



Shifting fish consumption preferences can impact coral reef resilience in the Maldives: a case study

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ABSTRACT

People's preferences and choices around food directly influence their resource use and the resilience of dynamically linked natural and human systems. In this study we examine fish preference and consumption patterns in Dhaalu atoll, Maldives, where fisheries have experienced rapid change in response to tourism and development. We find that reef fishes are now a significant part of local diets, with 58% of interview respondents preferring to eat reef fish over the historically more popular and sustainable tuna. Our findings suggest that preferences, which vary with gender and age, are an important yet underutilized indicator of changing pressures on reefs. While demand from nearby resorts currently drives the majority of reef fishing in these islands, we document seasonal spikes in the local catch and consumption of reef fishes and record an informal network of sharing that should be considered while developing management plans. Rising levels of reef fish consumption could have significant environmental impacts in the Maldives with implications for island food security and community wellbeing.

1. Introduction

How people assign value to places and species ultimately impacts how they are used and managed [22,26]. Management in turn affects community health and wellbeing in part by shaping how critical resources like land and water are utilized [11,34]. On islands with little agricultural land, fish are frequently the primary source of protein, contributing in some small island states to over half of the animal protein intake [7]. Fisheries management in these contexts has direct consequences for people's nutrition and for the ecological resilience of coral reef habitats [5].

However, fisheries are complex systems involving multiple stakeholders [9,21]. Often, conflicts arise when governance fails to consider the plurality of values - including not only economic and ecological but also social and cultural - that a resource such as fish might possess [29]. For example, Chinese values around luxury seafood and a preference for "plate-sized" red coral groupers pushes fishers in the Philippines to target sub-adults of this species that have not yet spawned, impacting the resilience of these fish stocks and the long-term livelihoods of fishers [17]. In the Andaman Islands, commoditization of the leopard coral

grouper (*Plectropomus leopardus*) since the 1990s has transformed the socioeconomic value of this fish, with certain communities that catch and export it now referring to this species simply as "dollar" [2].

Value differences can be especially pronounced in islands where tourism, urbanization, and development are transforming local economies [42,49]. Numerous studies have documented the complex and diverse ways in which people understand and relate to fish [18,25,46], how fish and fisheries help to maintain or build sharing networks within communities [13,14], their traditional and spiritual value [24,38], and their importance to community identities [43,47]. However, despite general consensus among scientists and policymakers that resource management is "people management" [8], and an understanding that there are severe consequences to social-ecological resilience when the human dimensions of these systems are ignored [4,10,15], prioritizing and integrating cultural and social values into marine management has remained a challenge [3]. In particular, values around certain kinds of fish and how they might drive people's preferences and consumption patterns remain an under-addressed part of planning [16]. This is partly because values have been understood and conceptualized in a variety of ways over time [27] and have only recently begun to be operationalized

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for conservation science [6].

In this study, we attempted to gain an initial understanding of the ways in which communities in the Maldives might value different species of fish (in particular, reef fish and tuna) by assessing their preferences and consumption patterns. We were also interested in understanding how the dynamics that currently shape reef fishing feed back into seasonal patterns of consumption, and are influenced by social, developmental, and environmental changes occurring on islands. We would like to note that while preferences and choices help structure people's actions, they are only one part of the larger landscape of value relations. Few people make choices based purely on their preferences and desires, but the latter can nevertheless be a useful and effective indicator of how people think about, use, and value resources in places that are rapidly globalizing. In this way, they may be revealing of how future policies could impact different sections of society and their wellbeing.

