The Use of Fishers' Local Ecological Knowledge (LEK) in Mobulid Conservation, Maldives

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Justification: Ecology and Society is a leading journal with a reputation for publishing innovative and high-impact papers on multi-disciplinary areas of research with a focus on accessibility of information. This paper aims to demonstrate how multi-disciplinary methods can contribute to applied conservation assessing direct management implications for marine species. I believe this encompasses the journals principle ideas and that the topic of research would be well suited for the journal's audience.

Declaration: I certify that this dissertation is entirely my own work and no part of it has been submitted for a degree or other qualification in this or another institution and give permission for a copy to be held by my supervisor and distributed at their discretion.

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Manta TRUST

MUI MALDIVES UNDERWATER INITIATIVE by Six Senses Laamu

MALDIVIAN MANTA RAY PROJECT

Abstract

The increasing impact of human activity on the environment has prompted a demand for multidisciplinary forms of research in conservation science that consider both social and environmental factors. Obtaining local ecological knowledge (LEK) from fishers via interviews is such an approach and is increasingly used in species conservation management to supplement and reinforce conventional scientific knowledge (CSK). This study explores the utility of applying LEK to mobulid conservation efforts in the Maldives. Data from 123 interviews with local fishers is used to map the distribution of mobulids in Laamu Atoll, identify potential anthropogenic threats they face and understand local attitudes towards conservation. The validity and scalability of the method is appraised by contrasting against CSK and considering more widespread application. By analysing the LEK, evidence was found for a potential new research site not previously considered as a prospective mobulid hotspot. Entanglement in bait fishing nets could indicate an activity of potential conservation concern for mobulids, and is recommended for further investigation by conservation bodies. Local attitudes towards mobulids and conservation efforts appeared to be mostly positive in Laamu Atoll, due to the tourism and economic benefits they bring. From these findings, it can be concluded that LEK complemented by CSK is a valuable resource for improving understanding of local ecology and attitudes and thus for recommending species conservation strategy. This offers a promising way forward for marine conservation management strategies in data-poor areas.

Keywords: local ecological knowledge, mobulids, ethnobiology, species conservation, social science, conservation science, fishers

Contents

1. Introduction

Marine ecosystems are threatened by anthropogenic influences (Bender et al. 2014; Krueck et al., 2017). The growing demand for natural resources due to increased anthropogenic activities is putting pressure on the marine environment to provide amplified ecosystem services (Early-Capistrán, 2020). The health of marine ecosystems is thus compromised, and biodiversity is declining (Knight et al. 2008; Bender at al. 2014). Acknowledging this growing dependency between humans and the environment is vital for implementing successful conservation strategies (Bessesen and González- Suárez, 2021). The need to incorporate social considerations in conservation has thus been increasingly recognised (Braga-Pereira et al. 2021). Conventional scientific knowledge (CSK), sometimes referred to as 'western science' (Brook and McLachlan, 2005), can lack the social perspective necessary to incorporate multifaceted socioenvironmental factors (Brook and McLachlan, 2008; Drury et al. 2011; Colloca et al. 2020). Furthermore, marine environments can be problematic for the collection of CSK due to physical and technological limitations introduced due to the hostile environment of marine habitats and the vast habitat extent of many marine fauna (Brook and McLachlan, 2008). Employing multiple research methods can contribute to a deeper and more versatile understanding of marine conservation issues (Turvey et al., 2013; Wedemeyer-Strombel et al. 2019).

Ethnoscience, particularly ethnobiology, has been increasingly used to assess conservation factors (Sousa et al. 2013). Ethnobiology can be defined as the study of concepts and knowledge presented by a community regarding local taxa (Peterson et al. 2008) and can be used as a tool to interpret relationships between marine ecosystems and communities (Thaman, 1994). Local ecological knowledge (LEK) provides a tool for ethnobiological conservation science, exploring the wealth of knowledge local communities have gained through observations and interactions with their natural surroundings over time (Ruddle, 1994; Charnley et al. 2007).

Using LEK as a tool for species conservation has grown in popularity over the past three decades (Braga-Pereira et al. 2021). In northern Canada, scientists are encouraged to include LEK data in their studies, and in some cases, it is mandatory (Brook and MchLachlan, 2008). Incorporating LEK alongside CSK can provide a more robust understanding of conservation issues facing an area (Charnley et al., 2007). By using LEK, scientists can survey large or inaccessible areas without draining resources (Braga-Pereira et al., 2021), encourage the participation of local communities in conservation efforts (Sousa et al., 2013) and effectively compile research on species abundance and habitat range (Penaherrera-Palma et al. 2018). Despite this, the application of LEK in conservation science is often criticised due to its perceived unreliability (Gilchrist et al., 2005) as it is susceptible to bias (Howard and Widdowson, 1996), incorrect recollection (Schacter, 2002) and affected by changing perceptions of an environment over time (Pauly 1995). However, careful design of LEK research methods (Johannes, 1998), rigorous trials (Anadón et al., 2009) and comparison with CSK and other sources of information (Beaudrea and Levin, 2014; Lopes et al. 2019) can substantiate results.

Fishers are the focus of increasing numbers of LEK studies relating to the marine environment, providing information on trends in migration, abundance and distribution of marine species and how anthropogenic activities affect them (Wilson et al. 2006; Murray et al., 2006; Silvano and Begossi, 2010; Braga and Schiavetti, 2013; Sousa et al. 2013; Bender et al. 2014). These studies suggest that small-scale fishers have detailed LEK regarding the marine environment which is particularly useful in tropical developing countries with limited data (Silvano and Begossi, 2010). Fishers have also been seen to provide more accurate knowledge on marine species than other local groups (Freitas et al. 2021) and can provide important monitoring data in marine areas that are remote and costly to monitor solely using CSK methods (Caruso et al. 2017). Speaking to fishers can also provide complementary information on local attitudes towards conservation facilitating community-based or grass-roots conservation strategy that will encourage participation in conservation measures (Davis and Wagner, 2003). However, fishers' LEK can also be affected by extenuating influences such as political factors (Palmer and Wadley, 2007) so cross analysing with CSK is important (Huntington, 2000).

Mobulids[1] play an important role in nutrient cycle regulation and plankton abundance and diversity (Farmer at al. 2022) and their charismatic status (Poortvliet et al. 2015) contributes significantly to economies through tourism (Hosegood et al. 2020). However, reef manta rays (*Mobula alfredi*) are currently listed as vulnerable and oceanic manta rays (*Mobula birostris*) and spinetail devil rays (*Mobula mobular)* are listed as endangered on the International Union for the Conservation of Nature (IUCN) Red list (IUCN, 2022). Mobulids are facing a range of threats related to anthropogenic activities (Lawson et al. 2017). They are taken in a range of targeted fisheries (Alava et al. 2002) exacerbated by increasing demand for mobulid gill plates which are used in traditional Chinese medicines (Lewis et al. 2015), and often caught incidentally with significant rates of post-release mortality (Poisson et al. 2014). Alongside this, climate change is altering marine ecosystems, changing the abundance and geographical range of plankton (Hays et al. 2005) possibly causing scarcity in mobulids' primary source of food (Stewart et al. 2018). Mobulids are highly sensitive to these threats due to long gestation periods, low fecundity, and slow growth (Lawson et al. 2017). Despite growing concern for these species, significant knowledge gaps still exist, in part due to the spatial and temporal difficulties of monitoring the highly mobile marine species in their vast oceanic environment (Couturier et al. 2012; Stewart et al. 2018).

Using mobulids in the Republic of Maldives (henceforth referred to as Maldives) as a case study, this study aims to explore if LEK, obtained through interviews with fishers, can be a useful source of information for implementing mobulid conservation management in Laamu Atoll and subsequently whether this could be replicated on a national scale. More specifically, the research objectives were;

- **Research Objective 1 (RO1):** To explore the potential of LEK to identify potential areas for conservation management.

[1] In this paper, 'manta rays' will be used generally to describe reef manta rays and giant manta rays. 'Mobula rays' will be used to describe other rays of the mobulidae family residing in the Laamu Atoll. When discussing 'manta rays' and 'mobula rays', they will be referred to as mobulids.

- **Research Objective 2 (RO2):** To assess the prevalence of behaviours by fishers that might be of concern for mobulid conservation.
- **Research Objective 3 (RO3):** To use LEK to explore fishers' attitudes and awareness concerning mobulid conservation.

This study contributes towards local interventions led by the Manta Trust and will inform future management strategies by the organisation regarding mobulids in Maldives.

2. Methodology

2.1 Study Site

The Republic of Maldives is a mid-ocean atoll nation 500 km from the southern tips of India and Sri Lanka (Fig. 1) (Kundar, 2012). It comprises 26 atolls consisting of 1,190 low-lying coral reef islands primarily home to small, local, rural communities characterised by low development levels and limited technical and financial facilities (Jaleel, 2013; Magnan and Duvat, 2020). The population has doubled approximately every quarter century since the 1960s standing at 402,071 in 2014 (Government of Maldives, 2014) with high population densities in urban areas (Magnan and Duvat, 2020). Maldives is recognised for its biologically diverse marine environment (Hameed, 2002). This supports the main economic industry of tourism, which contributes 56.6% to the total economy and supports 59.6% of employment, and fishing (Techera and Cannell-Lunn, 2019), which has been the primary source of food and trade for hundreds of years and is particularly important in rural communities where it remains vital for employment and food security (Stevens and Froman, 2019).

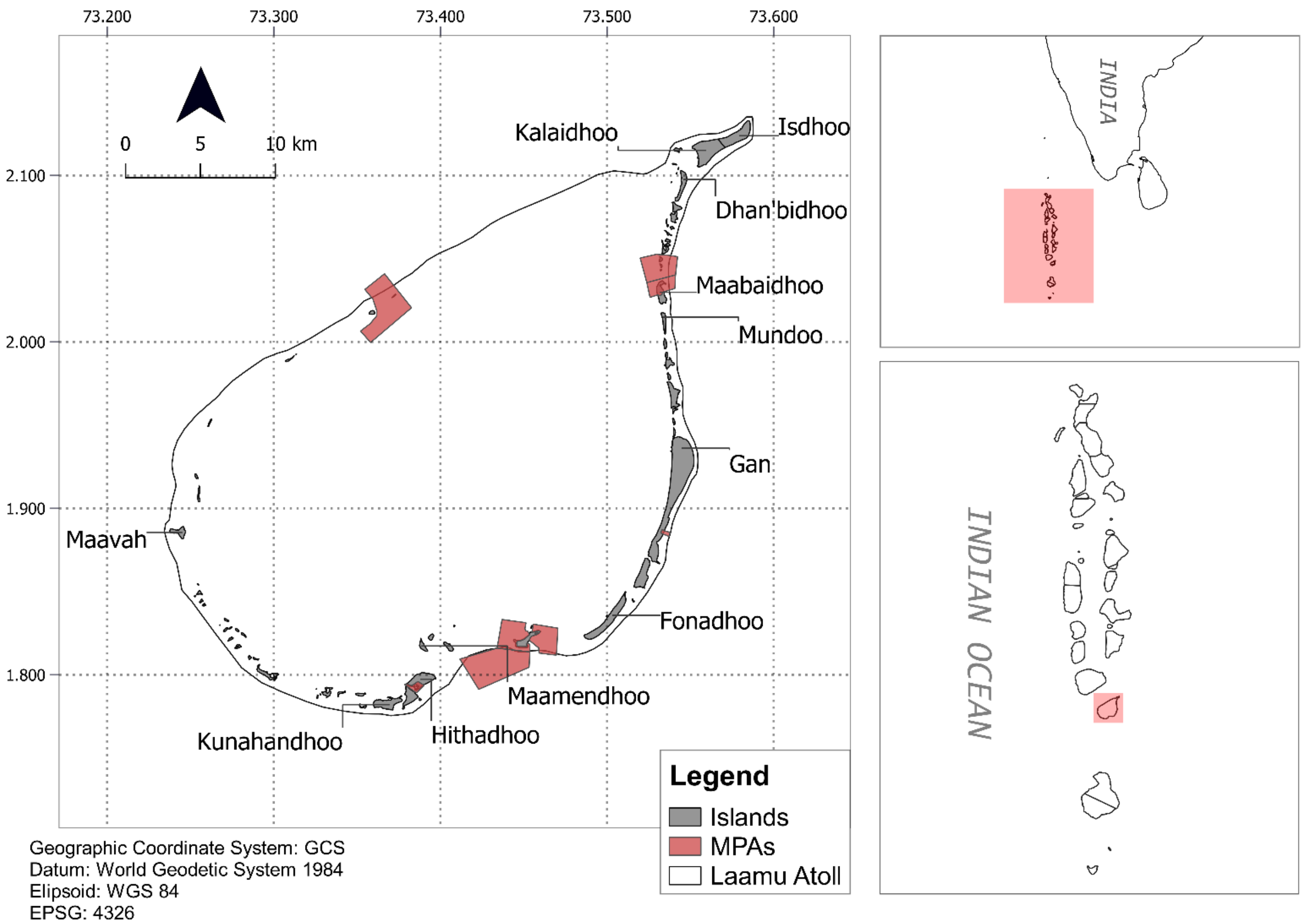

Figure 1: The study area of Laamu Atoll with inhabited islands labelled and marine protected areas (MPAs) indicated with the atoll location within Maldives archipelago and the country's location indicated on the right.

Laamu Atoll (2.0°N, 73.5°E) (Fig. 1) is located in southern Maldives and consists of 75 coral reef islands, 11 of which are inhabited with a total population of 18,281 (National Bureau of Statistics (NBS), 2019). Gan is the largest island of both the atoll and Maldives with an area of 6 km^2 (Sovacool, 2012) with the island of Fonadhoo being the atoll's administrative capital (NBS 2019). The major economic industries of the atoll are fisheries and agriculture (ibid.). Tourism is still developing in the atoll with three resorts operational and 11 planned (Ministry of Environment, Climate Change and Technology (MECCT), 2022). The atoll contains a diverse range of ecosystems which support rich biological diversity and key habitats for fisheries (ibid.). There are six designated marine protected areas (MPAs) in the atoll (Fig. 1)(ibid.).

Maldives supports the largest known population of manta rays (Kitchen-Wheeler et al., 2012; Stevens, 2016). Manta rays are a major attraction for tourists in Maldives with one study estimating the direct revenue of reef manta rays alone to be $15 million per year (Stevens and Froman, 2019). However, increasing anthropogenic pressures predominantly originating from the tourism and fishing sectors, such as net and fishing line entanglement and boat traffic injuries (Anderson et al. 2011), are threatening manta and mobula ray species necessitating research into their conservation. The Manta Trust led Maldivian Manta Ray Project (MMRP) carry out monitoring and evaluation of mobulids throughout Maldives (MMRP, 2014). Currently they primarily achieve this by monitoring sightings using photographic identification, distinguishing and re-identifying individuals over time (Stevens, 2016). Mobulids have been protected in Maldives since 2014, a movement spearheaded by the MMRP (MMRP, 2014).

