The Status of Kabin Meto Fisheries

A technical report prepared for the Micronesia Conservation Trust and the Marshall Islands Conservation Society, with assistance from the Marshall Islands Marine Resource Authority

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Introduction

The three atolls of Lae, Ujae, and Wotho constitute what is collectively known as Kabin Meto. This cluster of atolls resides along the north western end of the Ralik island chain. Each island is unique in its size, shape, and bathymetry, which is reflected by the biological communities. Fisheries are a central part of Marshallese culture, and citizens living on outer islands rely heavily on them as a source of food and supplemental income. To provide increased logistical and economic support to the outer islands the Marshall Islands Marine Resource Authority is trying to create a sustained commercial market within the region. To make this beneficial for all stakeholders, proper management of this system must be a priority. Therefore, this report aims to provide conservation recommendations and inform management decisions based on the biological data available at this time.

Lae is the smallest of the three atolls with 0.56 square miles of land area to its 6.82 square miles of lagoon. The approximately 350 people living on the atoll make it the most densely populated in Kabin Meto. The populated island of Lae is on the eastern side of the atoll. Due to its small size and accessibility, Lae is also the most vulnerable to overfishing.

Ujae lies 30 miles west of Lae and is shaped very differently. Whereas Lae is nearly circular, Ujae is around 26 miles long but only 6 miles wide. This limits the amount of lagoon habitat but allows almost half of the atoll to be sheltered from wind and wave energy. The entire population of Ujae resides on the southernmost island allowing most of the northernmost reefs to go unfished. Unfortunately, within the atoll there are many concerns about ciguatera toxins within the fishery's piscivores that will need to be considered when harvesting for commercial purposes.

Wotho is the northernmost atoll within Kabin Meto. It also happens to be the most sparsely populated with less than 100 residents. Wotho is also unique in that its leeward side is very open, with many channels likely reducing the residence time of water within the lagoon. At the southern end of the atoll, is a traditional protected area or *mo* that only receives occasional harvesting pressure at the request of the community leaders.

Fish community data for these atolls was collected in June of 2016 as part of a MIMRA research cruise to perform a rapid ecological assessment of the underwater environment as part of the Reimaanlok near-shore marine and socioeconomic indicators monitoring network. The purpose of these surveys was to gather baseline ecological data and to provide needed scientific support for local management efforts in Kabin Meto.

Survey Design

Sites for underwater visual censuses were selected using a standardized set of criteria. First, sites had to be divided amongst the two major habitats, outer barrier reefs and inner patch/back reefs. Site were then distributed along a distance gradient from human populations, both inside and outside any site-based management, and across major environmental regimes such as wave energy, when conditions permitted. This design provides a representative snapshot of fish assemblages for each atoll that is suitable for comparative analysis. A total of 34 sites were sampled across the Kabin Meto: Lae (13), Ujae (16), Wotho (12).

Biological data collection

At each site, fish assemblages were assessed using a modified stationary point count (SPC) method. Every 20m along a series of 5 x 50 m transect lines, the observer

paused and recorded the size and species of all food fish greater than 10 cm that came within a 5 to 6 m radius for 3 minutes. This resulted in 12 replicate SPC stations per site following the 10 meter depth contour of the reef. Fish lengths were later grouped into 5 cm bins prior to analyses. Biomass estimates were calculated using length-weight relationships gathered from fisheries-dependent studies in Micronesia, or FishBase (www.fishbase.org). Fish data were also aggregated by several grouping categories for analyses: (i) families, (ii) genus, (iii) genus plus body-size (e.g., small and large-bodied parrotfishes, see Houk et al. 2017 for specific criteria), and (iv) trophic levels (Fig. 1).