In the Maldives, with its extensive coral reef ecosystems, an economy once dependent on fishing now relies on tourism. Tourism directly and indirectly accounts for two thirds of the country's GDP [51]. In 2019, a record number of 1.7 million tourists visited the Maldives. The resulting pressures on the country's resources have been significant [45]. Notably, the tourist industry has created new markets for fisheries products by creating a steadily growing demand for reef fish [44]. Reef fishes make up 83% of the fish consumed by tourists [19] and resorts can demand 500 kg of reef fish per day (Supplementary Information). However, it has been unclear to what extent reef fish are being eaten outside of resorts and whether local preferences for fish are changing. Historically, tuna has been at the center of traditional cuisine in the Maldives [1]. While there is an unfortunate paucity of historical information on reef fish consumption, archeological work across the archipelago has found that scombrid (tuna) remains dominate in both the Buddhist (pre-1153 CE) and the Islamic (1153-present) periods of settlement. As Litster [32] writes, "the dominance of tuna in all periods, despite the availability of inshore reef fish highlights a deliberate and continued practice perhaps linked to the... cultural preference for tuna". While reef fish do appear in the archeological record, they are found in significantly smaller quantities, suggesting that they were fished to a much lesser degree. This points to a relatively underutilized reef fishery, despite the availability of reef fish, and stands in contrast to other islands in the tropics where reef fishing has played a more prominent role in society and been practiced for millennia. In some cases, this long-term demand for nearshore and reef species has become unsustainable and contributed to its overfishing [39,48]. In Palau, there are efforts now underway to shift consumer demand towards more pelagic species like tuna to help offset pressures on the reef [13,14,49]. While knowledge of reef fish behavior and reef fishing methods are extensive in islands with a long history of reef fishing, in the Maldives, it is references to tuna – as an item of trade, a dietary staple in the islands, and the methods used to fish it – that abound in ethnographic and other writing. The pole-and-line fishery for pelagic tuna dates back to the 14th century [52] and current records indicate that more than half the tuna caught is consumed locally rather than exported [36]. It's this historical reliance on and connection to tuna that has enabled reef fish populations here to remain healthy even in the face of major climate change-related disturbances [12,40]. However, shifting preferences and consumption patterns could intensify pressures on coral reefs [31]. While there are some informal rules that govern the fishing of some lagoon fish on particular islands [37], apart from the grouper fishery, reef fisheries in the Maldives currently do not have a national management plan [44].

We aimed to gain insight into the ways in which people value tuna and reef fish today by documenting individual preferences and consumption patterns of fish across four islands in Dhaalu atoll, Maldives. We expected strong preferences for tuna and a higher consumption of tuna over other fish given the age of this fishery and the ubiquity of tuna in traditional cuisine. We collected social and demographic data on age, gender, and profession, among other variables to help understand what

influenced individual preference. Additionally, we also gathered information regarding seasonality in reef fishing, catch composition, reef fish markets, and fishing practices from fishers to better understand the dynamics that governed reef fishing. Since these fisheries are local and small-scale, we paid particular attention to how fishing practices may be linked to fish consumption patterns, cultural events, and community networks, and how these may be changing over time.

2. Methods

The Maldives is a double chain of 26 atolls and over 1190 islands in the central Indian Ocean, extending from 0.5°S to 7°N of the equator. 539, 834 people live across its 190 inhabited islands, although close to 40% of the total population is concentrated in the capital city of Malé. This study was conducted on 4 islands in Dhaalu atoll, in the central province of the Maldives. Dhaalu is an atoll ringed by 59 islands, of which 6 are inhabited by local communities. Historically, the chief employment on these islands has been tuna fishing, but a significant proportion of residents today also work in government jobs, in local schools and offices, in small businesses and shops, and in resorts. Currently, there are 6 resorts in Dhaalu located on separate resort islands that lack an Indigenous population.

We used structured surveys with a combination of fixed responses and open-ended questions to collect data on individual preferences and assess the household consumption of reef fish and tuna (see Supplementary Information for survey instrument). Surveys were conducted in English or Dhivehi (the local language), based on the respondent's preference. We used a mixed approach to identify respondents, with both snowball and convenience sampling. To begin, island council members directed us to long-time residents or fishers to invite to be surveyed, who directed us to other potential respondents. We also recruited participants in public spaces, e.g., around harbor areas, in cafes, or during daily community gatherings outdoors, and interviewed them if they consented to participate in the study. Two of the people who were invited to participate in the study declined.

