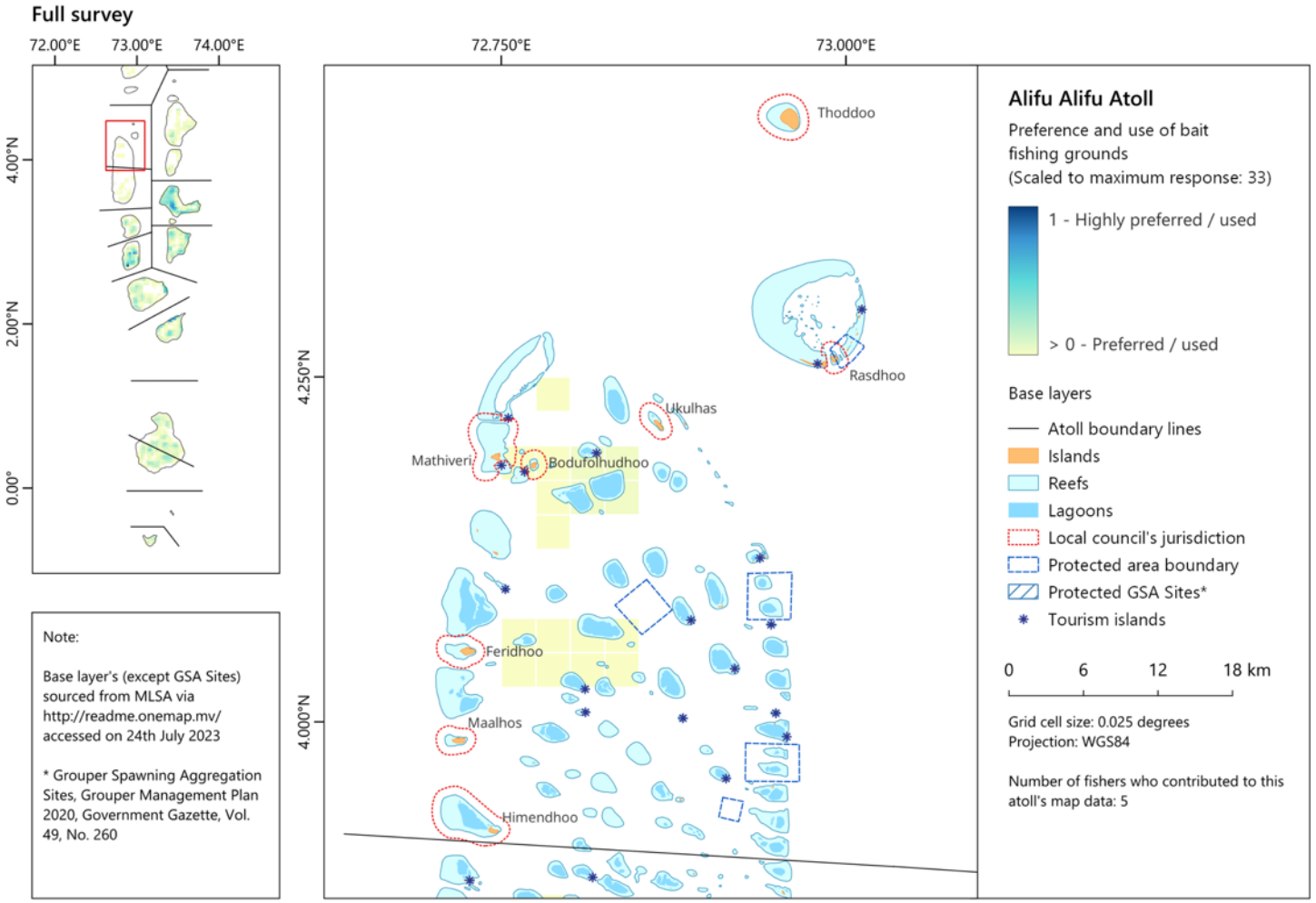

Figure 28: Livebait fishing ground for North Alifu Atoll.