Environmental data

Data for a number of environmental factors was acquired from several open access sources online. Geographical measurements of atoll size, and distances were estimated using Google Earth Pro software and a mapping package, leaflet, for R. Site-level wave energy data will be calculated from 10 year records, fetch distances, and angles of exposure, following previous studies (Quikscat wind dataset 1999-2009; Houk et al. 2014; Houk et al. 2015)). Anthropogenic factors were quantified from a variety of sources. A 2011 census conducted by the RMI government provided the human populations from each atoll (EPPSO, 2011). A local fishing access proxy was calculated as the standardized product of wave energy, noted above, and traveling distance to the nearest human population on each atoll. Finally, a commercial fishing pressure proxy was quantified based upon the reported frequency of governmental boat trips to collect fish from outer islands for sale in markets in Majuro or Ebeye.

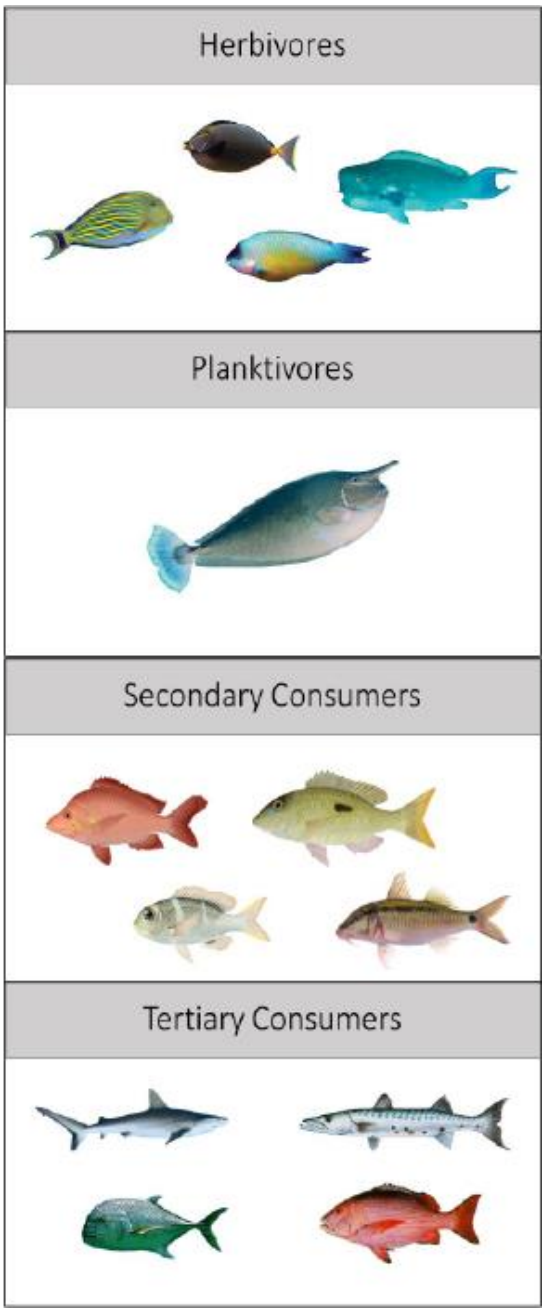

Figure 1. A table of pictures of common fish species from each trophic guild.

Statistical Analysis

The suite of analyses chosen for this research were selected to comprehensively quantify relationships between reef fish assemblages, natural environmental factors, and

proxies to fishing pressure across the RMI at multiple spatial scales without the luxury of time-series data. Predictive relationships were generated for two scales of investigation, between the 10 study atolls and within each atoll, the latter using a nested design. In all cases, analyses first determined the contributions of natural environmental factors in shaping several key attributes of fish assemblages (i.e., several dependent variables). Subsequently, residuals of these relationships were examined with respect to human factors. This approach allowed natural and human factors to be partitioned to the greatest extent possible. For both inter and intra-atoll investigations, the dependent variables were: biomass in each trophic level, that serves as a primary indicator of system productivity; assemblage structure, which may signal functional changes within populations; and an overall fish assemblage condition score derived from a previous study (Houk et al. 2015) that combines a suite of individual metrics into a single "condition" variable. These variables are total biomass, size, species evenness, assemblage heterogeneity, and predator biomass, representing key attributes without overlapping roles available from the present data.