Of the 100 respondents we surveyed, 56 were fishers (full-time, part-time, subsistence, or recreational), 78 were male and 22 were female (see Table S1 for island-level differences). The ethnic (Maldivian) and religious (Muslim) background of respondents was homogenous; these characteristics of our sample are similar to the population of this atoll, and to the archipelago in general. The mean age of men interviewed was 43.5 (+/- 14.3 SD) and of women was 42 (+/- 14.2 SD) (Fig. S1). Since our surveys were not a random sample of the population, they may not adequately represent the entire population of these islands. However, our study was aimed at gathering baseline information and identifying potential social and cultural factors which may influence preferences, consumption, and fishing for future investigation.

We used a two-way ANOVA to test for differences in household consumption of reef fishes and tuna (consumption (kg) ~ fish_type + island). Consumption was generally reported as a weight (kg) of fish consumed per household per week. In a few instances, it was reported for the individual – in these cases, we extrapolated the value for the number of household members to get an estimate for the entire household. We used a log (x + 1) transformation on the data to improve normality of residuals while avoiding zero values.

We used a generalized linear mixed model (GLMM) with a binomial link function to determine the best predictors of fish preference among the population interviewed. We coded preference for reef fish as 0 and tuna as 1 and tested for the effects of (a) gender (m/f), (b) age (19–80), (c) profession, (d) historical preference and (e) island (random effect) on an individual's current preference for tuna or reef fish (grouped into these two categories based on more detailed species-specific responses, see Supplementary Information). We included profession in our model to assess if one's role as a fisher influenced their preferences for certain species of fish (we pooled profession into three categories – tuna fisher, reef fisher, and other). In our interviews, reef fishers often mentioned

they took home a small proportion of their catch to consume with family; tuna fishers said the same. We therefore thought it important to consider profession and the role it might play in influencing individual preference. We defined historical preference as the past preference for a particular kind of fish that an individual reported to have had when they were younger. All respondents gave us the relative percentage of different reef fish and tuna species in their diets in the past versus today. Our global model was: preference \sim gender + age + profession + historical preference + island (random). We sequentially dropped variables using the *drop1* function to select our best model (preference \sim gender + age + island). All analyses were run in R [41].

Finally, we interviewed the respondents who identified as reef fishers to understand the dynamics related to reef fishing (e.g., seasonality, gear, markets), which we then coded inductively and condensed into six broad themes given in Table 2 below. While these conversations generated a rich amount of information, we limited our discussion in this manuscript to addressing the main factors that fishers identified as influencing reef fish catch and consumption and the changes they have observed over time.

3. Results

We expected tuna to be consumed at a higher quantity than reef fish in households. Strikingly, we found no significant differences in the reported average weekly household consumption of fresh tuna and reef fish in the islands surveyed (Fig. 1; Table S2, $p > 0.05$).

Meanwhile, 58% of all interview respondents said they preferred to eat reef fish over tuna today. Our model indicated that gender and age were key determinants of people's preferences for certain species of fish (Fig. 2; Table 1). Men preferred to eat reef fishes (in particular, snappers, emperors, groupers, and chubs), while women reported a preference for tuna (skipjack, frigate, or yellowfin tuna). After gender, age was a significant determinant of individual fish preference, with preference for reef fish increasing in people around the age of 40–45. Profession and historical preference were dropped from the final model because they did not have a significant effect on the variance explained.

When it came to the dynamics that influenced reef fishing, fishers noted several factors – from seasonality and market demand to coral bleaching and changing gear – that could influence current and future

consumption patterns (Table 2). In general, they perceived changes in the abundance and composition of their catch in response to coral bleaching (specifically, a post-bleaching decline in *Chromis* spp. used for bait) and developmental changes on the island (e.g., reclamation, harbor construction), as well as modifications in fishing practices and gear over time. Some noted that fish abundance had decreased during land reclamation and after, and also during the dredging of the channel and harbor areas. Others did not observe a change in reef fish species due to development on land.