2.2 Data Collection and Analysis

2.2.1 Survey Design

Interviews to collect LEK data from fishers concerning mobulids in Laamu Atoll were designed based on a questionnaire which examined five dominant areas – i.e.: i) *background information*: (namely age, home island, years spent fishing); ii) *fishing practices employed and primary catch*; iii) *knowledge about native marine species and mobulids;* iv) *knowledge about mobulid occurrences and threats faced by the group*; v) *knowledge of measures for mobulid protection and attitude towards conservation of the taxonomic group* (Appendix 1). The topics were ordered as above to generate a dynamic flow (Kvale, 2007), provide relevant prompts to prepare interviewees for the main line of questioning (Fylan, 2005) and to put participants at ease (Sousa et al. 2013) increasing the reliability of fishers' answers. Reliability is the confidence that fishers are answering to the best of their knowledge whilst accuracy is the level to which the information provided relates to real-world biological phenomena (Maurstad et al. 2007). Therefore, an answer that is reliable could be inaccurate (Silvano and Begossi, 2012). By comparing fisher LEK to CSK accuracy can be checked (ibid.).

The first two sections consisted of “warm up” questions which are easy for participants to answer and frame the subsequent sections of the interview (Bearman, 2009). Participants respond with more reliability when they do not feel threatened (ibid.) so these sections opened the interview to put participants at ease before asking questions about more sensitive topics such as the intentional or unintentional catches of protected species. Furthermore, cognitive, and experimental psychology research indicates that providing respondents with appropriate prompts or cues can improve their consistency in recollecting particular details of events (Thurstan et al. 2016). Asking participants about their fishing history and knowledge of mobulids before asking more specific questions about particular events should facilitate more accurate recollection processes.

Section three evaluated the knowledge of participants. When using LEK data, it is necessary to assess reliability to ensure a robust research method (Gilchrist et al. 2005). Assessing the expertise of participants is useful in attempting to retain reliable data on fauna abundance and distribution (Madson et al. 2020). Participants were asked questions relating to their knowledge of marine fauna in the study site, followed by specific questions about manta and mobula rays.

Section four consisted of the main focus of the interview and addressed the three research objectives. The risk of misidentification or incorrect recollection was minimised by showing participants species images at the beginning of this section (Azzurro et al. 2011; Zeller et al. 2011). Maps with a grid system were used for participants to point out areas coinciding with manta and mobula ray occurrences (Appendix 2). The concluding section regarded participants’ knowledge and perceptions of mobulid conservation including participants’ awareness of the Manta Trust and how they and their communities perceived the work of conservationists. Participants were also given a chance to make any comments they would like recorded. Bearman (2009) refers to the last section of an interview as ‘final reflections’ where abstract questions are most appropriate, limiting interruption of the dynamic flow. Understanding wider perceptions of participants towards conservation will be useful in implementing successful species management strategy in the area (Braga and Schiavetti, 2013).

2.2.2 Data Collection

Data collection took place from April to June 2022 on all 11 inhabited islands of the Laamu Atoll (figure 1). Each island was visited for a mean duration of 3 days and face-to-face interviews were conducted. Interviews were conducted in Dhivehi via an interpreter and after each question the answers were recorded in English by the same interpreter. Prior to data collection, this project was approved by the CLES Cornwall Ethics Committee (ID: 511829), and the survey was tested on seven participants with minor amendments made thereafter to streamline the interview process.

Originally, any participants with experience at sea were eligible for inclusion in the study, alongside fishers. However due to the small sample sizes of other categories (7% (N = 9) were boat captains, 2% (N = 4) were 'other' which included two boat crew, one dive guide and one underwater photographer) and therefore the difficulties of statistical significance, those who did not fish were removed from this analysis.

Island inhabitants were initially sampled for interviews through opportunistic sampling whereby potential participants were approached in harbour areas and asked if they would be willing to participate in the study. Further contacts were then obtained through snowball sampling whereby respondents would identify other appropriate interview candidates (Bernard, 1995). Prior to the interview, participants would be given a brief background of the study and asked for their permission to continue (Appendix 3). Respondent answers were recorded on an iPad with the app Qualtrics (Qualtrics, 2020) and interviews were also recorded. Where possible, individuals were approached individually to minimise interference from their community. Where this was not possible, interference was minimal as questions were directed solely to the participant and the answers recorded were their own.

Contact details were collected using a separate form to anonymise answers to the main survey (Appendix 4). This information will be stored confidentially by the Manta Trust and used to inform participants of study updates and collect more information where permission has been given.

During the data collection, participatory meetings were also held for local councils and fishers to explain the research taking place and the work of the Manta Trust around Laamu Atoll. The intention is to notify participants and return to islands to discuss the results and implications of this study.

2.2.3 Data Analysis

The initial steps in data analysis were to produce descriptive summaries to characterise the study participants.

Relationships between variables in all models were analysed using R version 4.2.1 (R Core Team, 2022). Multivariate models were tested for multicollinearity using the *car* package (Fox and Weisberg, 2019) to work out variance inflation factors (VIF) for variables (VIF < 2) (Craney and Surles, 2002).

To assess the effect of age on knowledge indicators (Low – Excellent; Table 1), the polr command from the *MASS* package (Venables and Ripley, 2002) was used to estimate an ordered logistic regression model. Ordered logit models are used for analysing the relationship between ordered categorical data and explanatory variables (Ettner and Grzywacz, 2001).

To explore effects on attitude, generalized linear models (GLMs) with Gaussian error distribution were fitted. To explore effects on binary variables, GLMs with binomial error distribution were fitted. These have been used to assess fishers reporting mobulid catches and awareness of conservation efforts.

Significance testing for all models was carried out using anova to obtain a p-value. Where there was one variable the full model was tested against a null model. Where there were ≥2 variables, the full model was tested against a model minus the variable of interest. This was to discern whether the variable explained significant variation in the model ($p < 0.05$).

2.2.3.1 Assessing LEK

For quantitative comparisons of reliability of knowledge of study participants, outcomes from section three of the questionnaire were converted using a scale whereby i) correct answers = 1; ii) partially correct answers = 0.5; iii) null or incorrect answers = 0. Where appropriate, answers were validated using comparisons with scientific papers. The scores were then summed for each participant and divided by the highest possible score to create proportional knowledge indicators (Braga and Schiavetti, 2013). These scores were then split into four ordinal classes (Table 1) to indicate the spread of knowledge of prospects.

Table 1: Conversion of proportional knowledge and attitude scores to ordinal ranked classes.

Class	Proportional Score	Knowledge Indicator
1	*0 – 0.25*	Low
2	*0.26 – 0.5*	Average
3	*0.51 – 0.75*	Good
4	*0.76 – 1*	Excellent
Class	**Proportional Score**	**Attitude Indicator**
1	*0 – 0.33*	Negative
2	*0.34 – 0.66*	Moderate
3	*0.67 – 0.1*	Positive

To assess the extent of effect of age on the knowledge indicators an ordered logistic regression model was estimated. Age was chosen to indicate whether it could explain significant variation in knowledge indicators, exploring whether it might be useful as an indicator of expertise in future studies as previous research suggests (McDade et al. 2007; Aswani et al. 2018). Increasing recommendations for the use of 'experts' when collecting LEK data, characterised by high levels of experiential knowledge of the study area, make this an important area to explore (Davis and Wagner, 2003). The knowledge proportional score data (Table 1) was also analysed using the Kruskal-Wallis rank sum test (Kruskal and Wallis, 1952) to test for any discrepancies in significance compared to the ordinal ranked data. In further analyses where knowledge is fitted as an independent variable, the knowledge proportional score has been fitted.

2.2.3.2 Abundance and Distribution Observations *(RO1)*

To explore the potential of LEK to complement CSK in identifying appropriate areas for conservation management, spatial distribution and abundance data regarding mobulid occurrences were collected from participants and analysed using QGIS version 3.16.11 (QGIS Development Team, 2022). These were then compared to CSK, namely mobulid abundance and distribution data collected by the MMRP and fishing hotspot data collected by Blue Marine Foundation (BMF). They were also compared to the Laamu Atoll designated MPAs. The overlap present in maps depicting where mobulids were most often seen compared to MMRP hotspots, fishing intensity and MPA locations was assessed.

2.2.3.3 Assessing Targeted Behaviours *(RO2)*

To assess the prevalence of behaviours that might be of concern to mobulid conservation, fishers who self-reported participating in potentially harmful activities were scored as: 1 = participated and 0 = did not participate. These behaviours were then analysed against participant's years of fishing experience and the proportional scores for attitude and knowledge using multivariate binomial GLMs as discussed above. This was done to assess potential contributing factors to these behaviours.

2.2.3.4 Assessing Fishers' attitudes and Perceptions *(RO3)*

To assess the attitudes of fishers towards mobulids, answers to questions that could indicate this were converted to a scale whereby: i) positive attitudes = 1; ii) moderate attitudes = 0.5; iii) negative attitudes = 0. Proportional attitude scores were split into three ordinal classes (Table 1).

Due to a disproportionate number of participants scoring 'Positive', the effects of variables were tested on the attitude proportional score rather than the ordinal classes (Table 1) so as not to lose important data points. The attitude proportional score was log transformed to ensure normality of model residuals and analysed using a GLM with Gaussian distribution.

To further explain the high number of positive outcomes, a conventional content analysis approach was used. The responses to open-ended questions regarding fishers' attitudes towards conservation were analysed to identify repeating keywords which were then grouped into wider categories (Hsieh and Shannon, 2005). These categories were intended to capture the key themes related to fishers' attitudes towards mobulid conservation.

Answers to the question – *'Are you aware of the Manta Trust?'* - were converted into a binary whereby; 1 = Yes, 0 = No. This data was analysed with a binomial GLM.

3. Results

3.1 Characteristics of Study Participants

In total, 123 interviews with fishers on Laamu Atoll were conducted over a two-month period with the mean number of interviews for each island being 11 (SD = 5) (Appendix 5). The respondents were all male and aged between 18 and 80 years with a median age of 40. The majority (97%; N = 119) of participants were local to the island they were interviewed on and had a mean residency of 36.5 years (SD = 17.2). The mean fishing experience was 19.6 years (SD = 15.1) with the majority (72%; N = 88) stating they were at sea 'most days'. The main method of fishing was pole and line (75%; N = 92) with 14% (N = 17) stating hand line and 11% (N = 14) employing a mix of methods including hand line, pole and line, trolling, spearfishing, jigging and net.

3.2 Assessing Fishers' LEK

Based on an assessment of fishers' knowledge of the morphological and behavioural traits of mobulids and knowledge of other native fauna, the majority (46%; N = 57) of participants scored 'Average' for knowledge indicators with 28% (N = 34) scoring 'Good' and 13% (N = 16) scoring both 'Excellent' and 'Low' (Table 1; Table 2).

When asked to identify native marine fauna of Maldives, 37% (N = 45) answered correctly with 46% (N = 55) answering partially correctly and only 17% (N = 23) answering incorrectly (Table 2). When asked to describe mobulids, their approachability and relative harmlessness (28%; N = 34), the large size of manta rays compared to smaller size of mobula rays (26%; N = 32) and their cephalic fins (24%; N = 30) were most commonly identified (Appendix 6). Only 18% (N = 22) could identify the difference between oceanic and reef manta rays when asked, but 79% (N = 97) could identify differences between mobula rays, eagle rays and sting rays. In addition, only 4% (N = 5) had not seen a manta ray and 33% (N = 40) had not seen a mobula ray with 2% (N = 3) having seen neither. This suggests that the majority (98%; N = 120) of participants have had contact with manta rays and/or mobula rays suggesting reliability in their answers.

3.2.1 Testing Age as an Indicator of Knowledge

When exploring the effects of age on knowledge indicators associated with fishers' knowledge about mobulids and marine fauna in the study area, it did not explain a significant amount of variation in the model (p>0.5; Appendix 7).

To ensure this was not a result of interpreting the knowledge proportional score as a categorical ordinal variable, the Kruskal-Wallis rank sum test was also performed to check the effect of age on the proportional score (both p>0.5; Appendix 8).

Table 2: Converting knowledge answers to three-point Likert scale of knowledge indicators.

Question	Method	Score		
Which of these species can be observed in Maldives?	➢ Shown a sheet with pictures of eight different species on it (Appendix 9). Four of these were common native species in Maldives and four were non-native species. ➢ Asked to identify which species could be found in Maldives.	**CORRECT = 1** *All native species identified with no non-native species being identified*	**PARTIALLY CORRECT = 0.5** *3+ native species identified, no more than one non-native species*	**NULL/INCORRECT = 0** *Less than 3 native species identified and/or more than one non-native species identified*
Could you describe [Manta/Mobula Rays] to me?	➢ Asked if they had seen a manta or mobula ray. ➢ If they responded 'Yes', asked to describe the species. ➢ See Appendix 6 for an extensive list of identified morphological characteristics/behavioural traits (MC/BT)	**CORRECT = 1** *Correct identification of MC/BT of both mobulids*	**PARTIALLY CORRECT = 0.5** *Correct identification of MC/BT of manta or mobula rays*	**NULL/INCORRECT = 0** *Incorrect identification of MC/BT of mobulids or no answer*
Can you tell the difference between these two species?	➢ Shown a laminated sheet depicting Oceanic Manta Rays and Reef Manta Rays (Appendix 10). ➢ Asked if they could differentiate between the two species.	**CORRECT = 1** *Correct identification of both species*	**PARTIALLY CORRECT = 0.5** *Could tell the difference between the two species but did not know names*	**NULL/INCORRECT = 0** *Could not tell the difference between the species or no answer*
Can you tell me anything about these species of rays?	➢ Shown a laminated sheet with pictures of three species of ray (Spotted Eagle Ray (*Aetobatus narinari)*, Cowtail Stingray (*Pastinachus sephen*) and Spinetail Devil Ray (Appendix 11). ➢ Asked if they knew anything about the different species of ray.	**CORRECT = 1** *Correct identification of all three species*	**PARTIALLY CORRECT = 0.5** *Correct identification of one or two species*	**NULL/INCORRECT = 0** *Could not identify any ray species or no answer*

3.3 Abundance and Distribution of Mobulids in Laamu Atoll *(RO1)*

When asked which species they saw most regularly (reef manta ray, oceanic manta ray or mobula ray), the majority (73%; N = 90) of participants answered reef manta ray. Results relating to historical abundance were inconclusive with 23% (N = 27) answering that they thought mobulids were becoming less common and 20% (N = 24) that they were becoming more common. The majority of participants (57%; N = 72) responded 'Don't know'.