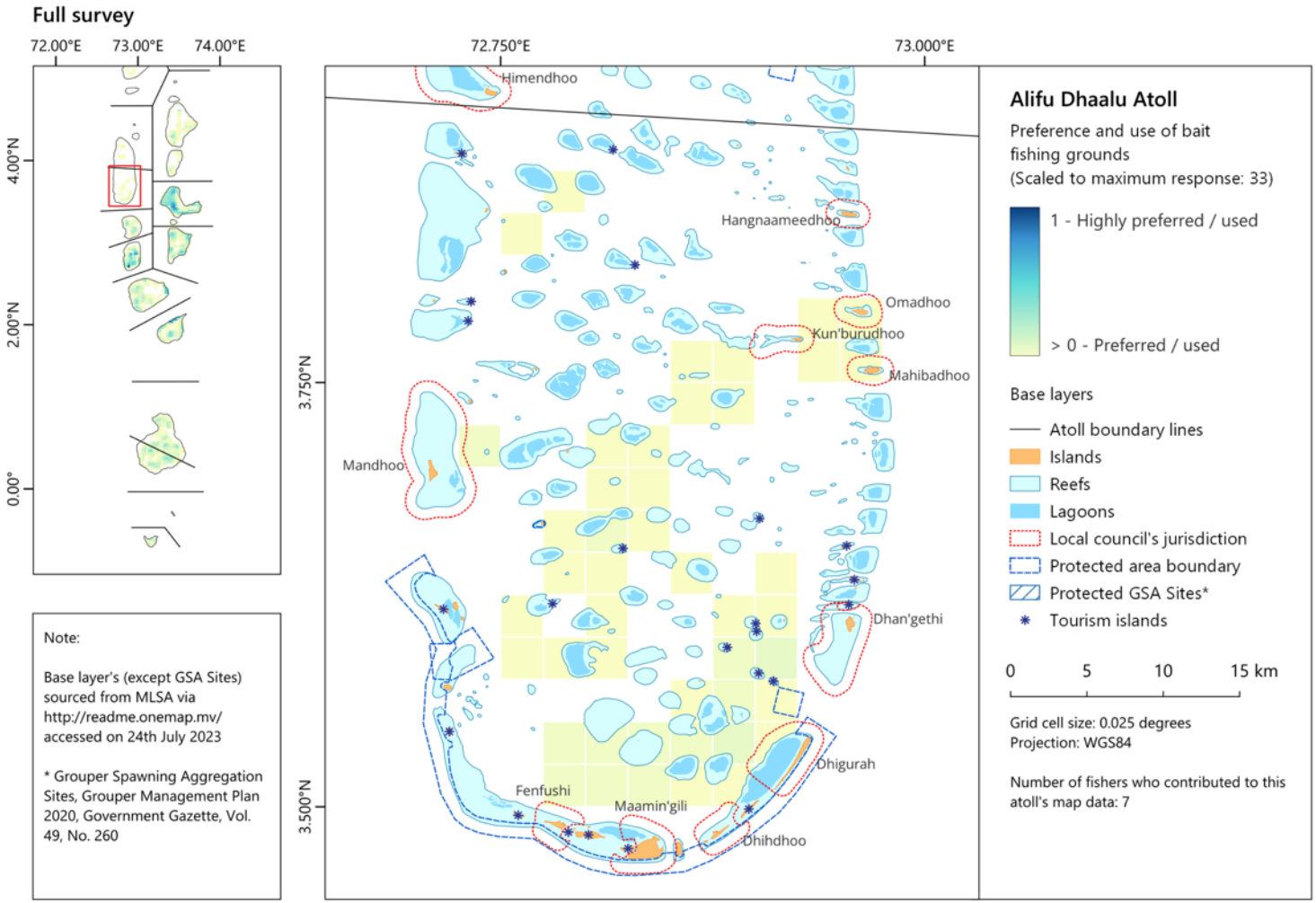

Figure 29: Livebait fishing ground for South Alifu Atoll.

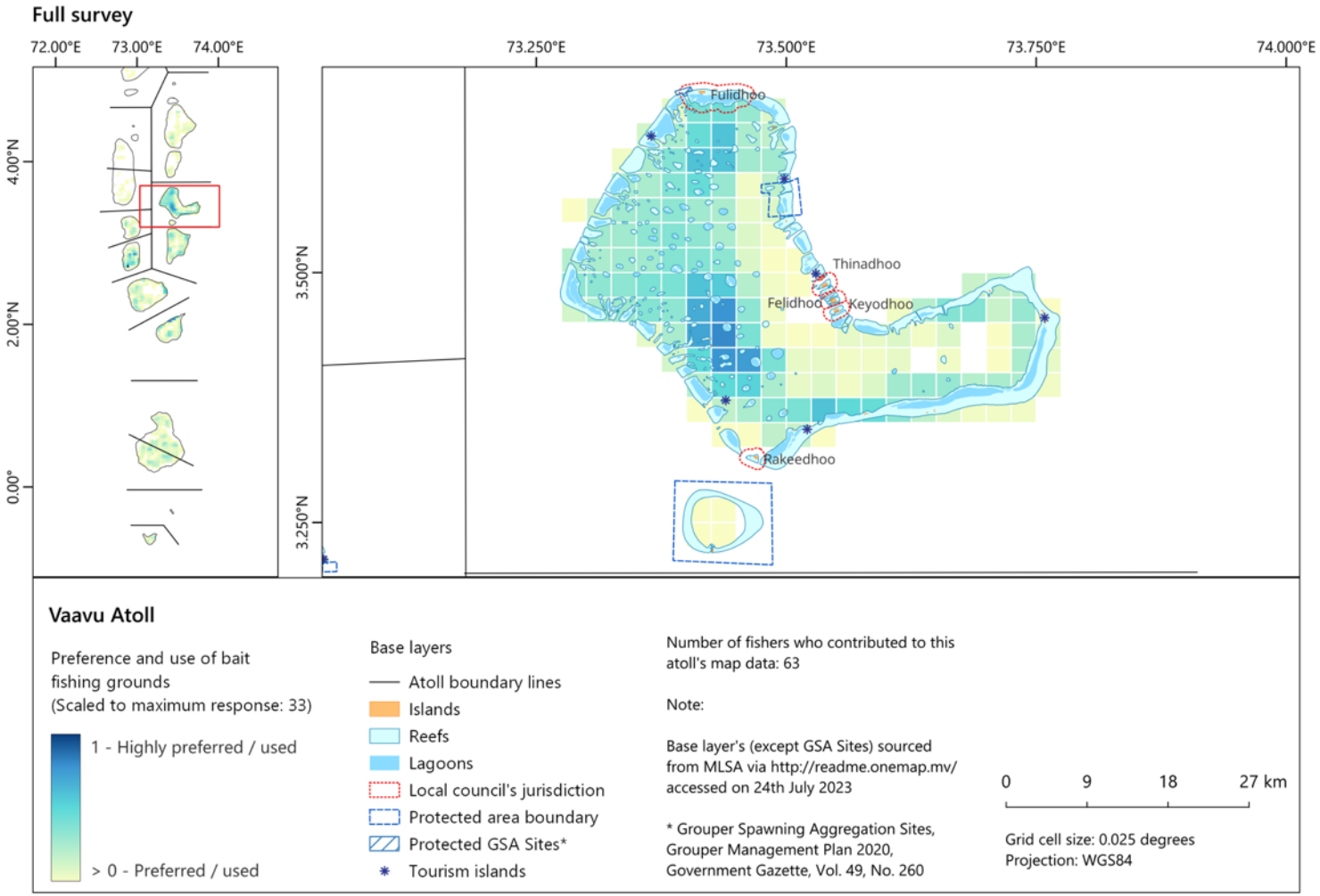

Figure 30: Livebait fishing ground for Vaavu Atoll.