Notably, almost all fishers spoke of a decrease in bait species and linked it to the extensive use of more exploitative methods of bait fishing recently, including the use of lights and SCUBA. They also identified a clear seasonality in the catch and consumption of reef fishes, with a spike in reef fish consumption occurring during the period of Ramadan and Eid when community barbeques and gatherings were more frequent. Reef fish were seen as the more appropriate fish for frying during these times, with the demand for reef fish and their price increasing during this period. In general, a wide variety of reef fish species were targeted by fishers in Dhaalu atoll. The most popular species fished were snappers (in particular, *Lutjanus gibbous*), groupers (*Epinephelus tauvina*, *E. microdon*, *E. caeruleopunctatus*, *Cephalopholis argus*, *Variola laoti*), emperors (*Lethrinus* spp.), jacks (*Caranx* spp.), sea chubs (*Kyphosus* spp.), soldierfish (*Sargocentron spillifera*), and rainbow runners (*Elegatis bipinnulata*). While reef fishers used several kinds of gear on reefs, handlines were the most commonly used. They were used with or without a weight, and with or without bait (live or dead).

In parallel to buying and selling fish, there appeared to be an active informal system of sharing fish with friends, family, and neighbors. 14% of respondents said the reef fish they obtained was procured exclusively through sharing, while 58% obtained it through a combination of sharing and/or direct fishing. Only 17% exclusively bought their reef fish.

4. Discussion

While the tuna fishery – and tuna – retains a place of prominence in Maldivian culture, our results indicate that reef fishes have so far been an overlooked part of local diets. Notably, reef fishes were preferred by a small but significant majority of our respondents, indicating that reef fish consumption may increase in the future. These dynamics need to be carefully examined in order to better support local communities' social adaptive capacities to urban development and accelerating tourism, and in managing their resilience to sea level rise, coral bleaching, and other threats due to contemporary global climate change [33,50].

Preferences were influenced by people's gender and age. Our interviews suggest that the preference for tuna amongst women might be partly rooted in the popularity of traditional cuisine and the diversity of culturally important dishes that are cooked with tuna (e.g., *rihakuru*, *garudiya*, *maashumi*). In contrast, reef fish were associated with a "bad smell," and women found the process of cleaning and gutting reef fish unappealing. Five of the women interviewed said they would never eat reef fish because they disliked it so much. Women's involvement in small-scale fisheries in the Maldives has not been the focus of any formal research before, even if women's roles, while less visible, might include a range of activities related to fishing like cleaning, cooking, selling, etc [30]. In the past, women used to be responsible for sewing nets and cleaning the catch of fish once it was landed. "Now the nets are imported and catch [of tuna] is sold to collector vessels or taken directly to Malé", an older respondent mentioned. However, another said that she had been fishing "daily from the shore since the age of 20... since I had children". She explained that she began fishing to provide her children with fresh fish since her husband was a tuna fisher and was frequently away. This suggests that women's involvement in small-scale reef fisheries, while not necessarily direct, might still be important to consider especially from the point of view of island food systems and the processes that contribute to the nutritional health of communities. The

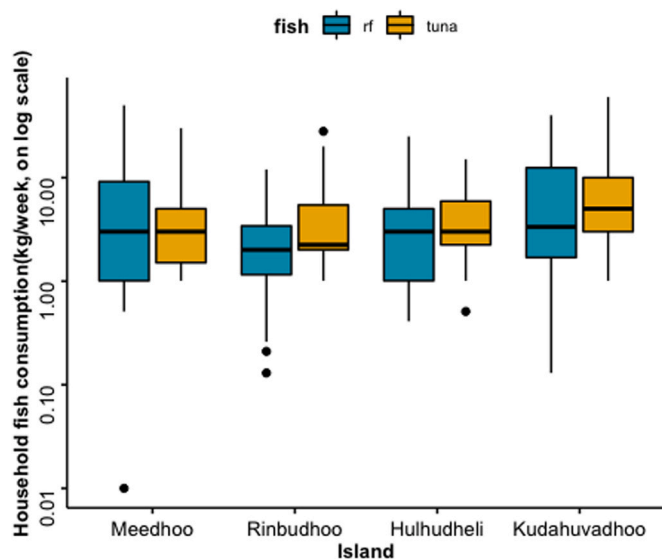


Fig. 1. Household consumption of reef fish and tuna (kg/week, on log scale) across the four islands surveyed ($n = 22, 25, 26, 27$, for each island respectively). Colors indicate fish consumed (blue = reef fish(rf); yellow = tuna). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