A total of 169 squares on the map shown to fishers (Appendix 2) were identified by 113 participants as places where they most commonly saw mobulids. The most frequently identified of these were M7 (N = 12), L7 (N = 11) and K7 (N = 11) (see Fig. 2/3). These areas are situated close to 'Bodufinolhu Faru' where sightings of mobulids have been previously reported (Appendix 12). Eighty-six percent (N = 19) of participants who identified these squares scored knowledge indicators of 'Average' to 'Excellent' (see Table 1). Figure 2 also shows areas identified by the MMRP as hotspots for mobulids; 75% of the MMRP hotspots were identified by fishers as places common for mobulid observations. Figure 3 also shows designated MPAs in the atoll indicating some identified squares are protected but the most commonly identified squares (n > 10) are close to but not within an MPA. Comparing the data to fishing intensity data from BMF (Appendix 13) it can be seen that the areas with the most frequently identified squares are also areas of high fishing intensity.

127 squares were identified by 101 participants as places where they had seen the largest number of mobulids aggregating (Fig. 4) in groups of between 2 and 50 with the mean being 10.86 (SD 10.34). The most frequently identified of these were M7 (N = 12), L7 (N = 8) and T7 (N = 8). Due to the frequency of the identification of M7 and L7 in both instances, this will henceforth be referred to as the 'LEK hotspot'.

3.3.1 Abundance and Distribution Maps

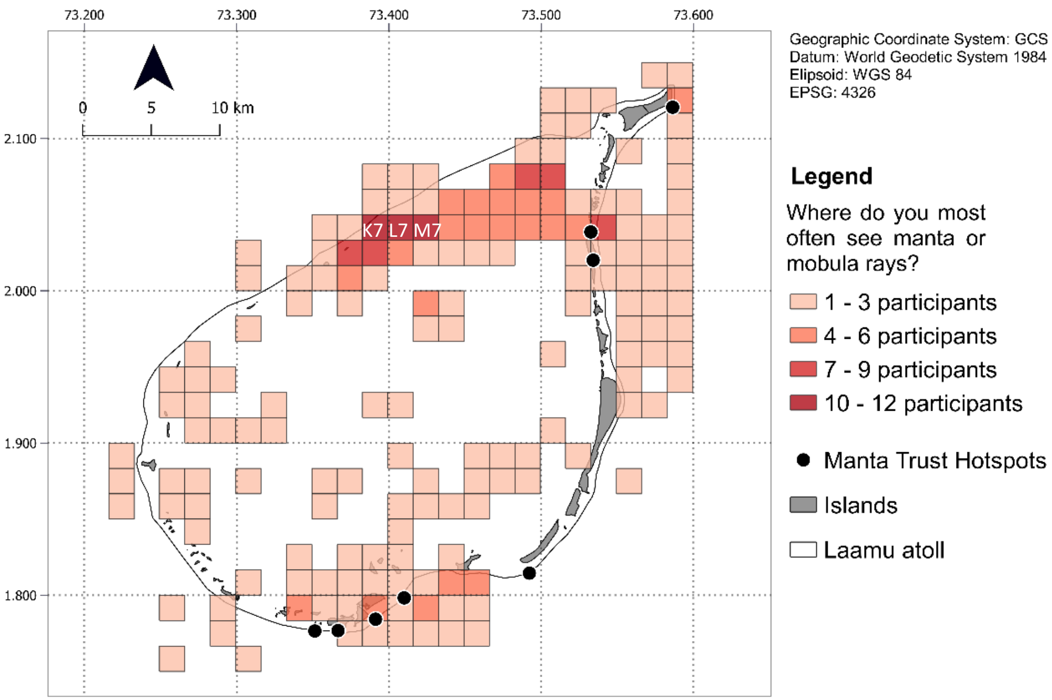

Figure 2: Laamu Atoll with islands, number of participants who identified grid squares where they reported to have most often seen mobulids and hotspots identified by the Manta Trust indicated.

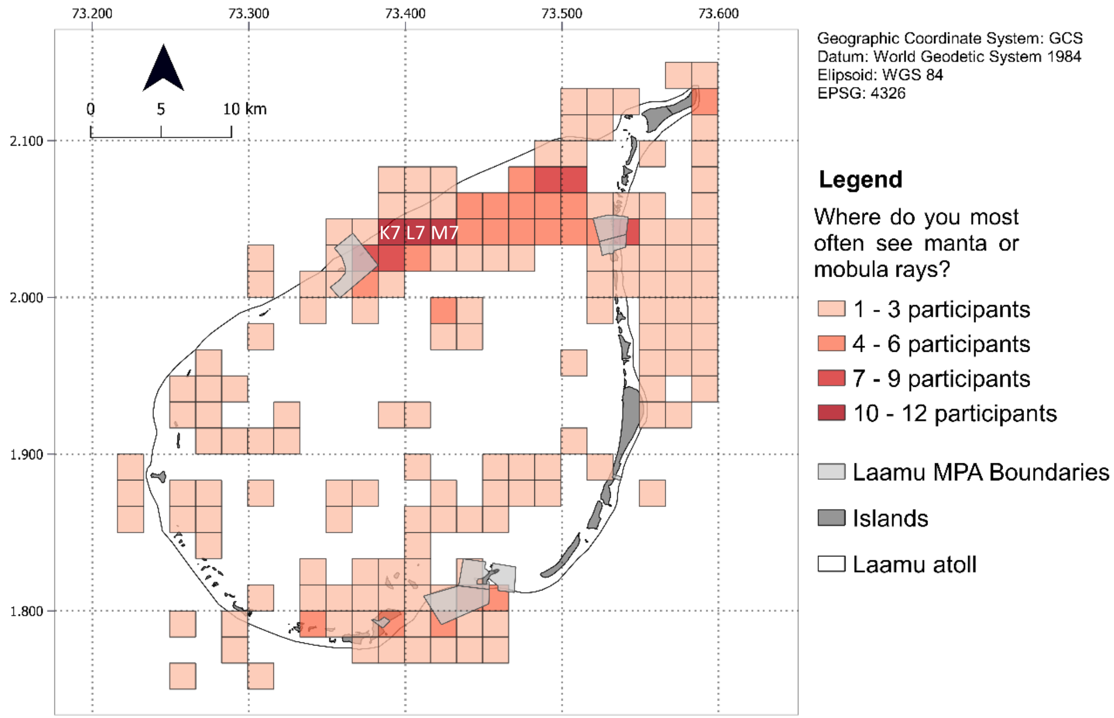

Figure 3: Laamu Atoll with islands, number of participants who identified grid squares where they reported to have most often seen mobulids and MPAs indicated.

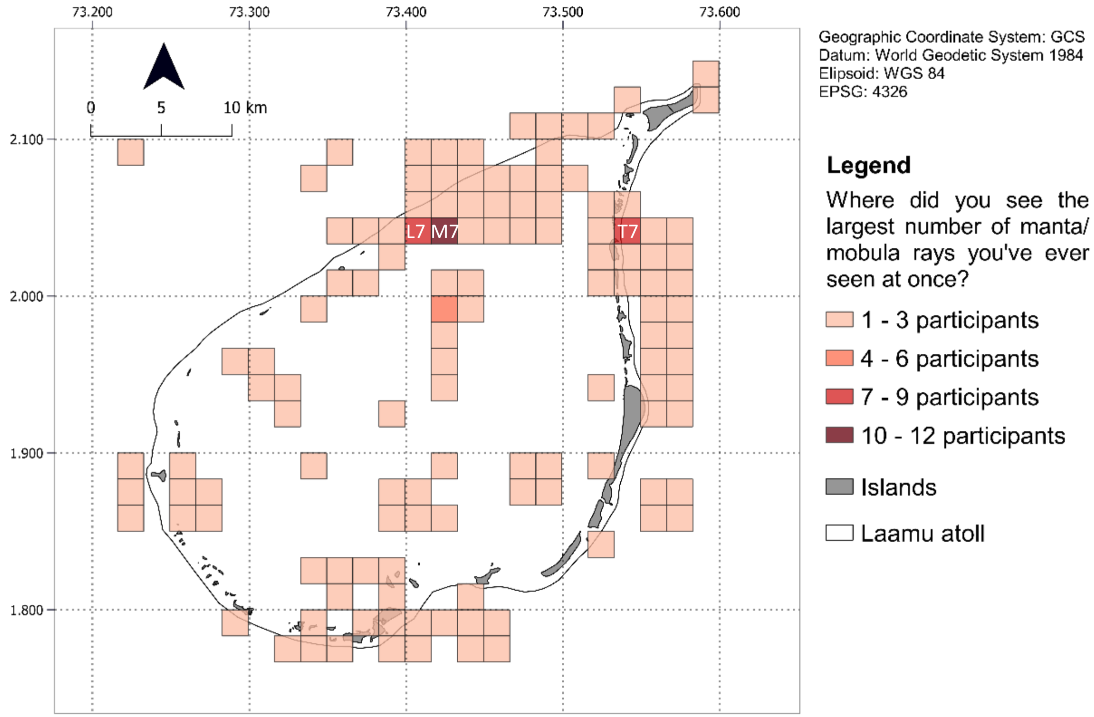

Figure 4: Laamu Atoll with islands and number of participants identifying grid squares for where they have seen the largest number of manta/mobula rays at one time indicated.

3.4 Assessing Prevalence of Potentially Harmful Behaviours *(RO2)*

Less than 2% (N = 2) of participants answered 'yes' when asked if mobulids had ever been caught intentionally in Maldives. However, out of the participants, 42% (N = 52) reported having caught mobulids unintentionally in their gear. Out of these, 75% (N = 39) said this happened 'Rarely' with 19% (N = 10) saying 'Often' and 6% (N = 3) saying 'Sometimes'. When considering multiple factors potentially associated with this behaviour, fishers with more years of experience and more positive attitudes were significantly more likely to report a mobulid entanglement event ($p < 0.05$; Table 3).

Table 3: Assessing the effects of years of fishing experience, attitude and knowledge on fishers that reported catching mobulids fitted to a binomial GLM analysed using anova. The full model is being reported.

Variables	SE*	χ^2	df	*p* value
Years fishing	0.06 ± 0.02	145.23	1	<0.001
Attitude proportional score	3.13 ± 1.62	145.23	1	0.049
Knowledge proportional score	0.85 ± 1.21	145.23	1	0.48

*Estimates on logit scale

When asked what gear they had used when these catches had happened, the majority said it had happened while using a net (69%; N = 36) which is used while bait fishing. Ninety-four percent (N = 116) of participants stated that mobulids were released if possible, when asked what happened when they were caught, with the other 6% (N = 7) stating they didn't know or not answering the question.

3.5 Fishers' Attitudes and Awareness Concerning Mobulid Conservation *(RO3)*

The vast majority (>86%; N = 106) scored 'Positive' for conservation attitude indicators with 13% (N = 16) scoring 'Moderate' and <1% (N = 1) scoring 'Negative' (Table 4). Due to this, the attitude proportional score was used for analysis.

Table 4: Converting attitude answers to three-point Likert scale of attitude indicators.

Question	Answers	Score		
In general, how do fishers and sea workers feel about manta or mobula rays?	➢ Respected ➢ Menace ➢ Don't bother	**POSITIVE PERCEPTION = 1** *Respected*	**MODERATE PERCEPTION = 0.5** *Don't bother/Don't know*	**NEGATIVE PERCEPTION = 0** *Menace*
Do you think mobulids should be protected?	➢ Yes ➢ No	**POSITIVE PERCEPTION = 1** *Yes*	**MODERATE PERCEPTION = 0.5** *Don't Know*	**NEGATIVE PERCEPTION = 0** *No*
How do you feel about the work of scientists and conservationists in Maldives?	➢ Important ➢ Unnecessary	**POSITIVE PERCEPTION = 1** *Important*	**MODERATE PERCEPTION = 0.5** *Don't Know*	**NEGATIVE PERCEPTION = 0** *Unnecessary*

When considering factors potentially associated with fishers' attitudes towards mobulids the results imply that younger fishers were significantly more positive towards conservation ($p < 0.05$).

Table 5: The effects of age and the proportional knowledge score fitted to a GLM analysed with ANOVA. The full model is being reported.

Variables	SE	χ^2	df	*p* value
Age	-0.004 ± 0.001	3.41	1	<0.001
Knowledge Score	-0.03 ± 0.09	3.41	1	0.76

*Estimates on logit scale

When fishers were asked what they thought about the work of conservationists and scientists, 94% (N = 116) said it was important (Table 6). When asked how fishers feel about mobulids in general, 48% (N = 59) responded that fishers don't bother with them, 42% (N = 52) said they were respected and 7% (N = 9) stated that they were a menace with the rest stating they didn't know (Table 6).

Table 6: Quotes to show how fishers perceived the work of scientists/conservationists as important and how they think fishers and sea workers feel about mobulids.

Question	Answers	LEK Quote
How do you feel about the work of scientists/ conservationists?	Important (N = 116)	*"It's something really good to understand more about the organism so people can be aware of the areas and how these rays and other organisms live."* *"By doing research and help from scientists we are able to identify hotspots and areas that can be protected for future generations."*
In general, how do fishers and sea workers feel about manta or mobula rays?	Don't bother (N = 59)	*"Fishermen don't really bother or care about manta rays."*
	Respected (N = 52)	*"The manta ray is something that is well respected among the fishermen"*
	Menace (N = 9)	*"We don't dislike manta rays but due to our nature of work (fishing) sometimes we have to chase them away as they get so close to our baitfish"*

When asked if they thought mobulids should be protected 96% (N = 118) said 'Yes', with >2% (N = 3) saying 'No' and <2% (N = 2) saying they didn't know. When participants who had responded yes were asked why, the category 'tourism' was most frequently seen in responses with 34% (N = 40) referring to this. Also notable was the 'ecological' category (16%; N = 19). Similarly, when asked what they would like to gain from conservation programmes, the category 'tourism' was most frequently mentioned in responses with 53% (N = 65) stating this as something they hoped to gain. Also notable was the 'education' category (31%; N = 38) (Table 7).

Table 7: Analysing and coding words recorded in response to why participants think mobulids should be protected and what benefits participants expect to receive from conservation programmes in Maldives.