To examine inter-atoll variation in biological data in relation to local environmental conditions, data was first aggregated at the site level, then the site averages were taken to represent individual atolls. Forward, step-wise multiple regressions were used to test natural environmental factors against the dependent biological variables. This process began by identifying the predictor variable with the best fit to the observed data, while ensuring residual normality. Additional predictors were only considered if (1) the effect size (R^2) and P-value were improved, and (2) the improvement made to the fit of the model outweighed the added complexity based on Akaike information criterion (AIC). To ensure that predictor variables were not overly correlated ($r>0.5$), any

correlations found were discussed and no correlated variables were considered simultaneously. Residual variance unaccounted for by natural factors was examined with respect to human factors following the same procedures. The findings from this larger scale analysis gives valuable insight into the regional processes that structure reef fish assemblages, and set the stage for investigating the factors that cause local populations to deviate from regional predictions or peer groups within an atoll.

For intra-atoll investigations, this entire process was repeated, however, a different suite of natural and human factors was used due to the difference in the scale of the investigation. There are fewer predictor variables suitable for site-level analyses so modeling focused on the influence of reef type, calculated wind/wave energy (from above), and travel distance to nearest human population, a proxy for fishing accessibility based on the interaction of the previous two variables. Nested models examined the generality of any localized gradients within each atoll for both inner and outer reef habitats. If significant relationships were to exist between the dependent variables depicting fish assemblages and local human factors, a fishing footprint would be evident. The strength of that potential relationship would then signify the relative scale of fishing impacts within an atoll.

Results

Comparisons Between Atolls

As a whole, the islands of Kabin Meto contain rather productive fish communities. This is unsurprising as this island group is traditionally known for its fisheries. In comparison to the other RMI atolls we have data for, Ujae and Wotho both contain some of the highest levels of predator biomasses, with the exception of Rongelap that represents a near-pristine state (Fig. 2). Lae has reduced predator biomass due to its size and human population density, but the herbivore community within the atoll has had a compensatory boost in biomass.