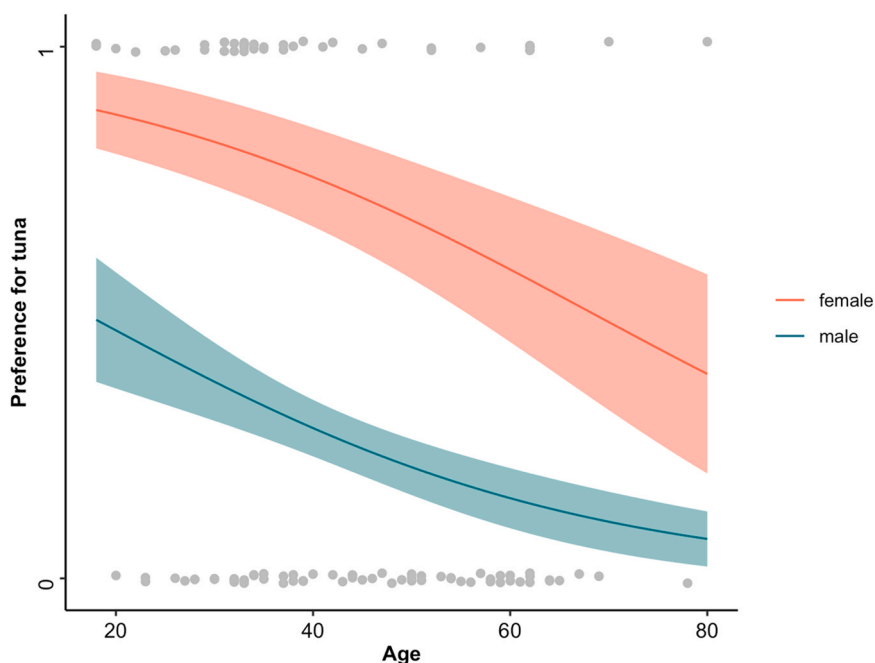


Fig. 2. Preference for tuna (1) or reef fish (0) as a function of age (x axis) and gender (female = red, male = teal). Gray points are the raw data ($n = 100$). Lines are model predictions with shaded areas showing standard error. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1

Results of best model (preference \sim gender + age + (1 | island)) for glmm testing determinants of fish preference.

Random effect:	Variance	Std. Dev.		
Island (intercept)	0.370	0.609		
Fixed effects:	Estimate	Std. Error	z value	Pr(> z)
Female (intercept)	2.92	1.023	2.856	0.004
Male	-2.094	0.588	-3.559	0
Age	-0.045	0.019	-2.404	0.016

gender-based differences in preference we record in this study could also point to a deeper split in values relating to marine resources, and more broadly to the ways in which the ocean is seen and used by men and women in the Maldives. This underscores the need to advance methodological and analytical approaches to gender for a comprehensive understanding of human-ecological interactions in coastal fisheries [28, 35].

Fish preference also varied by age, which reflects generational changes in diet (Fig. 2). Reef fishes were commonly perceived to be the healthier fish amongst older people (> 40 years), with multiple respondents stating that their doctors had advised them to eat less tuna and more reef fish. However, 70% of people over the age of 40 still cited tuna-based preparations as their favorite dishes, suggesting that while there is a preference for reef fish as an everyday food, it does not replace traditional preparations made with tuna. The nutritional implications of these differences in diet with age could be significant, especially for younger people whose food choices today are more influenced by global trends. These patterns in preference were largely consistent across the 4 islands, but respondents on Rinbudhoo showed a slightly stronger preference for frigate tuna (*Auxis thazard*) over all other fish. This was likely related to their observance of community fishing days for frigate tuna which enter the island lagoon during particular lunar periods, prompting fishers to pool resources and organize fishing days during this time. During the course of our survey, 20+ fishers were involved in landing a catch of over 1500 frigate tuna in one evening. This catch was shared between all community members and was distributed to several