Question: *Why do you think mobulids should be protected?*			
Word Recorded	**Category**	**Count (>10)**	**LEK Quote**
Tourism/visitors/tourists	**Tourism**	40	*"It is not something that disturb anyone also it benefits to tourism so I think it should be protected."*
Helps/benefits	**Beneficial**	37	*"Manta rays benefit the economy and also the fishermen and they don't make any harm or disturb anyone I think it should be protected."*
Rare/baitfish	**Ecological**	19	*"Manta rays are not something that is commonly seen therefore as it is a rare creature to see it should be conserved." / "Manta rays usually live in areas with lots of baitfish so it indicates that bait fishing is good therefore I believe they are something that needs to be protected."*
Question: *What benefits do you expect to receive from conservation programmes in Maldives?*			
Word Recorded	**Category**	**Count (>10)**	**LEK Quote**
Tourism/visitors/tourists	**Tourism**	65	*"Research helps to understand more areas where species like manta rays live and which will help to bring in more tourism to the country."*
Awareness/information	**Education**	38	*"Research will help us gain more information. I would like to learn more about manta rays its closely related to our fishing and any information that is related to fishing is something which can be beneficial to me."*

When asking specifically if participants were aware of the Manta Trust, only 27% (N = 33) of participants were aware of the organisation with 64% (N = 21) of those having some knowledge of the activities they conduct around the atoll. Younger people were more likely to be aware of the organisation (b ± SE = -0.04 ± 0.02, $\chi^2_1 = 7.38$, $p < 0.01$; estimates on logit scale).

4. Discussion

The LEK regarding mobulids and marine fauna in the study site was mostly average to excellent in terms of the knowledge indicator score of fishers surveyed. The majority of fishers acknowledged having seen mobulids in the study and demonstrated some knowledge of key characteristics compared to CSK. Many fishers were also able to demonstrate that they had an understanding of marine species in the study site. Distinguishing between the two species of manta ray present in the study area proved to be a challenge for most fishers, however as questions predominantly referred to mobulids as a group this result was primarily used to indicate the level of knowledge of the fisher and should not have a significant effect on the information presented here. Furthermore, fishers identified reef manta rays as the most commonly occurring species in the study site which coincides with CSK data reported by the MMRP (2020). These factors provide evidence of reliability and accuracy in the presented information (Braga and Schiavetti, 2013; Sousa et al. 2013).

4.1 Using Fishers' LEK to Identify Areas of Conservation Importance for Mobulids *(RO1)*

To effectively manage mobulids it is necessary to identify and protect important species aggregation sites (Stewart et al. 2018). In this study, fishers' LEK has identified a potential new site of conservation importance, close to the newly designated MPA of L. Vadinolhu, through the sharing of mobulid abundance and distribution information. The MMRP has observed mobulids in this area before (Appendix 12) but it is not one of their designated research sites (Fig.3).

Fishers' LEK regarding habitat use and aggregation sites can be used to fill knowledge gaps in scientific literature and provide information potentially useful for MPAs (Gerhardinger et al. 2009), fisheries (Silvano and Begossi, 2012), habitat (Berkstrom et al. 2019) and species management (Sousa et al. 2013). For example, Sousa et al. (2013) use LEK as a tool to find suitable areas for the reintroduction of rehabilitated manatees. By using fishers' LEK on the locations of common occurrences of manatees complemented by scientific knowledge of the most suitable environmental factors they were able to identify the most appropriate area for reintroduction. The L.Fushi MPA contains a channel between two islands which is a favourable environmental factor for mobulids as channels concentrate their prey, the strong currents pulling plankton-rich water from the deep sea creating feeding opportunities (Harris and Stevens, 2021). This may explain the high reported frequency of sightings.

LEK is often used to inform fisheries management with studies finding that fishers' recollection of fish species hotspots, particularly exploited ones (Le Fur et al. 2011; de Souza Junior et al. 2020), agree with CSK (Begossi and Silvano, 2008; Gaspare et al. 2015) with other studies suggesting species distribution knowledge is less developed when concerning non-target species (Begossi, 2015). Furthermore, fishing intensity data from BMF (2021) indicated four fishing hotspots in the atoll, one of which crossed over with the LEK hotspot possibly indicating bias in the data, yet no other sites considered high fishing intensity spots were identified as frequently by fishers (Appendix 13).

This research suggests that local fishers can provide consistent and coherent information on the common locations of protected species and therefore should be considered an important source of information when locating areas of conservation importance. However, there is also a suggestion that bias in the recollection of non-target species and high visitation of fishing vessels to the area may cause inaccuracy in answers and undermine the validity of the information. Further research would be required to understand the extent of this bias and methods to mitigate its impact.

4.2 Using Fishers' LEK to Assess the Prevalence of Behaviours of Potential Concern for Conservation *(RO2)*

Entanglement in fishing gear and wounds from boat propellers are major anthropogenic threats for mobulids that cause global concern (Stewart et al. 2018). Whilst Maldivian mobulids are protected and therefore not targeted by fisheries (Stevens, 2016), they still face these second-hand anthropogenic threats generated by the fishing and tourism sectors (Couturier et al. 2012). Fishers'

LEK indicated that the more prevalent threat was entanglement, predominantly in nets, with only a very small proportion reporting involvement in mobulid vessel strike incidents.

Strike et al. (2022) suggests that net entanglement injuries occur infrequently in mobulids in Maldives compared to fishing line or hook injuries as a result of the industrial net fishing ban implemented in 2019 by the Maldivian government (Nizar and Ibrahim, 2019). Just under half of participants in this study reported catching mobulids in their fishing gear with the majority being in nets whilst bait fishing. Baitfish nets are smaller and less damaging than industrial nets (e.g. gill nets) but the adverse effects that entanglement could have are still not understood (Deakos et al. 2011).

Strike et al. (2022) also find that vessel strike injuries were the least common anthropogenic injury for reef manta rays in Maldives and suggested that vessel strike wounds are most likely caused primarily by tourist boats searching for megafauna which supports the lack of fishers exhibiting the behaviour in this study.

Due to the sensitive nature of this line of questioning there is a possibility fishers could be less forthcoming with reliable data about their participation in harmful activities, even if these actions were unintentional (Fylan, 2005; Manzan and Lopes, 2015). This study found attitudes to be predominantly positive towards conservation and that those with positive attitudes would be more likely to report mobulid entanglement incidents suggesting that establishing positive relationships between fishers and research organisations could help improve data reliability (Huntington, 1999).

It is important to continue building positive relationships with fishing communities in order to create an open dialogue in which reliable data informing on potentially harmful activities can be reported. In this instance, fishers' LEK has highlighted a potential concern in the prevalence of mobulid entanglement in bait fishing nets that should be further monitored and evaluated to understand the magnitude of concern for conservation.

4.4 Using Fishers' LEK to Assess Fishers' attitudes and Awareness Concerning Mobulid Conservation *(RO3)*

Understanding conservation attitudes of stakeholders is important in implementing inclusive management strategies (Hill, 2002; Musiello-Fernandes et al. 2021). A high number of fishers had a positive attitude towards mobulid conservation due mainly to its implications on tourism and the resulting economic benefits. Other areas of interest were conservation education and the role of mobulids as an indicator species for baitfish, crucial to fishers' livelihood, which often leads to them being seen as a positive symbol (Anderson et al. 2011).

Economic incentives and empowerment of local communities are commonly related to positive attitudes towards conservation initiatives (Wang et al. 2006; Musiello-Fernandes et al. 2021). Perceptions and beliefs have also been found to have a significant influence over an individual's attitude (Bright and Barro, 2000; Allendorf, 2006). This study suggests that the opportunity for economic development creates positive perceptions of mobulids as a result of Maldives' large tourism sector and the positive belief that they are aiding fishing efforts by indicating baitfish presence. This could facilitate an increased interest and positive perception of conservation education with locals pursuing inclusivity in management decisions concerning mobulids, as an important species for their economy.

A common criticism of LEK studies is the tendency of participants to be influenced by the interviewers (Brook and McLachlan, 2005). It is likely that fisher's answers were influenced by the interviewers affiliation with a conservation organization (ibid.). Furthermore, it has been noted that attitudes are difficult to measure to a scale, especially for non-target species where the value of the species cannot be quantified (Musiello-Fernandes et al. 2021) and external factors such as bad weather conditions or low catch can influence fishers' moods and attitudes when being questioned (Saavedra-Diaz et al. 2015).

Fishers' LEK has indicated that primarily tourism but also education and ecological benefits contribute to positive attitudes towards conservation, however, the limitations of subjective data must be borne in mind when drawing conclusions on attitudes and awareness.

4.5 LEK Limitations

LEK has well-documented limitations that this study has considered and attempted to address in survey design, data collection and data analysis with LEK being compared to CSK where possible (Le Fur et al. 2011). However, more specificity and a stricter social science framework may have yielded more interesting results. For example, no significant results were found as a result of the knowledge indicators or proportional scores. An increased number and more specific questions regarding mobulids morphological characteristics and behavioural traits could be incorporated to enhance assessments of species-specific knowledge and therefore reliability in answers (Braga and Sciavetti, 2013).

Several studies suggest the identification of 'experts', characterised by high levels of experiential knowledge of the study area, can increase the accuracy of LEK data (Davis and Wagner, 2003; Chalmers and Fabricius, 2007; Steele and Shackleton, 2010). For example, results relating to historical abundance were inconclusive due to a lack of data as most participants responded, 'Don't Know'. More conclusive answers might be obtained by using 'expert' fishers (Davis and Wagner, 2003). There is debate over how experts can be identified (ibid.). Some studies suggest the use of elders in communities (McDade et al. 2007; Aswani et al. 2018) however the results of this study have shown that in this instance, age had no significant effect on the knowledge indicators used. Whilst this is not a comprehensive study, Braga and Schiavetti (2013) also found that age had no significant effect on knowledge. They used experts in their LEK study to give more reliability to their answers, identifying fishers to interview through recommendations from presidents of colonies who were considered 'native experts' and then snowball sampling from these to identify other 'experts' (ibid.). Using 'expert' fishers in future LEK studies, possibly identified by members of the community, could provide potentially more informed and accurate information.

4.6 Recommendations for Using Fishers' LEK to Inform Mobulid Conservation

The MECCT is currently gathering stakeholder comments to develop regulations and zonation for the atoll's newly designated MPAs (2022). The MPAs in the atoll are a focus of efforts to introduce innovative sustainable practices aimed at reducing the human ecological footprint, including in the tourism and fishing sectors (MECCT, 2022). As the tourism sector in Maldives grows, it has adverse effects on marine ecosystems and wildlife (Stevens and Froman, 2019). There has already been an increase in boat propeller injuries in mobulids since 2016 likely linked to the increase in tourism-fuelled boat traffic (Murray et al. 2020). When finalising the management plans for the MPAs close to identified MMRP hotspots, they should consider evaluating threats from tourism and bait fishing whilst encouraging eco-tourism and sustainable fishing as these have been suggested as notable drivers in fishers' positivity to conservation. Furthermore, this study recommends considering the extension of the L. Fushi Island MPA to include the LEK hotspot identified by fishers following further monitoring and evaluation.

A participative management approach, in which fishers are included in management decisions regarding conservation, is recommended for any study that uses fishers' LEK (Murray et al. 2005; Usseglio et al. 2013). This empowers communities and original knowledge holders to contribute to local conservation methods and to ensure that the research impacts positively on communities providing local benefits and discouraging the narrative of marginalisation that can result from LEK studies (Berkes et al. 2000). Collaboration between scientists and fishers was crucial to the success of this research and this relationship should be developed with knowledge exchange between the MMRP and the local communities, for example, in continued research of the LEK hotspot (Chuenpagdee et al. 2013). Fishers should be informed of study results and included in the next steps taken by the MMRP. Baleia Franca Environmental Protection Area is an area that focuses on sustainable tourism, sustainable fisheries and whale conservation employing a combination of scientific and local knowledge to inform its management including local people in the management council meetings (Gerhardinger et al. 2009). A similar strategy could be implemented here to ensure empowerment and inclusion of local communities and sustainable and environmentally sound conservation management strategy.

Raising awareness and educating local communities on the importance of conservation efforts is crucial to ensuring sustainable and successful conservation management (Sousa et al. 2013) as studies indicate that negative attitudes are cultivated by a lack of local participation (Mauro and Hardison, 2000; Wang et al. 2006). Awareness of the Manta Trust's work and positive attitudes to conservation were more prevalent in younger fishers in the Laamu Atoll, a result also found by Braga et al. (2017) when researching fishers conservation attitudes toward sardines in Portugal. MMRP currently carries out work with local schools through their Marine Education Programmes (Manta Trust, 2022). By incorporating a participative management approach older members of the community could also be included in this outreach and further knowledge exchange could take place beneficial to both fishers and researchers thereby giving local communities a key role in their natural environment (Davis and Wagner 2003; Chuenpagdee et al. 2013).

This study has used LEK from fishers to highlight areas of potential conservation importance for mobulids in Laamu Atoll. The research from this paper can be seen as a preliminary assessment of how LEK can be used in the study site and how this might be successfully repeated on a larger scale, with reference to the wider conservation implications.

References

Alava, M. N. R., Dolumbalo, E. R. Z., Yaptinchay, A. A., Trono, R. B. (2002). Fishery and trade of whale sharks and manta rays in the Bohol Sea, Philippines. In: Fowler SL, Reed TM, Dipper FA, eds. Elasmobranch biodiversity, conservation, and management: proceedings of the international seminar and workshop, Sabah, Malaysia, July 1997. *Gland, Switzerland and Cambridge: IUCN SSC Shark Specialist Group,* 132-148

Allendorf, T., Swe, K. K., Oo, T., Htut, Y., Aung, M., Allendorf, K., Hayek, L., Leimgruber, P., & Wemmer, C. (2006). Community attitudes toward three protected areas in upper Myanmar (Burma). *Environmental Conservation*, 33, 344–352.

Anadón, J. D., Giménez, A., Ballestar, R., & Pérez, I. (2009). Evaluation of Local Ecological Knowledge as a Method for Collecting Extensive Data on Animal Abundance. *Biology*, 23(3), 617–625. https://doi.org/10.1111/j

Anderson, R. C., Adam, M. S., & Goes J. I. (2011). From monsoons to mantas: seasonal distribution of Manta alfredi in the Maldives. *Fisheries Oceanography*, 20(2), 104-113. https://doi.org/10.1111/j.1365-2419.2011.00571.

Anderson, R. C., Adam, M. S., Kitchen-Wheeler, A., & Stevens, G. (2010) Extent and Economic Value of Manta Ray Watching in Maldives. *Tourism in Marine Environments*, 7(1), 15-27

Aswani, S., Lemahieu, A., & Sauer, W. H. H. (2018). Global trends of local ecological knowledge and future implications. *PLoS ONE*, 13(4). https://doi.org/10.1371/journal.pone.0195440

Azzurro, E., Moschella, P., & Maynou, F. (2011). Tracking signals of change in mediterranean fish diversity based on local ecological knowledge. *PLoS ONE* , 6(9). https://doi.org/10.1371/journal.pone.0024885.