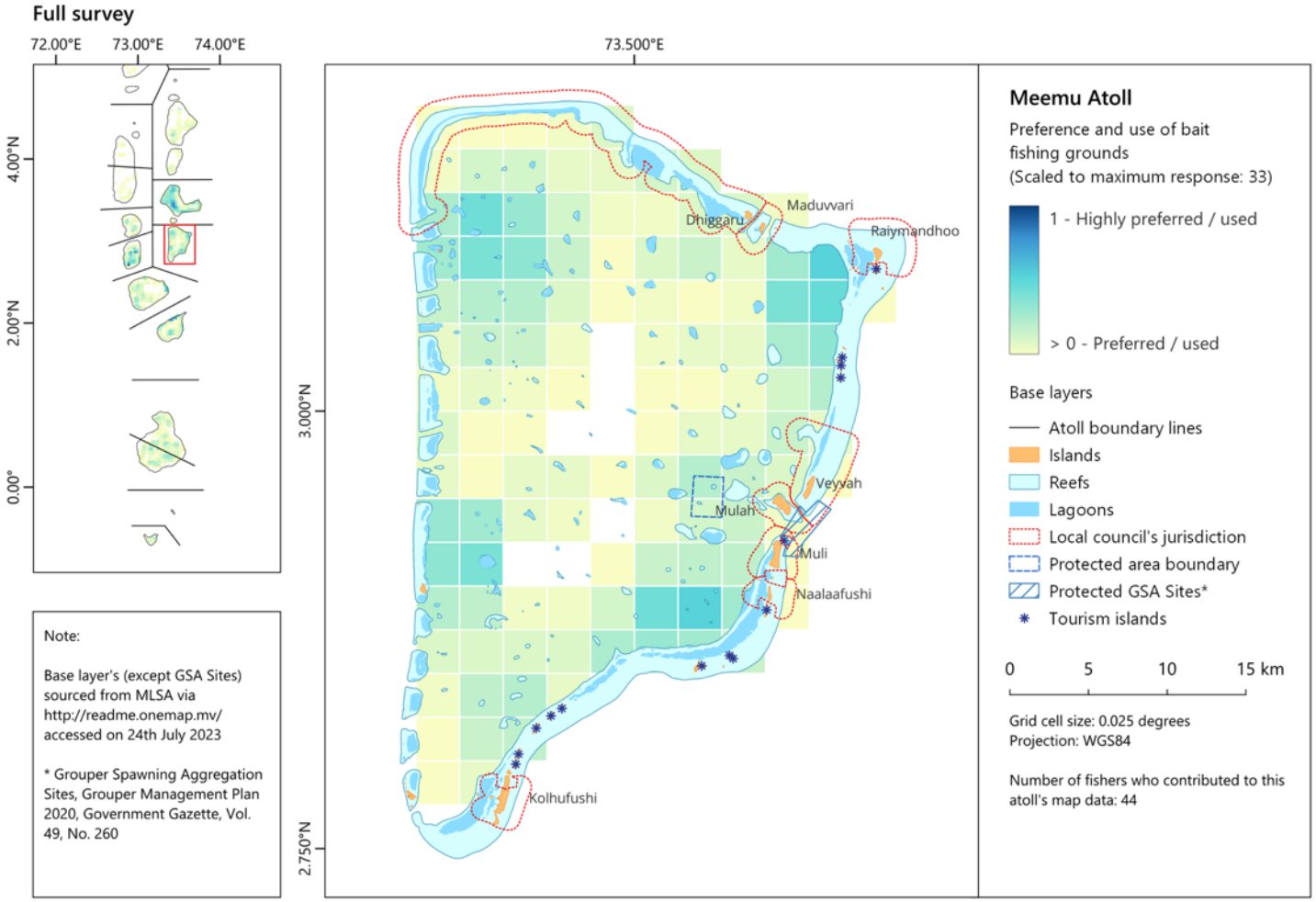

Figure 31: Livebait fishing ground for Meemu Atoll.