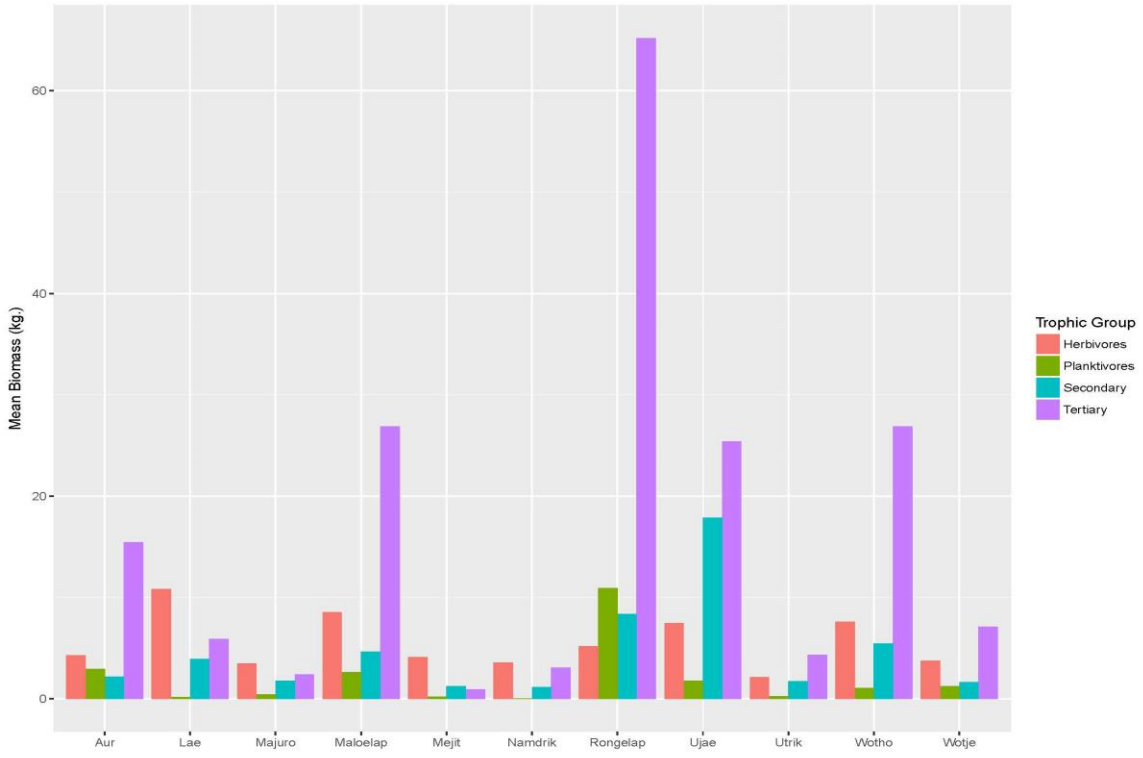

Figure 2. The average fish biomass of each major trophic level observed per SPC across all sites within an island.

Overall, atoll size shows a clear positive logarithmic relationship with fish biomass (Fig. 3), especially within the predator (Fig. 4) and planktivore guilds (Fig. 5). The large lagoons of Wotho and Ujae have additional habitat space for fish to utilize, the potential to increase primary productivity, and limit fishing access resulting in a large standing stock. There is anecdotal evidence that occurrences of ciguatera poisoning are quite common in piscivores within these two atolls which could explain some of the higher than expected secondary and tertiary consumer biomasses (Fig. 4).

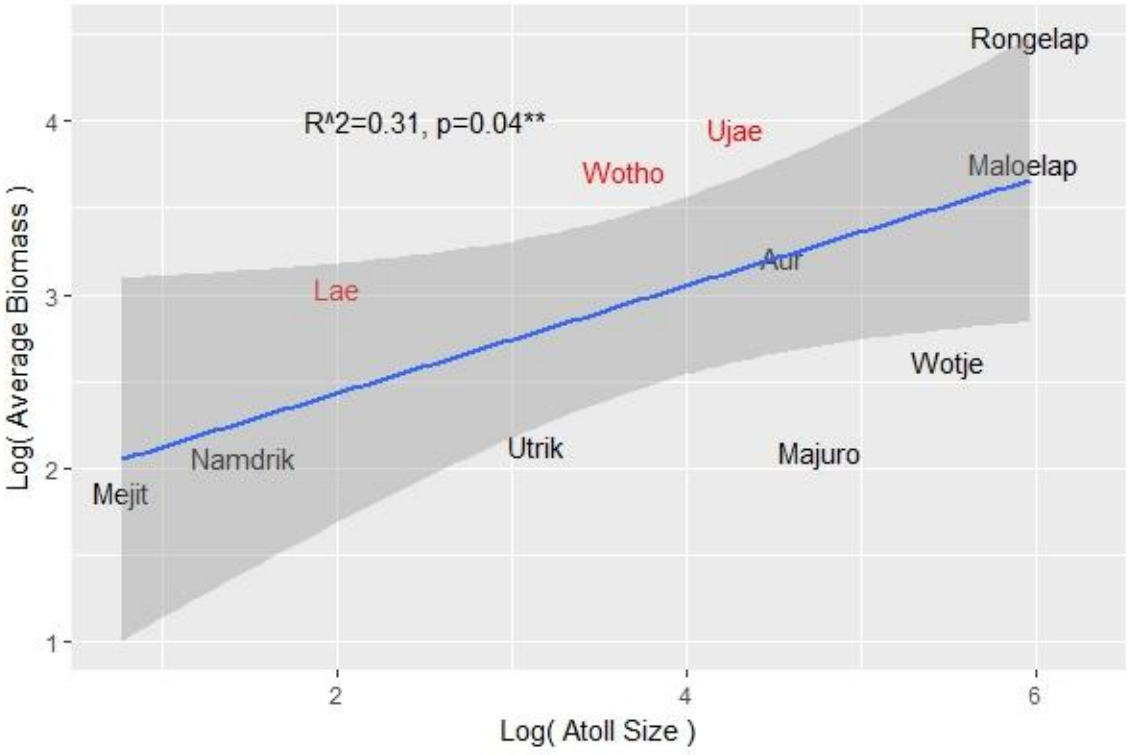

Figure 3. The size of a lagoon has a positive logarithmic relationship with the average observed fish biomass of atolls.