Bearman, M. (2009). Eliciting rich data: A practical approach to writing semi-structured interview schedules. DOI:10.11157/fohpe.v20i3.387

Beaudreau, A. H., & Levin, P. S. (2014). Advancing the use of local ecological knowledge for assessing data-poor species in coastal ecosystems. *Ecological Applications*, 24(2).

Begossi, A, & Silvano, R. A. (2008). Ecology and ethnoecology of dusky grouper [garoupa, Epinephelus marginatus (Lowe, 1834)] along the coast of Brazil. *Journal of Ethnobiology and Ethnomedicine*, 4 20. https://doi.org/10.1186/1746-4269-4-20

Begossi, A. (2015). Local ecological knowledge (LEK): understanding and managing fisheries. In: Fishers’ knowledge and the ecosystem approach to fisheries Applications, experiences and lessons in Latin America. Section 1, 7-18. Published by Food and Agriculture Organization of the United Nations.

Bender, M. G., Machado, G. R., de Azevedo Silva, P. J., Floeter,S. R., Monteiro-Netto, C., Luiz, O. J., & Ferreira C. E. L. (2014). Local Ecological Knowledge and Scientific Data Reveal Overexploitation by Multigear Artisanal Fisheries in the Southwestern Atlantic. *PLoS ONE* . https://doi.org/10.1371/journal.pone.0110332

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological applications*, 10(5), 1251-1262. https://doi.org/10.1890/1051-0761(2000)010[1251:ROTEKA]2.0.CO;2

Berkström, C., Papadopoulis, M., Saleh Jiddawi, N. & Mtwana Nordlund, L. (2019). Fishers' Local Ecological Knowledge (LEK) on Connectivity and Seascape Management. *Frontiers in Marine Science*. 6(130). https://doi.org/10.3389/fmars.2019.00130.

Bernard, H. R. (1995). Research methods in anthropology. Walnut Creek, CA: AltaMira. 2000. *Social research methods*. Thousand Oaks, CA: Sage

Bessesen, B. L., & González-Suárez, M. (2021). The value and limitations of local ecological knowledge: Longitudinal and retrospective assessment of flagship species in Golfo Dulce, Costa Rica. *People and Nature*, 3(3), 627–638. https://doi.org/10.1002/pan3.10219

Braga, H. de O., & Schiavetti, A. (2013). Attitudes and local ecological knowledge of experts fishermen in relation to conservation and bycatch of sea turtles (reptilia: Testudines), Southern Bahia, Brazil. *Journal of Ethnobiology and Ethnomedicine*, 9(1).

Braga, H. O., Azeiteiro, U. M., Oliveira, H. M. F., & Pardal, M. A. (2017). Evaluating fishermen's conservation attitudes and local ecological knowledge of the European sardine (Sardina pilchardus), Peniche, Portugal. *Journal of Ethnobiology and Ethnomedicine*, 13(1). https://doi.org/10.1186/s13002-017-0154-y

Braga-Pereira, F., Morcatty, T. Q., el Bizri, H. R., Tavares, A. S., Mere-Roncal, C., González-Crespo, C., Bertsch, C., Rodriguez, C. R., Bardales-Alvites, C., von Mühlen, E. M., Bernárdez-Rodríguez, G. F., Paim, F. P., Tamayo, J. S., Valsecchi, J., Gonçalves, J., Torres-Oyarce, L., Lemos, L. P., de Mattos Vieira, M. A. R., Bowler, M. & Mayor, P. (2021). Congruence of local ecological knowledge (LEK)-based methods and line-transect surveys in estimating wildlife abundance in tropical forests. *Methods in Ecology and Evolution.* https://doi.org/10.1111/2041- 210X.13773

Braun, C. D. (2013). Movement Ecology of the Reef Manta Ray Manta alfredi in the Eastern Red Sea. *KAUST Research Repository*. https://doi.org/10.25781/KAUST-Q3Y05

Braun, C. D., Skomal, G. B., Thorrold, S. R., & Berumen, M.L. (2014) Diving Behavior of the Reef Manta Ray Links Coral Reefs with Adjacent Deep Pelagic Habitats. *PLoS ONE* 9(2): e88170. https://doi.org/10.1371/journal.pone.0088170

Bright, A. D., & Barro, S.C, (2000). Integrative complexity and attitudes: a case study of plant and wildlife species protection. *Hum Dimens Wildl*, 5:30–47. https://doi.org/10.1080/10871200009359193

Brook, R. K., & Mclachlan, S. M. (2005). On Using Expert-Based Science to "Test" Local Ecological Knowledge. *Ecology and Society,* 10(2).

Brook, R. K., & McLachlan, S. M. (2008). Trends and prospects for local knowledge in ecological and conservation research and monitoring. *Biodiversity and Conservation,* 17(14), 3501–3512. https://doi.org/10.1007/s10531-008-9445-x

Bucair, N., Venables, S. K., Balboni, A. P., & Marshall, A. D. (2021). Sightings trends and behaviour of manta rays in Fernando de Noronha Archipelago, Brazil. *Mar Biodivers,* 14, Article No. 10. https://doi.org/10.1186/s41200-021-00204-w

Carpentier, A. S., Berthe, C., Ender, I., Jaine, F. R. A., Mourier, J., Stevens, G., et al. (2019). Preliminary insights into the population characteristics and distribution of reef (Mobula alfredi) and oceanic (M. birostris) Manta rays in French Polynesia. *Coral Reefs,* 38, 1197–1210. https://doi.org/10.1007/s00338-019-01854-0

Caruso, N., Luengos Vidal, E., Guerisoli, M., & Lucherini, M. (2017). Carnivore occurrence: Do interview-based surveys produce unreliable results? *ORYX*, 51(2), 240–245. Cambridge University Press. https://doi.org/10.1017/S0030605315001192

Chalmers, N., & Fabricius, C. (2007). Expert and Generalist Local Knowledge about Land-cover Change on South Africa's Wild Coast: Can Local Ecological Knowledge Add Value to Science? *Ecology and Society*, 12(1). http://www.jstor.org/stable/26267835

Charnley, S., Fischer, A. P., & Jones, E. T. (2007). Integrating traditional and local ecological knowledge into forest biodiversity conservation in the Pacific Northwest. *Forest Ecology and Management*, 246(1), 14–28. https://doi.org/10.1016/j.foreco.2007.03.047

Chuenpagdee, R., Pascual-Fernandez, J. J., Szelianszky, E. J., Alergret, L., Fraga, J. & Jentoft S. (2013). Marine protected areas: Re-thinking their inception*. Mar Policy*, 39, 234-240.

Clark, R. P. & Smits, A. J. (2006). Visualisations of the Unsteady Wake of a Manta Ray Model. *44th AIAA Aerospace and Sciences Meeting and Exhibit.* https://doi.org/10.2514/6.2006-352

Colloca, F., Carrozzi, V., Simonetti, A., & di Lorenzo, M. (2020). Using Local Ecological Knowledge of Fishers to Reconstruct Abundance Trends of Elasmobranch Populations in the Strait of Sicily. *Frontiers in Marine Science*, 7. https://doi.org/10.3389/fmars.2020.00508

Couturier, L. I. E., Marshall, A. D., Jaine, F. R. A., Kashiwagi, T., Pierce, S. J., Townsend, K. A., Weeks, S. J., Bennett, M. B., & Richardson, A. J. (2012). Biology, ecology and conservation of the Mobulidae. *Journal of Fish Biology*, 80(5), 1075-1119. https://doi.org/10.1111/j.1095-8649.2012.03264.x

Craney, T. A, & Surles, J. G. (2002). Model-Dependent Variance Inflation Factor Cutoff Values. *Quality Engineering*, 14:3, 391-403, DOI: 10.1081/QEN-120001878

Davis, A., Wagner, J.R. (2003). Who Knows? On the Importance of Identifying "Experts" When Researching Local Ecological Knowledge. *Human Ecology* 31, 463–489. https://doi.org/10.1023/A:1025075923297

de Souza Junior, O. G., Nunes, J. L. G., & Silvano, R. A. M. (2020). Biology, ecology and behavior of the acoupa weakfish Cynoscion acoupa (Lacepède, 1801) according to the local knowledge of fishermen in the northern coast of Brazil*. Mar. Pol*., 115. 10.1016/j.marpol.2020.103870

Deakos, M. H. (2010). Paired-laser photogrammetry as a simple and accurate system for measuring the body size of free-ranging manta rays Manta alfredi. *Aquatic Biology*, 10(1-10). https://doi.org/10.3354/ab00258

Deakos, M. H., Baker, J. D., & Bejder, L. (2011). Characteristics of a Manta ray Manta alfredi – population off Maui, Hawaii, and implications for management. *Mar. Ecol. Prog. Ser*., 429, 245–260. https://doi.org/10.3354/meps09085

Divi, R. V., Strother, J. A., & Paig-Tran, E. W. M. (2018). Manta rays feed using ricochet separation, a novel nonclogging filtration mechanism. *Science Advances*, 4(9). https://doi.org/10.1126/sciadv.aat9533

Drury, R., Homewood, K., & Randall, S. (2011). Less is more: The potential of qualitative approaches in conservation research. *Animal Conservation*, 14(21), 18–24. https://doi.org/10.1111/j.1469-1795.2010.00375.x

Early-Capistrán, M. M., Solana-Arellano, E., Alberto Abreu-Grobois, F., Narchi, N. E., Garibay-Melo, G., Seminoff, J. A., Koch, V., & Saenz-Arroyo, A. (2020). Quantifying local ecological knowledge to model historical abundance of long-lived, heavily-exploited fauna. *PeerJ,* 8. https://doi.org/10.7717/peerj.9494

Ettner, S. L. & Grzywacz, J. G. (2001). Workers' Perceptions of How Jobs Affect Health: A Social Ecological Perspective. *Journal of Occupational Health Psychology*. 6(2), 101–113

Farmer, N. A., Garrison, L. P., Horn, C., Miller, M., Gowan T., Kenney, R. D., Vukovich, M., Robinson Willmott J., Pate, J., Webb, D. H., Mullican, T. J., Stewart, J. D., Bassos-Hull, K., Jones, C., Adams, D., Pelletier, N. A., Waldron, J. & Kajiura, S. (2022). The distribution of manta rays in the western North Atlantic Ocean of the eastern United States. *Sci Rep* 12, 6544 (2022). https://doi.org/10.1038/s41598-022-10482-8.

Farmer, N.A., Garrison, L.P., Horn, C. et al. The distribution of manta rays in the western North Atlantic Ocean off the eastern United States. *Sci Rep* 12, 6544 (2022). https://doi.org/10.1038/s41598-022-10482-8

Fish, F. E., Dong, H., Zhu, J. J., & Bart-Smith, H. (2017). Kinematics and Hydrodynamics of Mobuliform Swimming: Oscillatory Winged Propulsion by Large Pelagic Batoids. *Marine Technology Society Journal,* 51(5) 35-47(13). https://doi.org/10.4031/MTSJ.51.5.5

Freitas, R. F., Machado, L. P., de Freitas, R. H. A., & Hanazaki, N. (2021). Differences and similarities in local ecological knowledge about rays among fishers, residents, and tourists. *Ethnobiology and Conservation,* 10, 1–14. https://doi.org/10.15451/EC2021-05-10.25-1-14

Fylan, F. (2005). Chapter 6 Semi Structured Interviewing. In *A Handbook of Research Methods for Clinical and Health Psychology*, Oxford University Press Jeremy Miles, Paul Gilbert

García-Quijano, C. G. (2007). Fishers' Knowledge of Marine Species Assemblages: Bridging between Scientific and Local Ecological Knowledge in Southeastern Puerto Rico. *American Anthropologist*, 109(3), 529-536. https://doi.org/10.1525/aa.2007.109.3.529

Gaspare, L., Bryceson, I., Kulindwa, K. (2015). Complementarity of Fishers' traditional ecological knowledge and conventional science: contributions to the management of groupers (Epinephelinae) fisheries around Mafia Island. *Tanzania Ocean Coast Manag.,* 114 (2015), pp. 88-101,

Gerhardinger, L. C., Godoy, E. A. S., & Jones, P. J. S. (2009). Local ecological knowledge and the management of marine protected areas in Brazil. *Ocean and Coastal Management*. 52(3-4), 154-165. https://doi.org/10.1016/j.ocecoaman.2008.12.007

Gilchrist, G., Mallory, M., & Merkel, F. (2005). Can Local Ecological Knowledge Contribute to Wildlife Management? Case Studies of Migratory Birds. *Ecology and Society*, 10(1) https://about.jstor.org/terms

Hameed, F (2002). First National Report to the Conference of the parties to the Convention on Biological Diversity. *Ministry of Home Affairs Housing and Environment.*

Harris J. L., & Stevens G. M. W. (2021) Environmental drivers of reef manta ray (Mobula alfredi) visitation patterns to key aggregation habitats in the Maldives. *PLoS ONE*, 16(6): e0252470. https://doi.org/10.1371/journal. pone.0252470

Hays, G. C., Richardson, A. J., & Robinson, C. (2005). Climate change and marine plankton. *Trends Ecol. Evo*l. 20, 337–344. doi: 10.1016/j.tree.2005.03.004

Heinrichs, S., O'Malley, M., Medd, H., & Hilton, P. (2011). Manta Ray of Hope: The global threat to Manta and Mobula rays. Manta Ray of Hope Project. www.mantarayofhope.com

Hill, C. M. (2002). Conflicting attitudes towards elephants around the Budongo Forest Reserve, Uganda. *Environmental Conservation*, 25(3). https://doi.org/10.1017/S0376892998000307

Hill, C. M. (2006). Conflicting attitudes towards elephants around the budongo forest reserve Uganda. *Environmental Conservation* 1998, 25:244–250. 75.

Hosegood, J., Humble, E., Ogden, R., de Bruyn, M., Creer, S., Stevens, G. M. W., Abudaya, M., Bassos-Hull, K., Bonfil, R., Fernando, D., Foote, A. D., Hipperson, H., Jabado, R. W., Kaden, J., Moazzam, M., Peel, L. R., Pollett, S., Ponzo, A., Poortvliet, M., Salah, J., Senn, H., Stewart, J. D., Wintner, S. & Carvalho, G. (2020). Phylogenomics and species delimitation for effective conservation of manta and devil rays. *Molecular Ecology*, 29(24), 4783-4796. https://doi.org/10.1111/mec.15683

Howard, A., & Widdowson, F. 1996. Traditional knowledge threatens environmental assessment. *Policy Options,* 17(9):34–36.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qual. Health Res*., 15, 1277-1288

Huntington, H. P. (1999). Traditional knowledge of the ecology of Beluga whales (Delphinapterus leucas) in the Eastern Chukchi and Northern Bering Seas, Alaska. *Artic,* 52(1), 49–61.