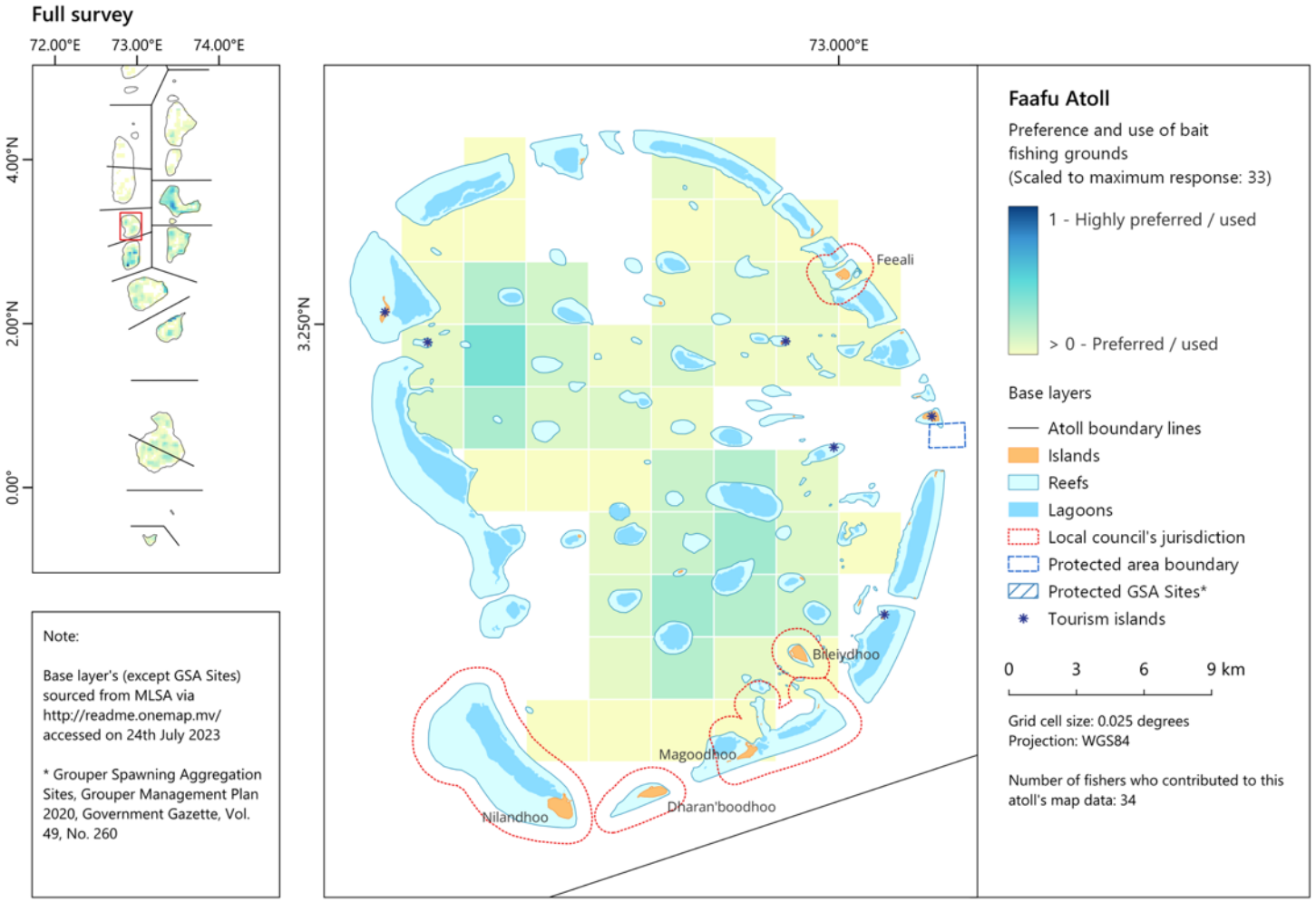

Figure 32: Livebait fishing ground for Faafu Atoll

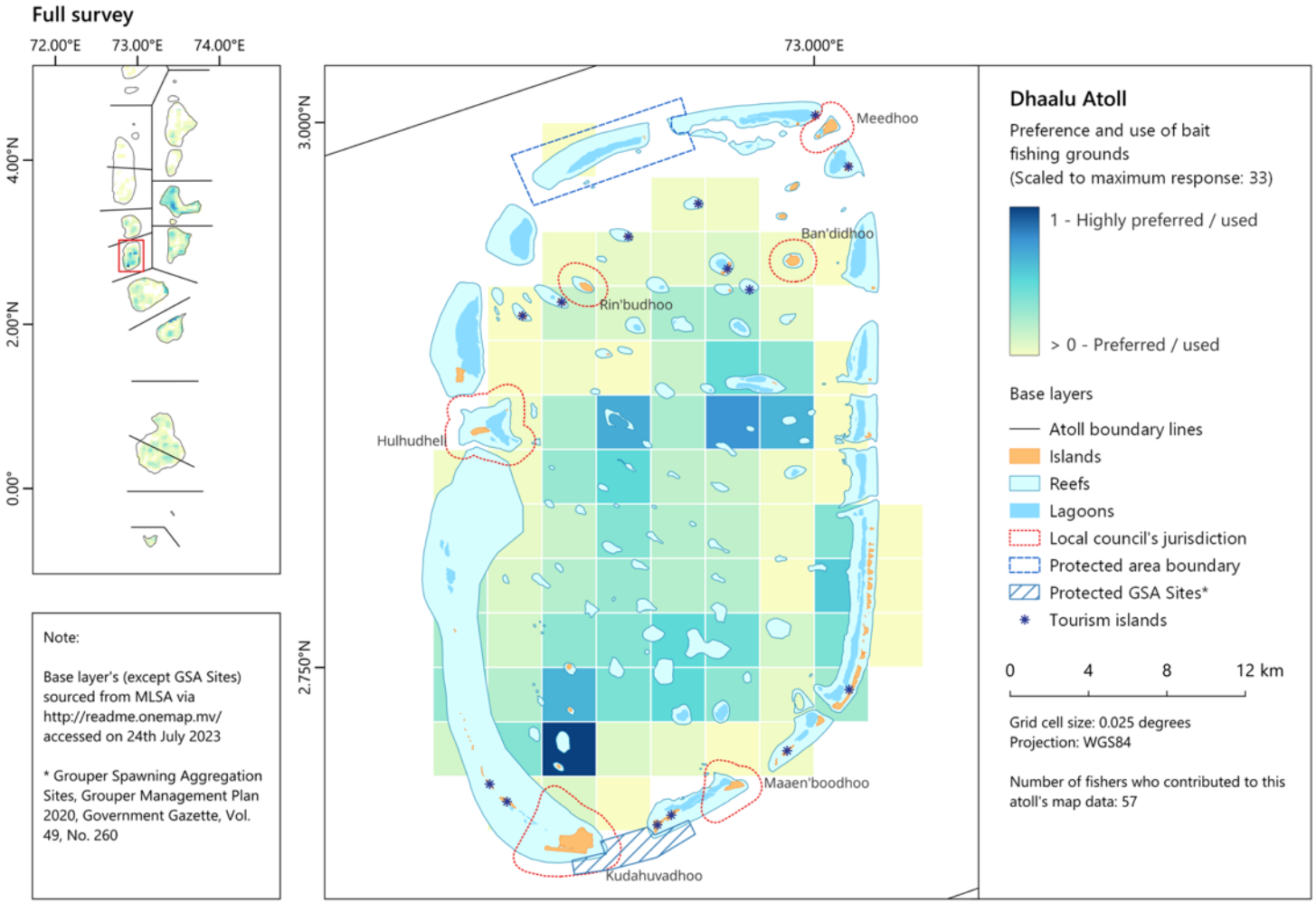

Figure 33: Livebait fishing ground for Dhaalu Atoll.