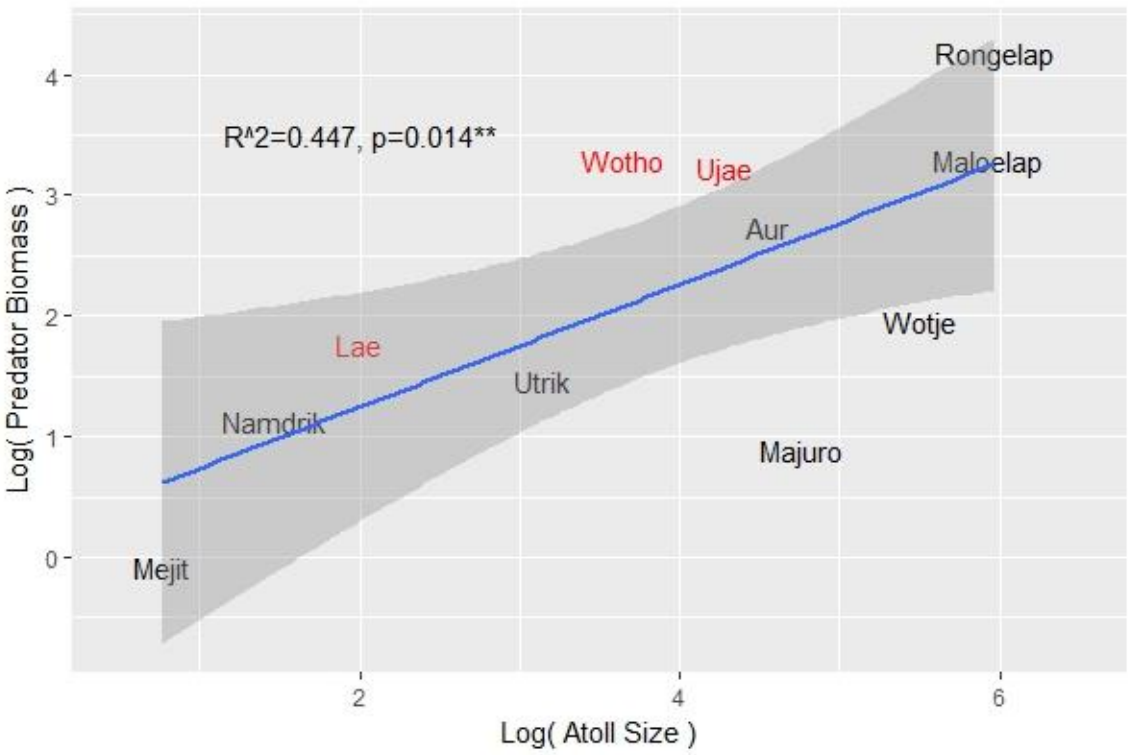

Figure 4. Piscivore biomass shows a tighter correlation with atoll size than total biomass.