Huntington, H. P. (2000). Using traditional ecological knowledge in science: methods and applications. *Ecological Applications,* 10, 1270–1274

IUCN (2022). The IUCN Red List of Threatened Species. Version 2022-1. https://www.iucnredlist.org.

Jaleel, A. (2013) The status of the coral reefs and the management approaches: The case of the Maldives. *Ocean and Coastal Management*, 82, 104-118. https://doi.org/10.1016/j.ocecoaman.2013.05.009

Joa, B., Winkel, G., & Primmer, E. (2018). The unknown known – A review of local ecological knowledge in relation to forest biodiversity conservation. *Land Use Policy,* 79, 520–530. https://doi.org/10.1016/j.landusepol.2018.09.001

Johannes, R. E. (1998). The case for data-less marine resource management: examples from tropical nearshore fin fisheries*. Trends in Ecology and Evolution,* 13, 243–246.

John Fox and Sanford Weisberg (2019). An {R} Companion to Applied Regression, Third Edition. Thousand Oaks CA: Sage URL: https://socialsciences.mcmaster.ca/jfox/Books/Companion/

Kitchen-Wheeler, A. M., Ari, C., & Edwards, A. J. (2012). Population estimates of Alfred mantas (Manta alfredi) in central Maldives atolls: North Male, Ari and Baa. *Environmental Biology of Fishes,* 93(4), 557–575. https://doi.org/10.1007/s10641-011-9950-8

Knight, A. T., Cowling, R. M., Rouget, M., Balmford, A., Lombard, A. T., & Campbell, B. M. (2008) 'Knowing but not doing: selecting priority conservation areas and the research-implementation gap' *Conservation Biology,* 22(3), pp. 610-617

Krueck, N. C., Ahmadia, G. N., Possingham, H. P., Riginos, C., Treml, E. A. & Mumby, P. J. (2017) 'Marine Reserve Targets to Sustain and Rebuild Unregulated Fisheries'. *Plos Biology.* https://doi.org/10.1371/journal.pbio.2000537

Kruskal, W. H., & Wallis, W. A. (1952). Use of Ranks in One-Criterion Variance Analysis. Journal of the American Statistical Association, 47, 583-621. http://dx.doi.org/10.1080/01621459.1952.10483441

Kundur, S.K., (2012). Development of tourism in Maldives. International Journal of Scientific and

Research Publications, 2(4), 1-5.

Kundur, S.K., (2012). Development of tourism in Maldives*. International Journal of Scientific and Research Publications,* 2(4), 1-5.

Kvale, S. (2007). Doing interviews. Thousand Oaks, CA: Sage.

Lawson, J. M., Fordham, S. V., O'Malley, M. P., Davidson, L. N. K., Walls, R. H. L., Heupel, M.R., Stevens, G., Fernando, D., Budziak, A., Simpfendorfer, C. A., Ender, I., Francis, M. P., Notarbartolo di Sciara, G., Dulvy, N. K. (2017). Sympathy for the devil: a conservation strategy for devil and manta rays. *PeerJ*, 5:3027. https://doi.org/10.7717/peerj.3027

Le Fur, J., Guilavogui, A., Teitelbaum, A., and Rochet, M. J. (2011). Contribution of local fishermen to improving knowledge of the marine ecosystem and resources in the Republic of Guinea, West Africa. *Can. J. Fish. Aquat. Sci.* 68, 1454–1469. doi: 10.1139/f2011-061.

Lewis, S. A., Setiasih, N., Fahmi, D., O'Malley, M. P., Campbell, S. J., Yusuf, M., Sianipar, A. B. (2015). Assessing Indonesian manta and devil ray populations through historical landings and fishing community interviews. *PeerJ*, 3:1334

Lopes, P. F. M., Verba, J. T., Begossi, A., & Pennino, M. G. (2019). Predicting species distribution from fishers' local ecological knowledge: A new alternative for data-poor management. *Canadian Journal of Fisheries and Aquatic Sciences,* 76(8), 1423–1431. https://doi.org/10.1139/cjfas-2018-0148

Madsen, E. K., Elliot, N. B., Mjingo, E. E., Masenga, E. H., Jackson, C. R., May, R. F., Røskaft, E., & Broekhuis, F. (2020). Evaluating the use of local ecological knowledge (LEK) in determining habitat preference and occurrence of multiple large carnivores. *Ecological Indicators,* 118.

Magnan, A. K., & Duvat, V. K. E. (2020). Towards adaptation pathways for atoll islands. Insights from the Maldives. *Reg Environ Change,* 20, 119. https://doi.org/10.1007/s10113-020-01691-w

Manta Trust (2022) Maldivian Manta Ray Project | Maldives — Manta Trust

Manzan, M. F., & Lopes, P. F. M. (2015). Fishers' knowledge as a source of information about the estuarine dolphin (Sotalia guianensis, van Bénéden, 1864). *Environ Monit Assess,* 187, 4096. https://doi.org/10.1007/s10661-014-4096-8

Marshall, A.D., Dudgeon, C.L., & Bennett, M. B. (2011). Size and structure of a photographically identified population of manta rays Manta alfredi in southern Mozambique. *Mar Biol,* 158, 1111–1124. https://doi.org/10.1007/s00227-011-1634-6

Mauro, F., & Hardison, P.D. (2000). Traditional knowledge of indigenous and local communities: international debate and policy initiatives. *Ecological applications,* 10(5), pp.1263-1269.

Maurstad, A., Trine Dale, T., & BjØrn, P. A. (2007). You Wouldn't Spawn in a Septic Tank, Would You? *Human Ecology*, 35: 601-610.

McDade, T. W., Reyes-García, V., Blackinton, P., Tanner, S., Huanca, T., & Leonard, W. R. (2007). Ethnobotanical knowledge is associated with indices of child health in the Bolivian Amazon. www.pnas.org/cgi/content/full/

Ministry of Environment, Climate Change and Technology, (2022). Report on zonation and boundary demarcation of proposed protected areas in Laamu Atoll. Ministry of Environment, Climate Change and Technology, Male', Maldives

MMRP (2014) Manta Ray Project - Baa Atoll Annual Report 2014. Available at: https://static1.squarespace.com/static/5a196500914e6b09132e911f/t/5ce40b9985cf6c0001e1eff6/1558449060279/MT_MMRP_Report_Baa+Atoll_2014.pdf.

Murray, A., Garrud, E., Ender, I., Lee-Brooks, K., Atkins, R., Lynam, R., et al. (2020). Protecting the million-dollar mantas; creating an evidence-based code of conduct for manta ray tourism interactions. *J. Ecotour*. 19, 132–147. doi: 10.1080/14724049.2019.1659802

Murray, G., Bavington, D., Neis, B. (2005). Local Ecological Knowledge, Science, Participation and Fisheries Governance in Newfoundland and Labrador: A Complex, Contested and Changing Relationship. In: Gray, T.S. (eds) *Participation in Fisheries Governance*. Reviews: Methods and Technologies in Fish Biology and Fisheries, vol 4. Springer, Dordrecht. https://doi.org/10.1007/1-4020-3778-3_16

Murray, G., Neis, B., & Johnsen, J.P. (2006). Lessons Learned from Reconstructing Interactions Between Local Ecological Knowledge, Fisheries Science, and Fisheries Management in the Commercial Fisheries of Newfoundland and Labrador, Canada. *Hum Ecol,* 34, 549–571. https://doi.org/10.1007/s10745-006-9010-8

Musiello-Fernandes, J., Zappes, C. A., Braga, H. O., & Hostim-Silva, M. (2021). Artisanal fishers' local ecological knowledge and attitudes toward conservation about the shrimp (Xiphopenaeus kroyeri) on the Brazilian central coast. *An Acad Bras Cienc*, 93(suppl 3):e20191047. https://doi.org/10.1590/0001-3765202120191047

NBS 2019, 'Statistical Year Book 2019'. Male', Maldives: National Bureau of Statistics, Ministry of National Planning, Housing and Infrastructure.

Nizar, H. R., & Ibrahim, M. (2019). Fishermen's Forum 2019: On the occasion of the 39th Fishermen's Day of the Maldives. Malé: Ministry of Fisheries, Marine Resources and Agriculture. https://www.gov.mv/en/files/report-fishermens-forum-2019-maldives.pdf

Notarbartolo-di-Sciara, G., & Hillyer, E. V. (1989). Mobulid Rays off Eastern Venezuela (Chondrichthyes, Mobulidae). *Copeia,* 3, 607-614. https://doi.org/10.2307/1445487

O'Malley, M. P., Lee-Brooks, K., Medd, H. B. (2013). The Global Economic Impact of Manta Ray Watching Tourism. *PLoS ONE*, 8(5): e65051. doi:10.1371/journal.pone.0065051

Palmer, C. T. & Wadley, R. L. (2007). Local environmental knowledge, talk, and skepticism: using 'LES' to distinguish 'LEK' from 'LET in Newfoundland. *Hum Ecol,* 35, 749–760 (2007). https://doi.org/10.1007/s10745-006-9108-z

Pauly, D. (1995). Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology and Evolution,* 10(10)

Peterson, D., Hanazaki, N. & Simões-Lopes, P. C. (2008). Natural resource appropriation in cooperative artisanal fishing between fishermen and dolphins (Tursiops truncatus) in Laguna, Brazil. *Ocean and Coastal Management*. 51 (6), 469-475. https://doi.org/10.1016/j.ocecoaman.2008.04.003

Peñaherrera-Palma, C., van Putten, I., Karpievitch, Y. V., Frusher, S., Llerena-Martillo, Y., Hearn, A. R., & Semmens, J. M. (2018). Evaluating abundance trends of iconic species using local ecological knowledge. *Biological Conservation*, 225, 197–207. https://doi.org/10.1016/j.biocon.2018.07.004

Poisson, F., Séret, B., Vernet, A-L., Goujon, M., & Dagorn, L. (2014). Collaborative research: development of a manual on elasmobranch handling and release best practices in tropical tuna purse-seine fisheries. *Marine Policy,* 44, 312-320

Polfus, J. L., Heinemeyer, K., & Hebblewhite, M. (2014). Comparing traditional ecological knowledge and western science woodland caribou habitat models. *Journal of Wildlife Management*, 78(1), 112–121. https://doi.org/10.1002/jwmg.643

Poortvliet, M., Olsen, J. L., Croll, D. A., Bernardi, G., Newton, K., Kollias, S., O'Sullivan, J., Fernando, D., Stevens, G., Galván Magaña, F., Seret, B., Wintner, S. & Hoarau, G. (2015). A dated molecular phylogeny of manta and devil rays (Mobulidae) based on mitogenome and nuclear sequences. *Molecular Phylogenetics and Evolution*, 83, 72-85. https://doi.org/10.1016/j.ympev.2014.10.012.

QGIS Development Team, (2022). QGIS Geographic Information System. Open Source Geospatial Foundation Project.

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R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rees, A., Hashim, S., Evans, V. (2021). Resource Use Survey Report: Laamu Atoll. Blue Marine Foundation.

Renato, A. M., & Begossi, S. A. (2012). Fishermen's local ecological knowledge on Southeastern Brazilian coastal fishes: contributions to research, conservation, and management. *Neotrop. ichthyol.* 10 (1). https://doi.org/10.1590/S1679-62252012000100013

Rilov, G., Fraschetti, S., Gissi, E., Pipitone, C., Badalamenti, F., Tamburello, L., Menini, E., Gorip, P., Mazarias, A. D., Garrabou, J., Benedetti-Cecchi, L., Danovaro, R., Loiseau, C., Claudet, J., & Katsanevakis S. (2019). A fastmoving target: achieving marine conservation goals under shifting climate and policies. *Ecological Applications,* 30(1)

Ruddle, K. (1994). Local knowledge in the folk management of fisheries and coastal marine environments. Pages 161-206 in C. L. Dyer and J. R. McGoodwin, editors. *Folk management in the world's fisheries: lessons for modern fisheries management.* University Press of Colorado, Niwot, CO.

Saavedra-Díaz, L. M., Rosenberg, A. A., & Pomeroy, R. (2015). Why Colombian marine fishers' knowledge is a fundamental tool for marine resource management and assessment. In: *Fishers' knowledge and the ecosystem approach to fisheries Applications, experiences and lessons in Latin America*, Section 2, pp 89-105. Publised by Food and Agriculture Organization of the United Nations.

Sathiendrakumar, R., Jaffur, Z. K., Seetanah, B. (2021). Tourism planning and development in South Asia. The role of international tourism in the Maldives, 132–148.

Scacco, U., Consalvo, I., & Mostarda, E. (2009). First documented catch of the giant devil ray Mobula mobular (Chondrichthyes: Mobulidae) in the Adriatic Sea. *Marine Biodiversity Records*, 2, E93. doi:10.1017/S1755267209001110

Schacter, D. L. (2002). The seven sins of memory: how the mindforgets and remembers. Boston, MA; New York, NY:Houghton Mifflin.

Silvano, R. A. M., & Begossi, A. (2010). What can be learned from fishers? An integrated survey of fishers' local ecological knowledge and bluefish (Pomatomus saltatrix) biology on the Brazilian coast. *Hydrobiologia,* 637, 3. https://doi.org/10.1007/s10750-009-9979-2

Silvano, R. A. M., & Begossi, A. (2012). Fishermen's local ecological knowledge on Southeastern Brazilian coastal fishes: contributions to research, conservation, and management. *Neotropical Ichthyology: Official Journal of the Sociedade Brasileira de Ictiologia,* 10(1), 133–147.

Silvano, R. A. M., Valbo-Jørgensen, J. (2008). Beyond fishermen's tales: contributions of fishers' local ecological knowledge to fish ecology and fisheries management. *Environ Dev Sustain,* 10, 657. https://doi.org/10.1007/s10668-008-9149-0

Solleliet-Ferreira, S., Macena, B., Laglbauer, B., Sobral, A. F., Afonso, P., & Fontes, J. (2020). Sicklefin devilray and common remora prey jointly on baitfish. *Environ Biol Fish,* 103, 993–1000. https://doi.org/10.1007/s10641-020-00990-9

Sousa, M. E. M., Martins, B. M. L., & Fernandes, M. E. B. (2013). Meeting the giants: The need for local ecological knowledge (LEK) as a tool for the participative management of manatees on Marajó Island, Brazilian Amazonian coast. *Ocean and Coastal Management*, 86, 53–60.

Sovacool B (2012). Perceptions of climate change risks and resilient island planning in the Maldives. *Mitigation and Adaptation Strategies for Global Change*, 17(7), 731−52.