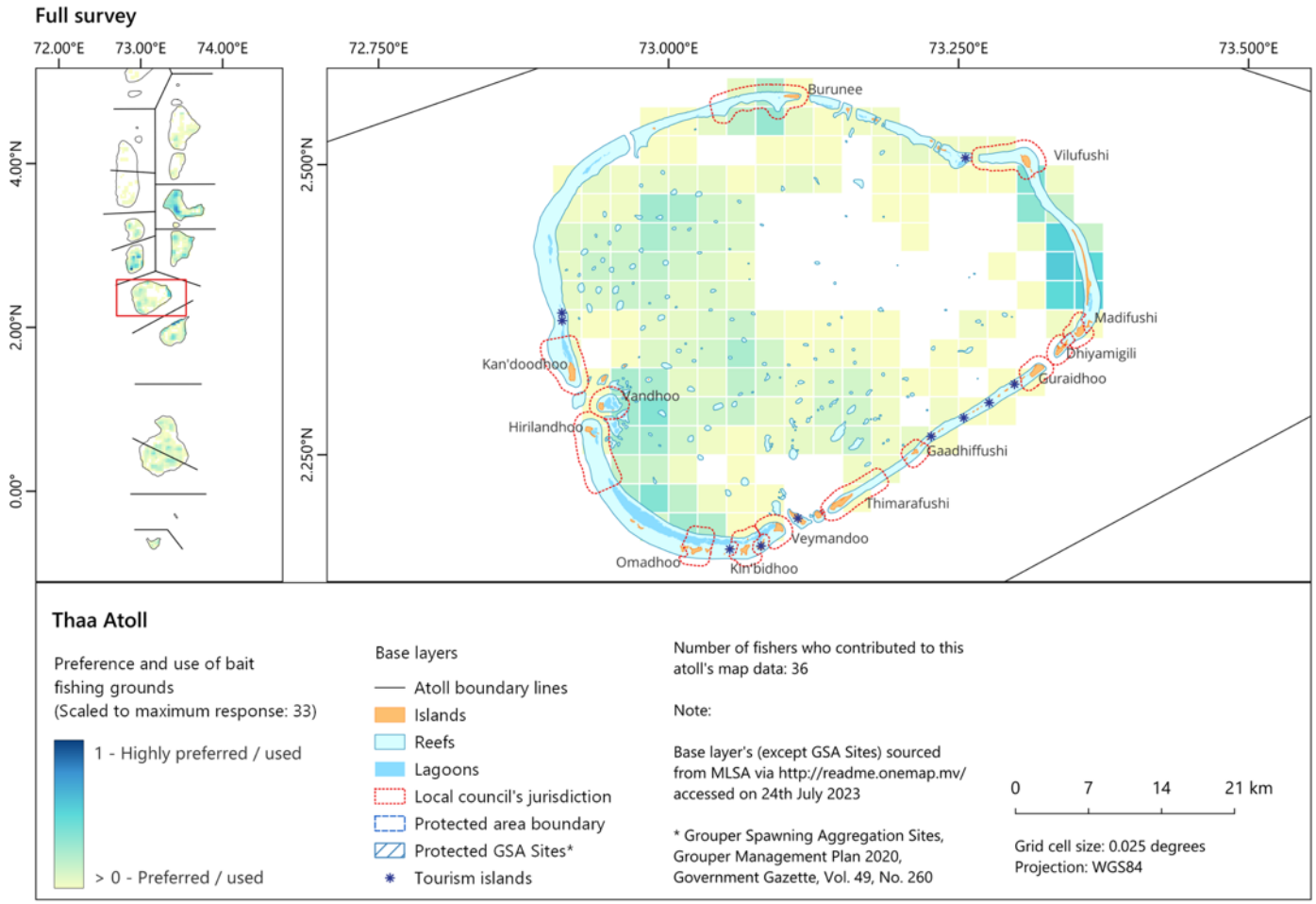

Figure 34: Livebait fishing ground for Thaa Atoll.