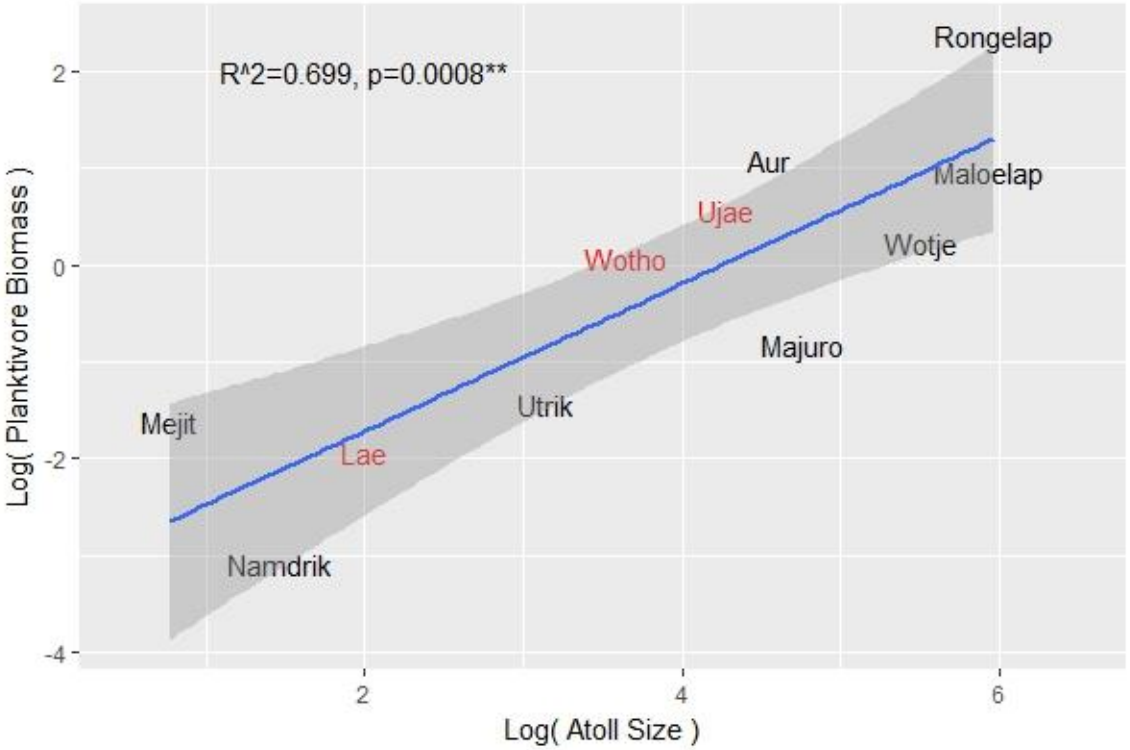

Figure 5. Planktivore biomass has the tightest relationship with atoll size of all the dependent variables.

Although atoll size certainly showed its importance in shaping these reef fish communities, human factors ultimately determine the standing stock of fish biomass within RMI atolls (Fig. 6). Fortunately, all three atolls of Kabin Meto are performing