households on the island. This observation points to the underexamined cultural and social role that reef fish might play in community well-being, for instance by maintaining or enhancing social networks [13, 14]. These networks seemed prevalent in the islands we surveyed, with 58% of all respondents obtaining their reef fish via an informal system of sharing with friends and family, or by direct fishing. Understanding these networks is important for developing bottom-up management that is sensitive to the impacts certain policies might have on social relationships and the role those relationships might play in supporting communities' responses to current or future challenges.

Cultural values and preferences have implications for social-ecological resilience by influencing what is fished, when, and how intensively. Fishing practices in turn affect people's choices when it comes to seafood consumption, especially in smaller, localized fisheries. Our interviews with fishers highlighted several important dynamics related to reef fishing (Table 2). One of most significant concerns fishers had, and one that was mentioned often, was around the use of baitfish species. Multiple respondents noted a reduction in damselfish (*Chromis* spp.) in response to coral bleaching events in the past decade. While damselfish are not consumed, they are frequently used as live bait for the tuna fishery. Along with reductions due to coral bleaching, our interviews revealed a sense among fishers that baitfish populations (*Spratelloides* spp., *Caesionid* spp.) were declining due to the increased use of lights and SCUBA to catch bait, and that other less preferable species such as triggerfish (Balistidae), damselfish (Pomacentridae) and cardinalfish (Apogonidae) were being targeted as a result of this. Mohamed et al. [38] previously found that many elderly fishers talked about current fishing practices resulting in the unavailability of baitfish, and that "all fishermen agreed that the lack of bait was due to the methods they used. [38]" While there is some natural seasonal fluctuation in baitfish numbers that fishers recognize, our study highlights the urgent need for a thorough understanding of the impacts of these new fishing practices on baitfish populations.

Resorts have been known to exert a substantial influence on reef fishing [44], and our interviews with fishers confirm that these were the main markets for full-time reef fishers, with fishers generally selling their catch to the resort closest to their home island. Fish were sold by

Table 2

Themes related to fishing and fisheries that emerged during interviews with full-time fishers. Quotes provided in this table elucidate some of the differing views that fishers held with regards to each line of questioning. Topics are ordered in descending order, from most to least mentions.

Theme	Number of individuals mentioning theme	Impact on fishing
Changes in reef fish abundance and composition	22	<p>“The size of the fish hasn’t changed but the numbers have reduced”</p> <p>“Number of fishers more now, so we get less fish”</p> <p>“No change in fish numbers but the reef is dead”</p>
Resort demand	12	<p>“Resorts drive reef fish catch”</p> <p>“Demand for reef fish has increased since resorts came up... more people engaged in reef fishing today”</p> <p>“Now reef fishers here go reef fishing on a demand basis... if resort requests it, they go”</p>
Impacts of coral bleaching	11	<p>“Less baitfish like Chromis because of coral bleaching”</p> <p>“Bait fishing has reduced because of coral bleaching”</p> <p>“Chromis spp. is difficult to find now after coral bleaching”</p>
Seasonality in reef fishing	10	<p>“During Ramadan people stay on the island and fish on reefs”</p> <p>“Reef fish catch is higher during full and new moon periods”</p> <p>“I target trevallies during the 28th and 29th and red snappers during the 14th-17th days of the lunar month”</p>
Impacts of development	7	<p>“There’s been no change or decrease in fish even with reclamation”</p> <p>“During reclamation there weren’t that many fish around, but it’s getting better again”</p> <p>“The entire coastline has changed because of reclamation and the fish have also changed in response to this”</p>
Impacts of changing bait fishing practices	6	<p>“Number of reef fish has decreased because there’s light being used in bait fishing”</p> <p>“Diving to catch baitfish should be banned because we end up catching the full community”</p> <p>“Earlier, people wouldn’t go beyond the atoll for bait. Now people are able to go further because of bigger engines”</p>
Impacts of changing gear	3	<p>“New fishing tools have made it easier to catch more fish”</p>