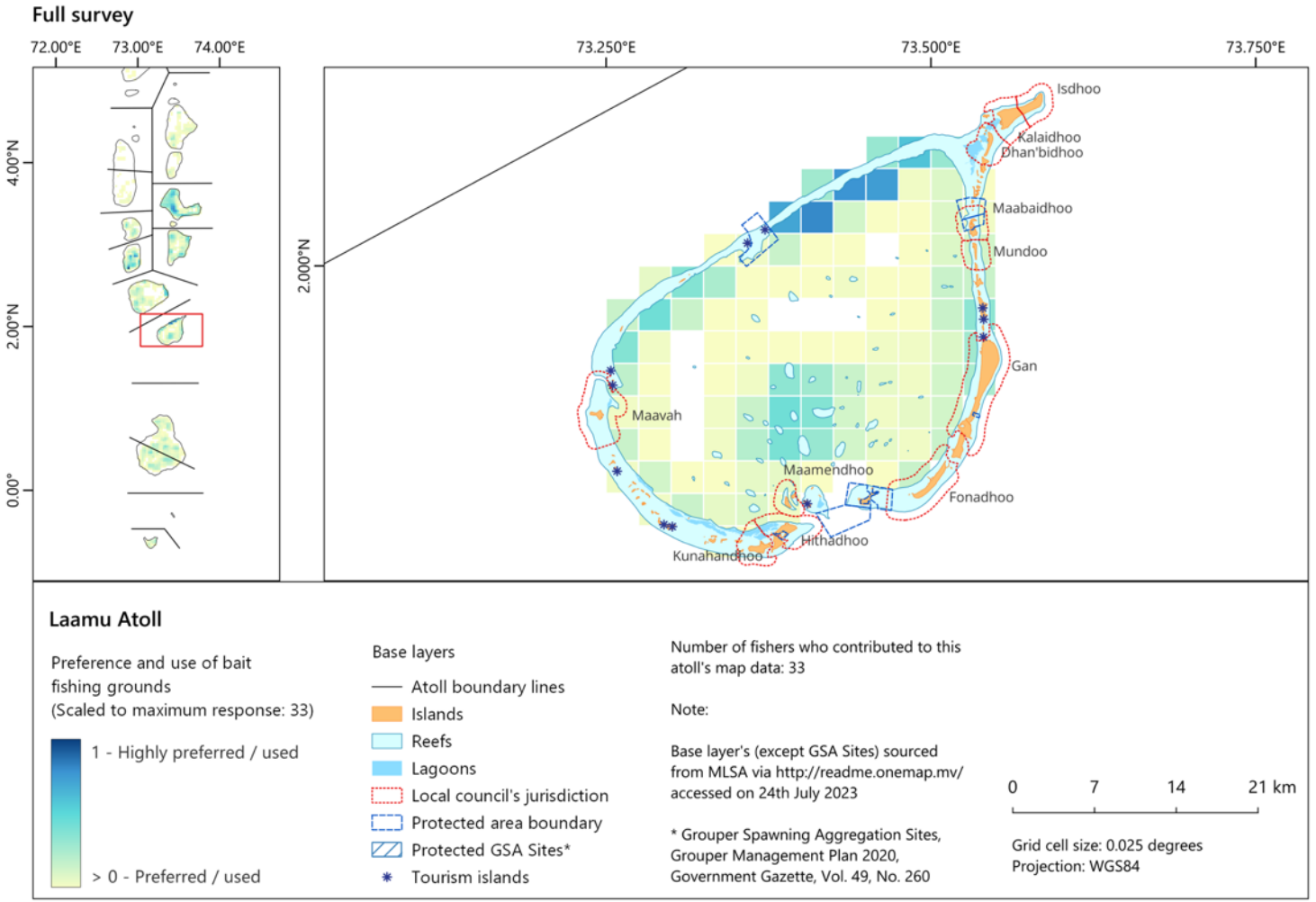

Figure 35: Livebait fishing ground for Laamu Atoll.

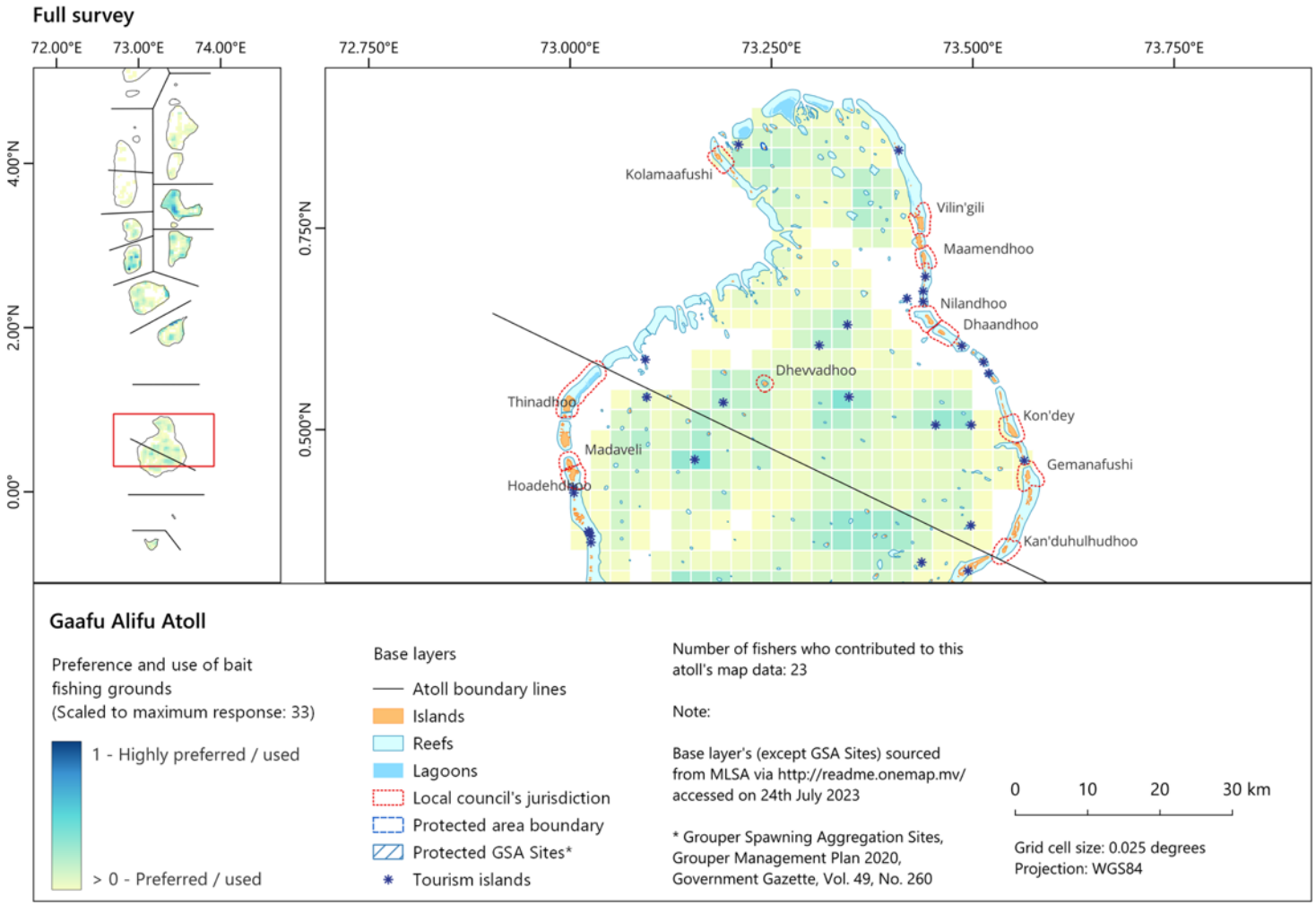

Figure 36: Livebait fishing ground for Gaafu Alifu Atoll.