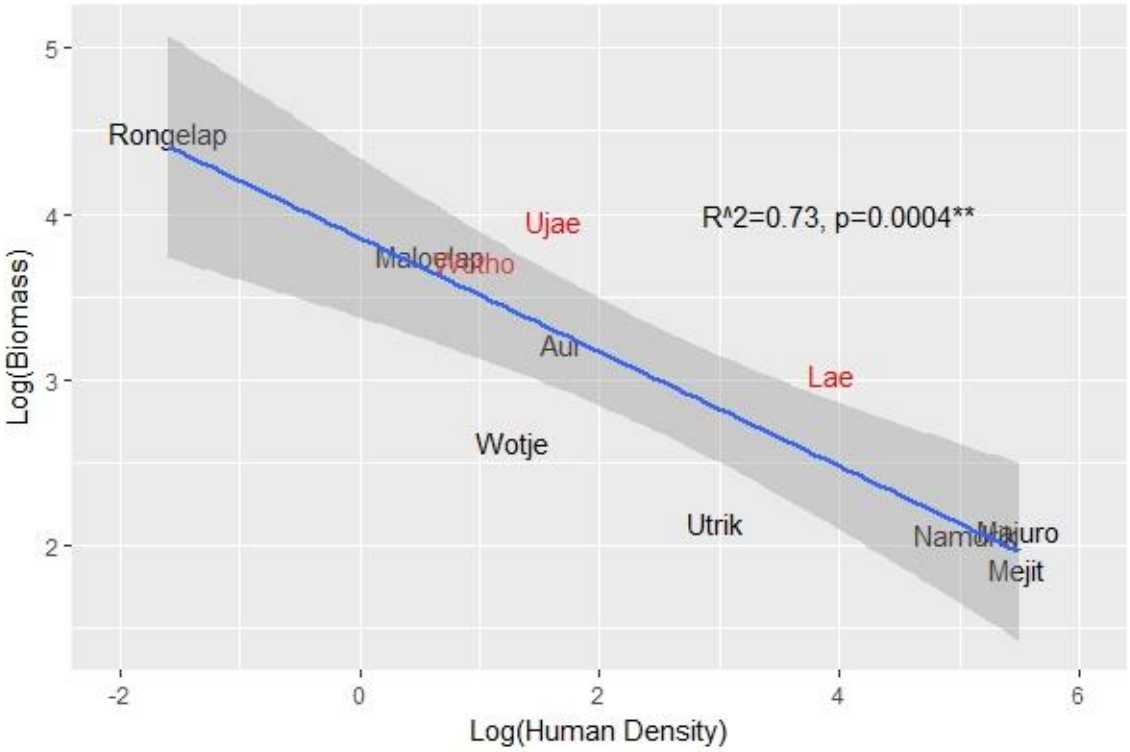

Figure 6. All three atolls of Kabin Meto have higher fish biomass, for Lae and Ujae this number is significantly higher, than would be expected based on their human population density per reef area (km²).

better than our model predicts they should which leaves room for additional harvesting, if done responsibly. Of course, humans tend to fish down the food chain, targeting large predatory fish first, so tertiary consumers are the most impacted by fishing activity Interestingly, planktivores are the next most responsive group to human factors and their biomass also decreases exponentially as human population density increases

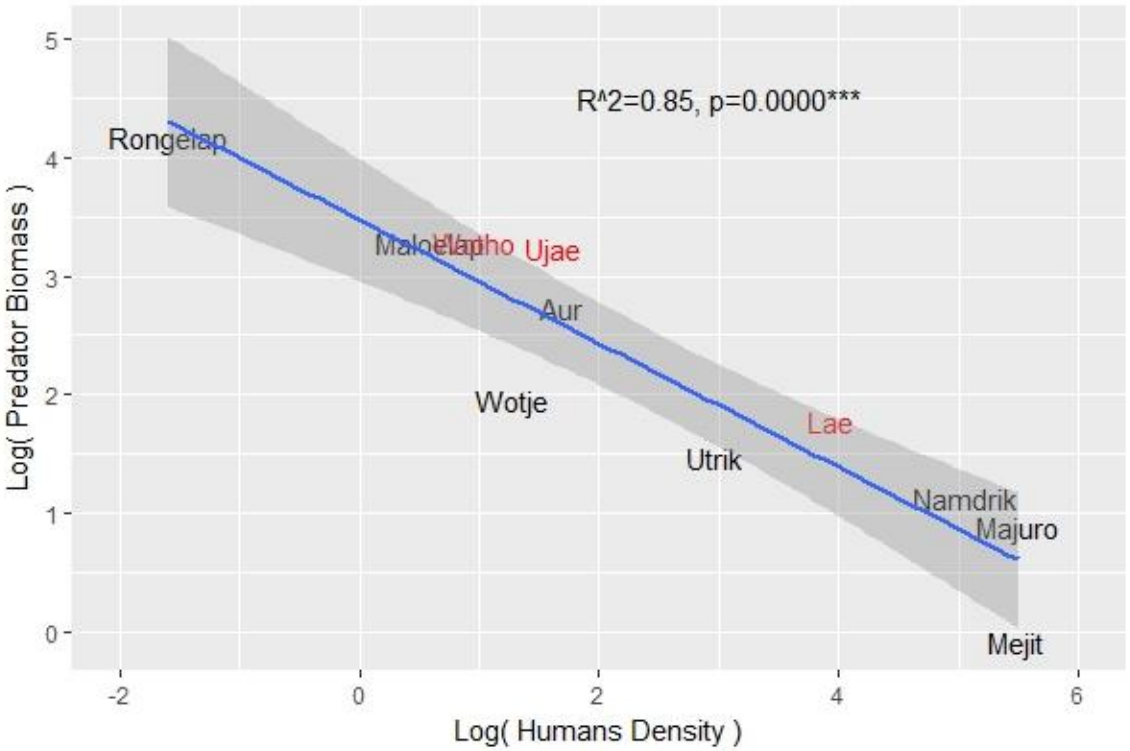

Figure 7. Predator biomass across the RMI decreases rapidly with increasing human population density per reef area (km²).

across the RMI. Retaining top predators within a reef fishery is important to the functioning of the system as they stabilize prey populations and promote biodiversity and resilience to disturbance events. The role of planktivores within reef systems is not as clear or well understood but their significant relationship with disturbances makes them a useful indicator group for detecting changes within a system.