weight and fishers did not indicate any difference in the prices for different species. However, the networks that are involved in the selling of reef fish are complex and are likely to vary by island, depending on the number of buyers and middlemen that transport catch to Malé before it is further distributed. While resorts drive reef fishing in a significant way (buying at between USD 1.3–3 per kg of reef fish directly from fishers) we found that community demand for reef fish during particular times of the month (e.g., the new and full moon) and year (during Ramadan), also increased local reef fishing effort. 39% of respondents reported an increase in their consumption of reef fish during Ramadan. One respondent mentioned that reef fish were essential during this period as “the morning meal always needs fried reef fish”. Apart from fresh reef fish, the consumption of canned and smoked tuna (*valhommas*) also increased during Ramadan. Our study was conducted in the early

part of 2020, but it is likely that reef fish consumption varies through the year, spiking during Ramadan. This is indicative of a dynamic landscape of personal preference and choice, which has the potential to impact island food systems and the ecology of coral reefs in this archipelago. While contemporary reef fishing methods (outside of the bait fishery) are still fairly inefficient (e.g., handlines), an increased demand among the local population, alongside resort demand, could quickly lead to increased fishing on coral reefs, with more efficient and potentially more destructive gear types. Notably, the reef fishery does not currently have a cohesive national management plan in the Maldives. While there are yearly fisheries regulations that recommend the implementation of rules (e.g., General Fisheries Regulation 2020/R-75) there is a lack of data on how and where these are implemented and monitored [23]. Identifying times of the month and year when the extraction of a resource increases – and the reasons for it – can be useful in implementing management designs that are steeped in local knowledge. Similarly, we suggest that future work should seek to better understand the linkages between a resort’s consumption dynamics with respect to the increasing exploitation of the reef fishery and the domestic consumption of reef fish among the broader community.

5. Conclusions

In conclusion, our study finds that reef fish are being actively consumed in local households in Dhaalu atoll, Maldives, and 58% of our respondents reported a preference for reef fish over tuna today. This highlights the need to better account for the preferences and choices around fish consumption and their seasonalities in particular cultures and societies across the globe’s island and coastal communities. If reef fishes continue to increase in their popularity, and if governing bodies do not monitor and manage their catch across the Maldives, the feed-backs to coral reef ecosystems could be quick and damaging. Here we suggest that preferences, along with consumption data, may be used as an early indicator of changing diets, but also that their incorporation into fisheries planning can help ensure that different stakeholder values guide and inform future management decisions. Second, we document an increase in the catch and demand for reef fish during particular times of the month and year, information that may help guide the formulation of future management plans. Finally, we emphasize the need to examine women’s roles in local reef fisheries in the Maldives, especially in the context of island food and nutritional security.

Sustainably managing fisheries so that their ecological and social functions are maintained remains one of the major challenges for marine conservation. It has become increasingly clear that equitable conservation policies will need to take a trans-disciplinary approach to be successful, integrating perspectives from both the natural and social sciences. People’s values guide the choices they make and impact their wellbeing and ability to adapt to change [20]. As the pressures of climate change continue to alter habitats worldwide, engaging with and integrating the human dimensions of social-ecological systems will be necessary to help formulate, guide, and improve on conservation outcomes.

CRedit authorship contribution statement

S.Y., R.D., and A.M. conceptualized and designed the study. S.Y. acquired funding for the study. S.Y. and A.F. conducted the interviews. S.Y., A.M., R.D. and J.M. conducted the analyses. S.Y. wrote the original draft. S.Y., R.D., A.F., A.M. and J.M. contributed to the writing.

Competing interests

The authors declare no competing interests.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.marpol.2021.104773](https://doi.org/10.1016/j.marpol.2021.104773).

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