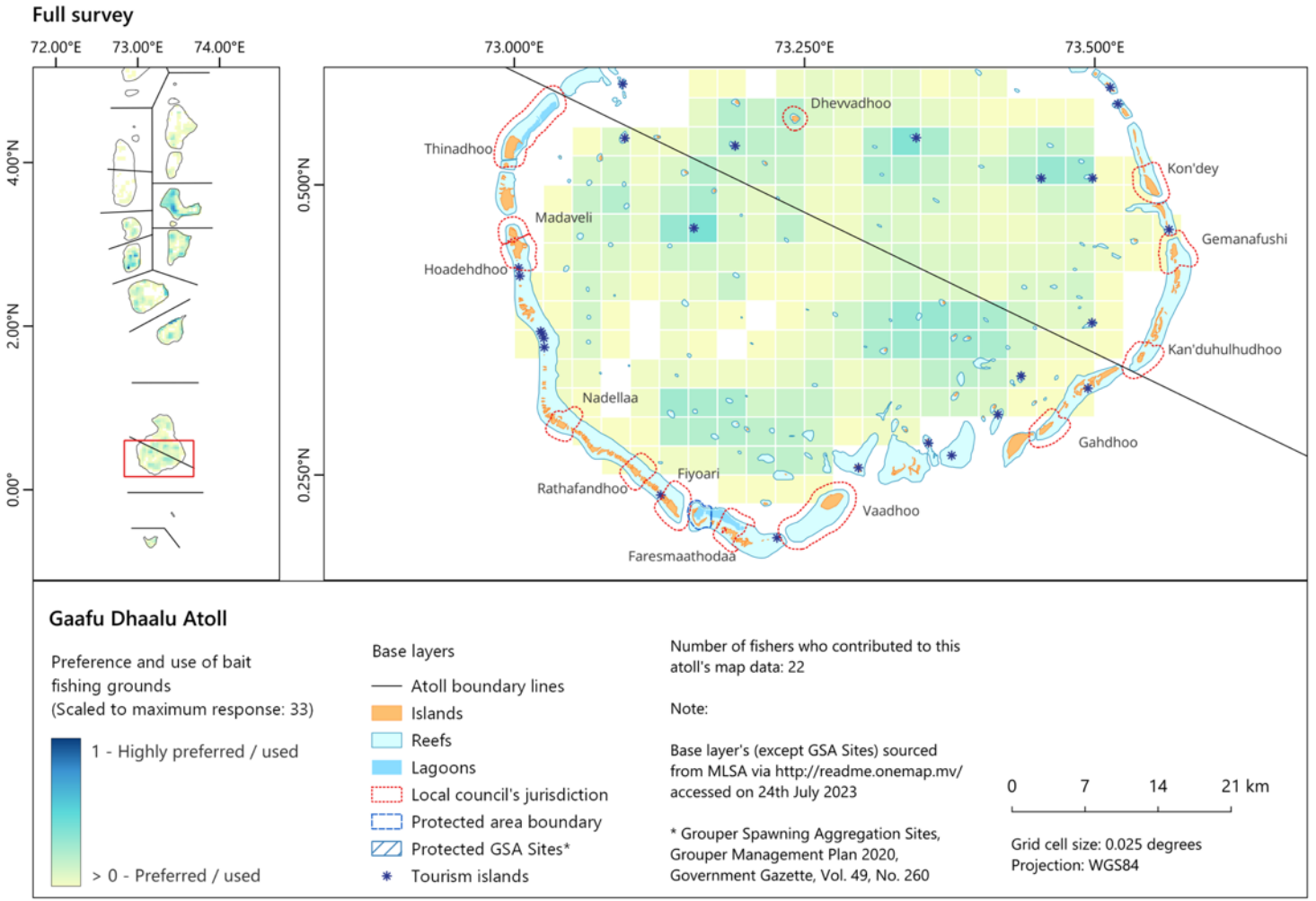

Figure 37: Livebait fishing ground for Gaafu Dhaalu Atoll.