Melita Z. Steele, Charlie M. Shackleton (2010) Using local experts as benchmarks for household local ecological knowledge: Scoring in South African savannas. *Journal of Environmental Management*, 91(8), 1641-1646.

Stevens, G. M. W. & Froman, N. (2019). Chapter 10 - The Maldives Archipelago. *World Seas: an Environmental Evaluation* (Second Edition), Academic Press, 211–236.

Stevens, G. M. W. (2016) Conservation and Population Ecology of Manta Rays in the Maldives. PhD thesis, University of York.

Stewart, j. D., Hoyos-Padilla, E. M., Kumli, K. R., & Rubin, R. D. (2016). Deep-water feeding and behavioral plasticity in Manta birostris revealed by archival tags and submersible observations. *Zoology*, 119(5), 406-413. https://doi.org/10.1016/j.zool.2016.05.010.

Stewart, J. D., Jaine, F. R. A., Armstrong, A. J., Armstrong, A. O., Bennett, M. B., Burgess, K. B., Couturier, L. I. E., Croll, D. A., Cronin, M. R., Deakos, M. H., Dudgeon, C. L., Fernando, D., Froman, N., Germanov, E. S., Hall, M. A., Hinojosa-Alvarez, S., Hosegood, J. E., Kashiwagi, T., Laglbauer, B. J. L. & Lezama-Ochoa, N., Marshall, A. D., McGregor, F., Notarbartolo di Sciara, G., Palacios, M. D., Peel, L. R., Richardson, A. J., Rubin, R. D., Townsend, K. A., Venables, S. K. & Stevens, G. M. W. (2018). Research Priorities to Support Effective Manta and Devil Ray Conservation. *Frontiers in Marine Science*, 5:314. doi: 10.3389/fmars.2018.00314

Strike, E. M., Harris, J. L., Ballard, K. L., Hawkins, J. P., Crockett, J., & Stevens, G. M. W. (2022). Sublethal Injuries and Physical Abnormalities in Maldives Manta Rays, Mobula alfredi and Mobula birostris. *Frontiers in Marine Science*, 9. https://doi.org/10.3389/fmars.2022.773897

Szałkiewicz, E., Sucholas, J. & Grygoruk, M. (2020). Feeding the Future with the Past: Incorporating Local Ecological Knowledge in River Restoration. *Resources* 9(4), 47. https://doi.org/10.3390/resources9040047

Techera, E. J., & Cannell-Lunn, M. (2019) A review of environmental law in Maldives with respect to conservation, biodiversity, fisheries and tourism. *Asia Pacific Journal of Environmental Law,* 22(2), 228-256.

Thaman, R. R. (1994). Marine Ethnobiology: A Foundation for Marine Science Education in the Pacific Islands. Department of Education and The Institute of Education, The University of the South Pacific, Suva, Fiji. *Pacific Curriculum Network,* vol.3, no.2, 1994.

Thurstan, R., Buckley, S. M., Ortiz, C. J. & Pandolfi, J. M. (2016). Setting the Record Straight: Assessing the Reliability of Retrospective Accounts of Change. *Conservation Letters*, 9(2), 98-105. https://doi.org/10.1111/conl.12184

Turvey, S. T., Risley, C. L., Moore, J. E., Barrett, L. A., Yujiang, H., Xiujiang, Z., Kaiya, Z., & Ding, W. (2013). Can local ecological knowledge be used to assess status and extinction drivers in a threatened freshwater cetacean? *Biological Conservation*, 157, 352–360. https://doi.org/10.1016/j.biocon.2012.07.016

Usseglio, P., Schuhbauer, A., Friedlander, A. (2014). Collaborative Approach to Fisheries Management as a Way to Increase the Effectiveness of Future Regulations in the Galapagos Archipelago. In: Denkinger, J., Vinueza, L. (eds) *The Galapagos Marine Reserve*. Social and Ecological Interactions in the Galapagos Islands. Springer, Cham. https://doi.org/10.1007/978-3-319-02769-2_9

Venables, S. K., Marshall, A. D., Germanov, E. S., Perryman, R. J. Y., Tapilatu, R. F., Hendrawan, I. G., Flam, A. L., van Keulen, M., Tomkins, J. L., & Kennington, W. J. (2019). It's not all black and white: investigating colour polymorphism in manta rays across Indo-Pacific populations. *Proc. R. Soc. B.,* 286(1912). https://doi.org/10.1098/rspb.2019.1879

Venables, W. N. & Ripley, B. D. (2002). Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0

Wang, S., Lassoie, J., & Curtis, P. (2006). Farmer attitudes towards conservation in Jigme Singye Wangchuck National Park, Bhutan. *Environmental Conservation,* 33(2), 148-156. doi:10.1017/S0376892906002931

Ward-Paige, C. A., Davis, B., & Worm, B. (2013). Global Population Trends and Human Use Patterns of Manta and Mobula Rays. *PLoS ONE.* https://doi.org/10.1371/journal.pone.0074835

Wedemeyer-Strombel, K. R., Peterson, M. J., Sanchez, R. N., Chavarría, S., Valle, M., Altamirano, E., Gadea, V., Sowards, S. K., Tweedie, C. E., & Liles, M. J. (2019). Engaging Fishers' Ecological Knowledge for Endangered Species Conservation: Four Advantages to Emphasizing Voice in Participatory Action Research. *Frontiers in Communication,* 4. https://doi.org/10.3389/fcomm.2019.00030

White, W. T., Corrigan, S., Yang, L., Henderson, A. C., Bazinet, A. L., Swofford, D. L. & Naylor, G. J. P. (2018). Phylogeny of the manta and devilrays (Chondrichthyes: mobulidae), with an updated taxonomic arrangement for the family. *Zoological Journal of the Linnean Society,* 182(1), 50–75. https://doi.org/10.1093/zoolinnean/zlx018

Wickham H, François R, Henry L, Müller K (2022). _dplyr: A Grammar of Data Manipulation_. R package version 1.0.9, <https://CRAN.R-project.org/package=dplyr>.

Wilson, D. C., Raakjær, J., & Degnbol, P. (2006). Local ecological knowledge and practical fisheries management in the tropics: A policy brief, *Marine Policy*, 30(6), 794-801.

Zeller, K. A., Nijhawan, S., Salom-Pérez, R., Potosme, S. H., & Hines, J. E. (2011). Integrating occupancy modeling and interview data for corridor identification: A case study for jaguars in Nicaragua. *Biological Conservation,* 144(2), 892–901.

Appendices

Appendix 1: The full questionnaire with all questions asked to participants in interviews and the percentage of each section in relation to the full questionnaire.

Section	Questions	Questionnaire %
Logistics	Date Island Introduction (Appendix 2)	6% (N = 3)
Background Information	How old are you? Are you based on this island? *(If yes) How many years have you lived here?* *(If no) Where are you based?* What is the nature of your work at sea? How many years have you been working at sea? How often are you at sea in a typical month? (Never, a few times a month, a few times a week, most days, everyday)	11% (N = 5)
Fishing practices employed and primary catch	How many years have you been fishing for? How often are you fishing at sea in a typical month? (Never, a few times a month, a few times a week, most days, everyday) What did/do you fish for? What is/was your method of fishing? (Pole and line, hand line, trolling, Other) Has your method changed since you began fishing? *(If yes) When did this change occur? Why did this change occur?*	11% (N = 5)
Knowledge about native marine species and mobulids	Which of these species can be observed in the Maldvies? (Appendix 9) Have you seen a manta ray before? *(If yes) Could you describe it to me?* Can you tell the difference between these two species? (Appendix 10) Have you seen a mobula ray before? *(If yes) Could you describe it to me?*	11% (N = 5)

	Can you tell me anything about these species of rays? (Appendix 11)	
Knowledge about mobulid occurrences and threats faced by the group	What months are manta and mobula rays most commonly observed? Has this changed since you started working at sea? *(If yes) How has it changed?* How often do you see manta or mobula rays when at sea? (Never, rarely, sometimes, often, always) Which species do you see most regularly? Where do you most often see manta or mobula rays? (Using Appendix 2) Has this changed since you started working at sea? *(If yes) How has it changed?* What is the largest number of manta or mobula rays you have ever seen at once? Where did you see them? (Using Appendix 2) Can you remember what year you saw them in? Do you think the numbers of manta or mobula rays have changed since you began working at sea? *(If yes) Are they more or less common today than they were then?* Are manta or mobula rays ever seen together with any other fish? *(If yes) Which species are they likely to be seen with?* Have you ever seen manta or mobula rays offshore? *(If yes) How far offshore? Where did you see this? (Using Appendix 2) How many individuals did you see?* Have you ever seen manta or mobula rays whilst bait fishing at night? *(If yes) Do you remember where this occurred?* Have manta or mobula rays ever been intentionally caught in the Maldives? *(If yes) What were they fished for? How many would be caught? When did this happen?* How often do you catch a manta or mobula ray in your fishing gear (intentionally or unintentionally)? (Never, rarely, sometimes, often, always)	36% (N = 17)

	(If not never) In which type of gear? Was there anything different in the technique/method used for fishing in this case? What type of lure/bait was used on this occasion?	
	What happens to any manta or mobula rays that are caught (by you or by others)?	
	Have manta or mobula rays ever been caused injury by your boat propeller? (Never, rarely, sometimes, often, always)	
Attitude towards and awareness of conservation of the taxonomic group	Before this interview, were you aware of the organisation 'The Manta Trust'? *(If yes) What activities do they do?*	
	How do you feel about the work of scientists and conservationists in the Maldives? (Important, too strict, cause problems, unnecessary, don't know, other) *Why?*	
	How do you think the rest of your community feels about the work of scientists and conservationists? (Important, too strict, cause problems, unnecessary, don't know, other) *Why?*	
	Would you like to learn more about what scientists and conservationists do and why they do it?	
	What benefits do you expect to receive from conservation programmes in the Maldives?	19% (N = 9)
	Would you like to take your family, children and friends to visit and swim with the manta or mobula rays?	
	Are you aware of any rules and regulations about the capture of manta or mobula rays in the Maldives? *(If yes) What is your understanding of the rules?*	
	In general how do fishers and sea workers feel about manta or mobula rays? (Menace, feared, respected, don't bother, don't know, other) *Why?*	
	Do you think manta and mobula rays should be protected? *Why?*	
Final reflections	Is there anything else you would like to tell me?	
	Is there anything you would like to ask me? Having completed this survey, can you recommend anybody else we should talk to?	6% (N = 3)

Appendix 2: Map of Laamu atoll overlaid with a fishnet grid shown to fishers during interviews so they could use the squares to identify mobulid sighting locations.

Appendix 3: Introduction to main survey.

"Introduction My name is Hannah/Jinaad and I would like to ask you a few questions. This interview forms part of a project being carried out by the Manta Trust and myself as part of an MSc study, to better understand the distribution of manta rays in Laamu Atoll, evaluate the local perceptions of this species, and identify any potential threats they might be facing. Everything that we discuss today will be completely confidential and all information will be anonymous.

We know very little about the manta rays of the world, but here in the Maldives we have a great opportunity to study them. Given your experiences and knowledge of the sea, we'd like to learn from you and gather info on manta rays in the Maldives. This is why we want to talk to you.

This interview will begin by asking you about your experience at sea. I then would like to ask some questions about manta rays and other big fish. If you do not understand anything or want to ask any questions during the interview, please stop me at any time.

The interview should last no longer than 45min -1hr. The interview will be recorded and notes taken, once the interview is transcribed the recording will be deleted. Only anonymised and grouped data will be used in the analysis and reporting. By taking part in this interview you are consenting to your data being used as part of this study. You have the right to withdraw from this interview or to request your data be removed from the project at any time. You do not have to answer any individual question that you do not wish to answer. It is crucial that you answer each question as accurately as possible. If you are not sure of the answer to a question, please state this as your answer.

Finally, please confirm your willingness to participate in this study and your understanding that you may withdraw consent at any time and discontinue participation.

Right, let us begin."

Appendix 4: Separate contact details and permissions survey.

Section	Questions	% Questionnaire
Introduction	Now we have finished the main interview, I would like to ask you about the possibility of contacting you in the future regarding the results of our study and any future manta ray sightings. The Manta Trust will only contact you with your express permission and you may withdraw your permission at any time and erase your contact details from our system. The following questions will outline how we will contact you in the future and what we will contact you about. Can you confirm you are happy to proceed?	12% (N = 1)
(If yes) Contact details	Name Email Phone Location (Island)	50% (N = 4)
Permissions	Do you give us permission to use this data? Can we use this data to update you with the results of this survey? Do we have your permission to contact you regarding future manta or mobula ray sightings in your area?	38% (N = 3)

Appendix 5: Number of interviews per island.

Island	No. Of Interviews
Gan	23
Hithadhoo	15
Maabaidhoo	14
Kunahandhoo	12
Maamendhoo	11
Maavah	11
Dhanbidhoo	11
Mundoo	10
Kalaidhoo	9
Isdhoo	4
Fonadhoo	3

Appendix 6: Fishers local ecological knowledge on the behavioral and morphological characteristics of mobulids.

Trait Identified (Manta rays)	LEK Quote	Scientific Knowledge
Belly markings	*"What I noticed is the belly is completely white, and can see they have black markings in the belly "*	"Manta rays have natural markings on their ventral surface from birth" (Marshall et al. 2011)
Large size	*"They are Large and the eyes are in the sides"*	"Manta rays are the largest batoid fishes in the world" (Marshall et al. 2011)
Not dangerous/Come close to boat/people	*"They come close to people but other species they will avoid people "/"there is nothing to be afraid about manta rays"*	"Their... perceived friendly and curious nature combined with the relative safety of interacting with a harmless animal has resulted in the aforementioned popularity with divers." "Although manta rays are conspicuous and often easy to approach" (Malley et al. 2013 ; Marshall et al. 2011)
Do rolls	*"They come and they will turn upside down and do rolls to eat "*	"During the submersible observation, the manta ray made continuous barrel rolls", "barrel-rolling behavior is observed frequently in near-surface waters" (Stewart et al. 2016)
Big mouth	*"They have a big mouth pointy wing and a long tail "*	"Manta rays are large elasmobranchs that feed by swimming with open mouths" (Divi et al. 2018)
No barbs/sting	*"Mantas don't have any barbs"*	See Table 1 in White et al. (2018).
Seen with bait fish	*"We see mantas they bring in a lot baitfish inside the atoll"*	"Manta rays are widely known in Dhivehi (Maldivian language) by the name en-madi (=baitfish-ray). This is a reference to their frequent occurrence with...baitfishes." (Anderson et al. 2011)
Not bottom dwellers	*"unlike other rays mantas are seen in the deep areas of the ocean and they are not bottom dwellers"*	"Mantas frequented the upper 10 m during daylight hours and tended to occupy deeper water throughout the night." "... this enigmatic group of large pelagic rays "
Black and white	*"they are black and white with a white belly "*	"Typical colour morphs are black on the dorsal surface with white shoulder patches on the supra-branchial region." (Braun et al. 2014)
Trait Identified (Mobula rays)	**LEK Quote**	**Scientific Knowledge**
Smaller size	*"…is small compared to the Mantas but they both look similar"*	See Table 1 in White et al. (2018).