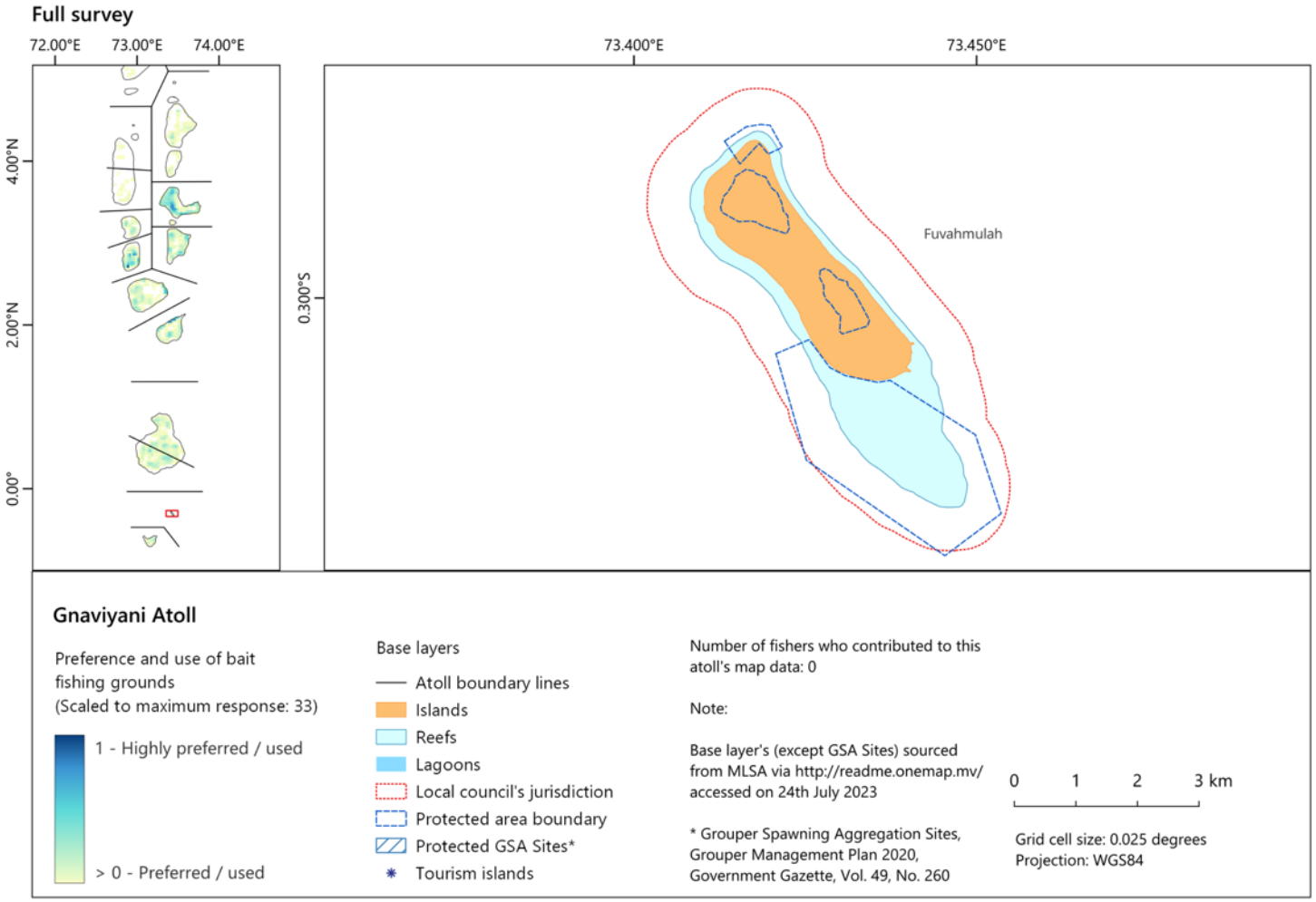

Figure 38: Livebait fishing ground for Gnaiviyani Atoll.

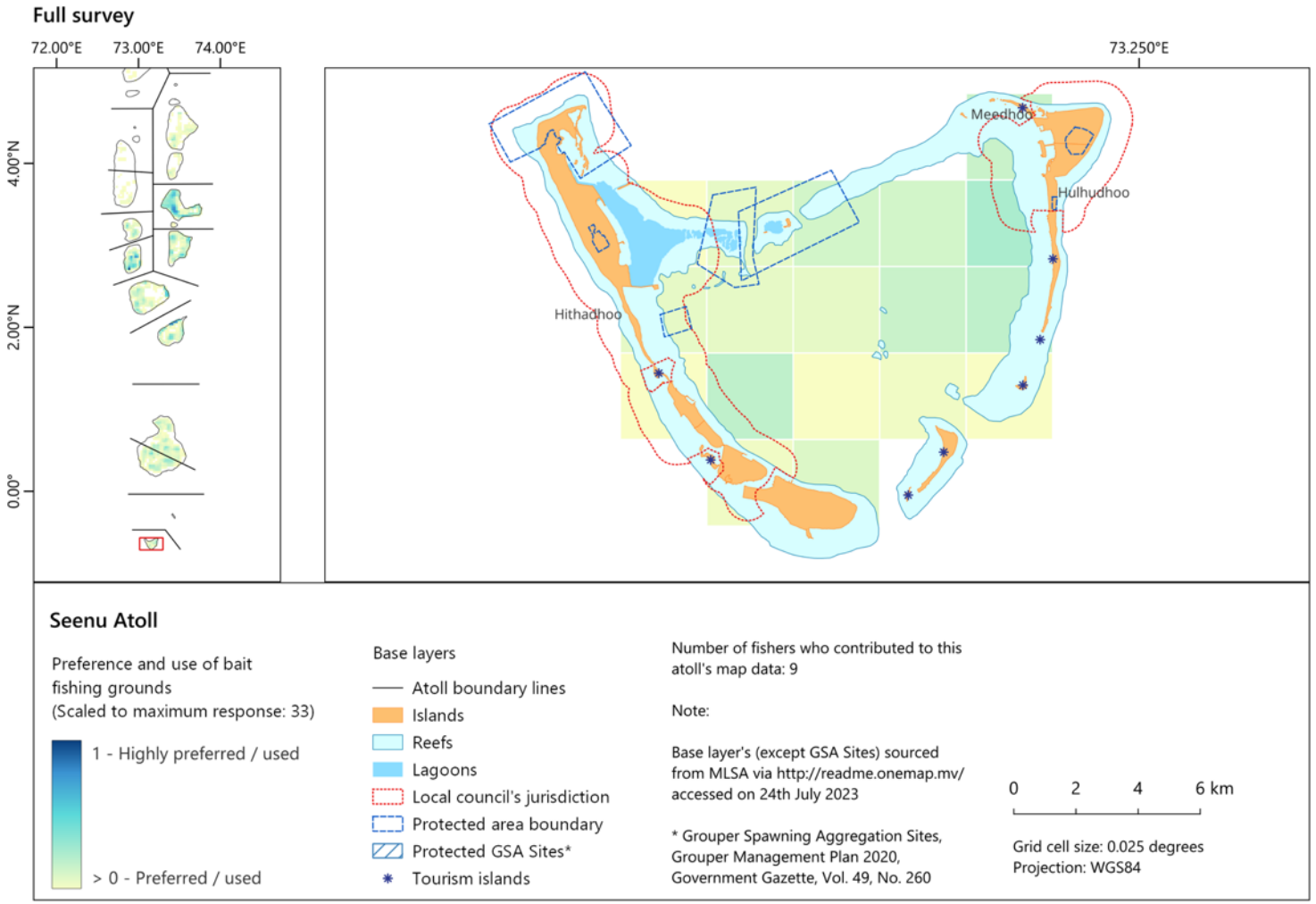

Figure 39: Livebait fishing ground for Seenu Atoll.

Acknowledgements

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