Smaller/shorter/ straighter cephalic fins	*"Manta have a bent cephalic fin while mobula they have a pointy cephalic fin"*	"The specimen had a broad head with a straight anterior margin, cephalic fins well separated one from the other and with eyes and spiracles located laterally" (Scacco et al. 2009)
Seen in shallows	*"Unlike manta we see them quite shallow areas especially during night"*	"aggregate in some shallow coastal waters" (Ward-Paige, 2013)
Fast	*"Mobulas also come to the light they will not stick around they move very fast and very active"*	"These rays have pectoral fins with a triangular planform and streamlined cross-sectional geometry that would minimize drag." (Fish et al. 2017)

Trait identified (Mobulids)	**LEK Quote**	**Scientific Knowledge**
Eats plankton	*"They come to eat planktons when fisherman light up for baitfish"*	"Mobulid rays are secondary consumers feeding on zooplankton throughout most of their range" (Solleliet-Ferreira et al. 2020)
Cephalic fins	*"They have two cephalic fins"*	"Mobulid rays were easily recognizable among surface-dwelling myliobatiforms because of greater body size and prominent cephalic fins." (Notarbartolo-di-Sciara and Hillyer, 1989)
Eyes on side	*"They are Large and the eyes are in the sides"*	"…manta ray's… eyes are not visible from above" (Deakos, 2010)
Seen in schools	*"Manta rays are seen in groups" / "When we see mobula we see them in large groups"*	"Schools may contain a few to hundreds of individuals and aggregate seasonally in large numbers at different locations" (Couturier et al. 2012)
Breach	*"I have seen them jump out of water"*	"Breaching mantas were particularly visible from surface craft." (Notarbartolo-di-Sciara and Hillyer, 1989)
Attracted to light	*"Manta rays come really close to the lights"*	"in 2019 manta rays were observed feeding at night in the harbour (Porto de Santo Antônio) on zooplankton attracted by artificial lights affixed to the jetty." (Bucair et al. 2021)
Can see on surface	*"black and can see them surface swimming"*	"Mobulids also often occur in surface coastal waters, making populations relatively easy to locate and exploit." (Ward-Paige, 2013)
Pointy wing	*"they have a big mouth pointy wing and a long tail"*	"These rays have pectoral fins with a triangular planform" (Fish et al. 2017)

Appendix 7: The non-significant effects of years of fishing and age on knowledge indicators fitted to an ordered logistic regression model.

Variables	*t* value*	Odds ratio (95% CI)	*p* value
Age	-0.28	[0.97, 1.04]	0.78

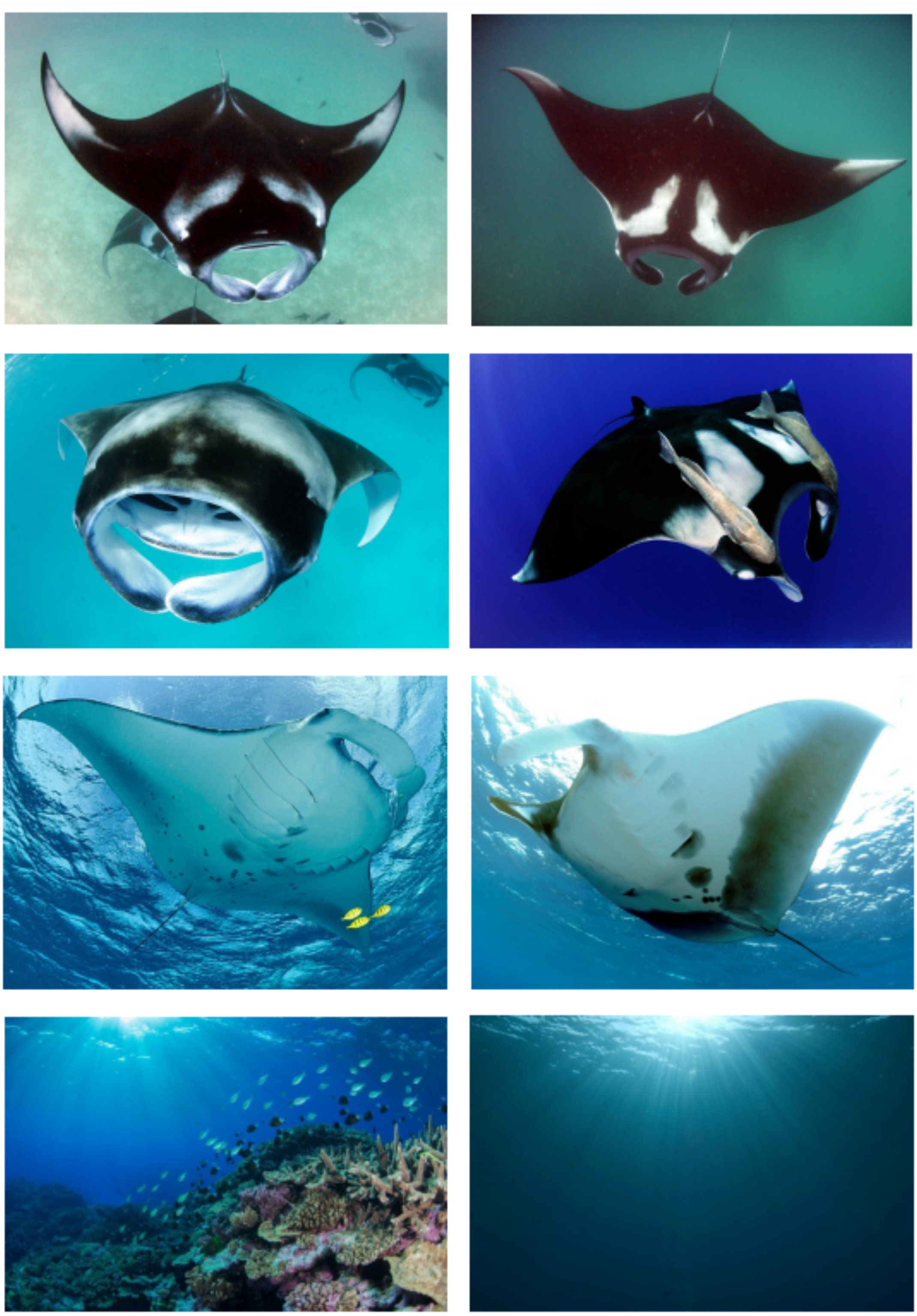
*Estimates on logit scale

Appendix 8: The results of the Kruskal-Wallis rank sum test to test the effect of age on knowledge score.

Variables	*H* statistic	df	*p* value
Age	42.83	48	0.68

Appendix 9: Eight species shown to fishers to asses their knowledge of local marine fauna.

Appendix 10: pictures shown to test if fishers knew the difference between oceanic (right) and reef (left) manta rays.



Appendix 11: pictures shown to fishers to test if they could identify some/all/none of the three species of rays: spotted eagle ray, cowtail stingray and spinetail devil ray.

Appendix 12: Map of Laamu Atoll showing the 31 locations in the atoll where reef manta rays have been observed (MMRP, 2021).

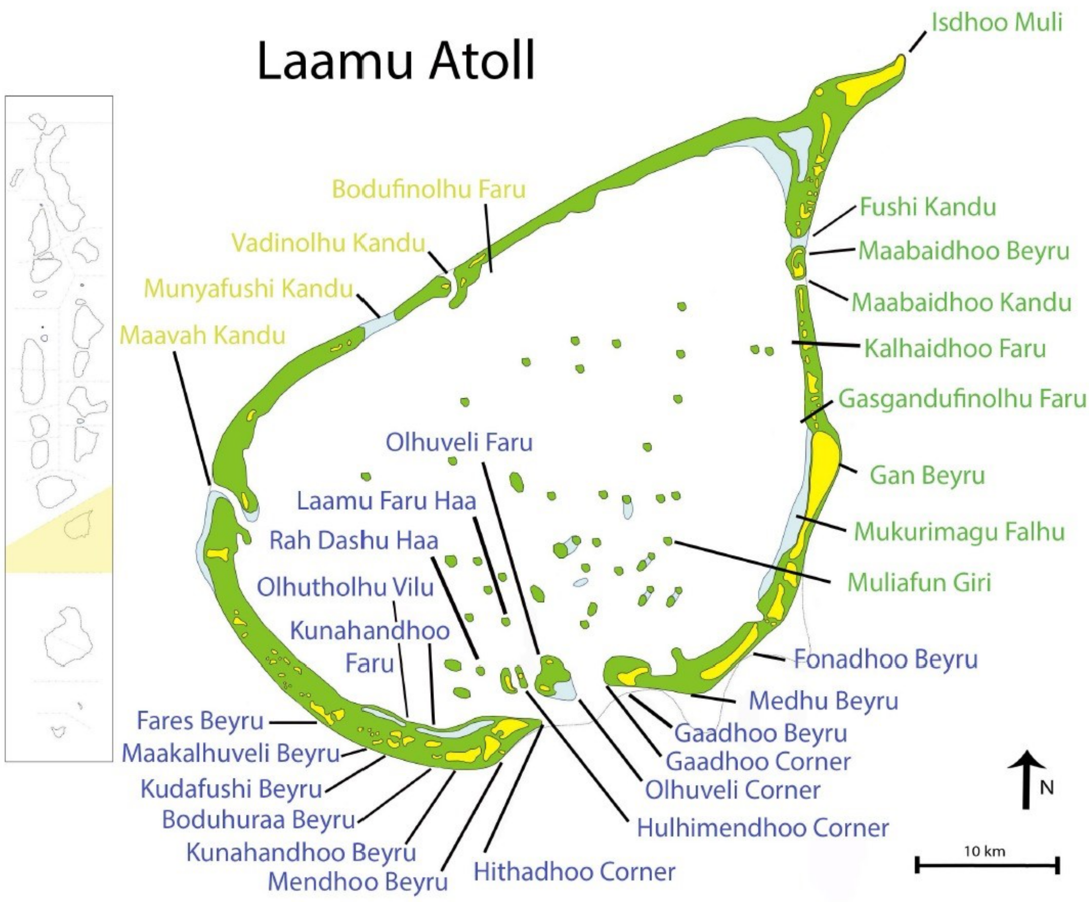


Figure 1: Map of Laamu Atoll showing the thirty-one locations in the atoll where reef manta rays (*Mobula alfredi*) have been observed (2014 - 2021).

Appendix 13: Hotspots of commercial and non-commercial fishing activities around Laamu Atoll. Darker areas indicate higher fishing activity (Rees et al. 2021).

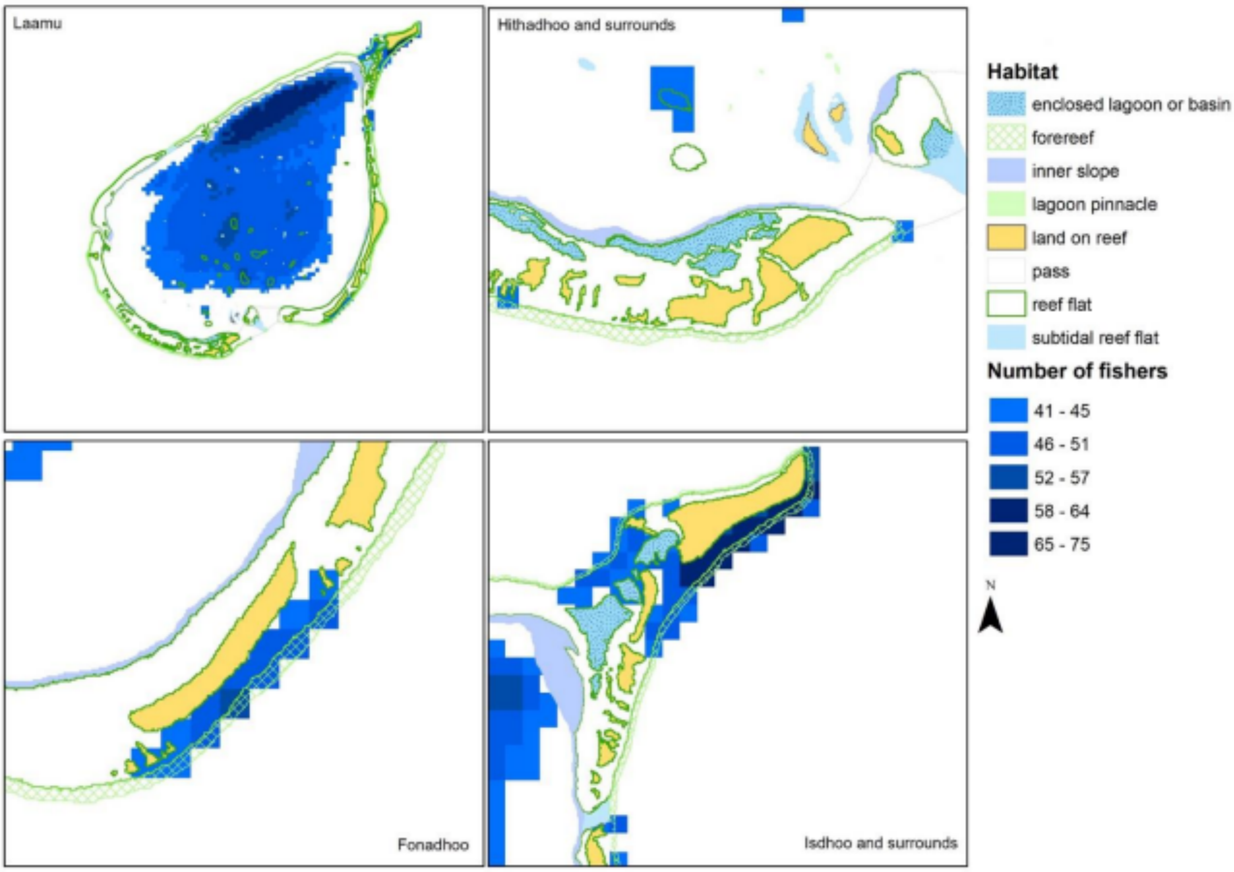


Figure 4b. *Hotspots of all commercial and non-commercial fishing activities around Laamu Atoll. Darker colours indicate higher activity density of selection by fishers. A gridded overlay (grid cell = 0.25km²) was applied and overlapping polygons by each fisher were summed to identify highest fished areas.*