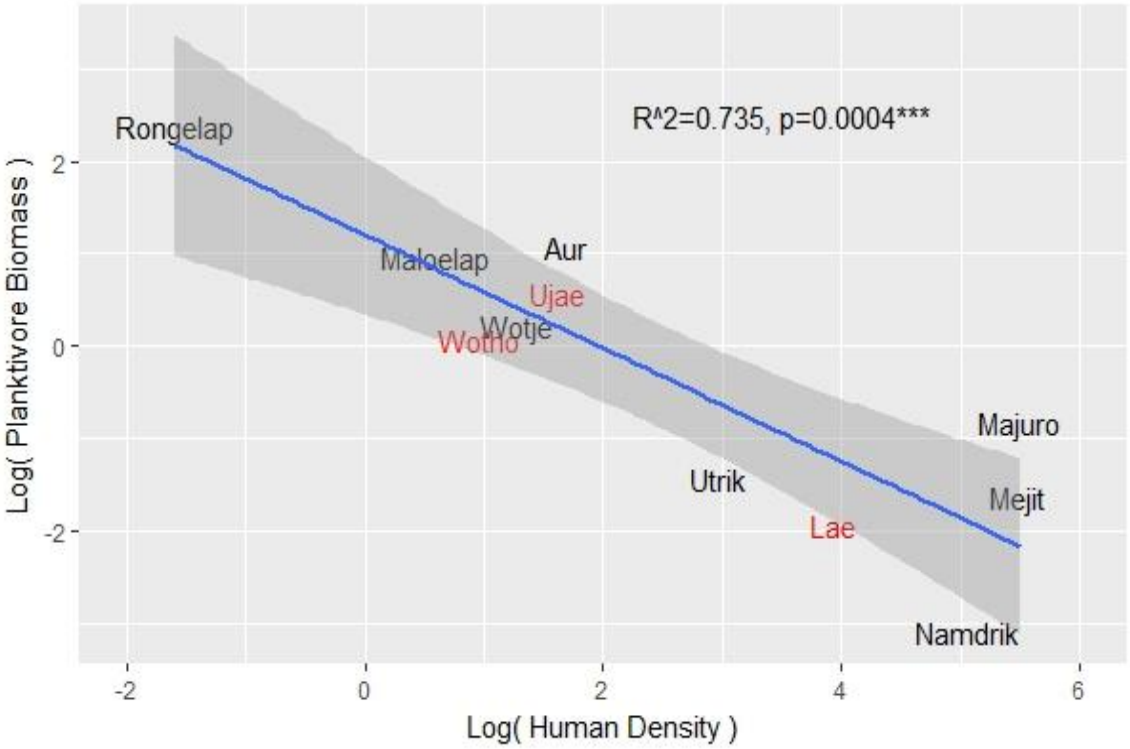

Figure 8. Planktivores are the next most responsive group to human interaction after predators.

Examining Fish Populations Across Individual Atolls

Lae Atoll

As seen in Figure 9, Lae Atoll has less than 50 percent of the average shark and large-bodied grouper biomass. This could be due to a combination of factors, however, the limited habitat space and human density likely play a large role in this predator reduction. Potentially, the absence of large piscivores has led to the high herbivore productivity we currently see with this data. However it is risky to make any causal assumptions without time-series data to know how the fish community has changed over time. Overall, the fish communities in Lae are doing well but important management decisions will have to be made about the harvesting of piscivores in order to avoid overfishing.

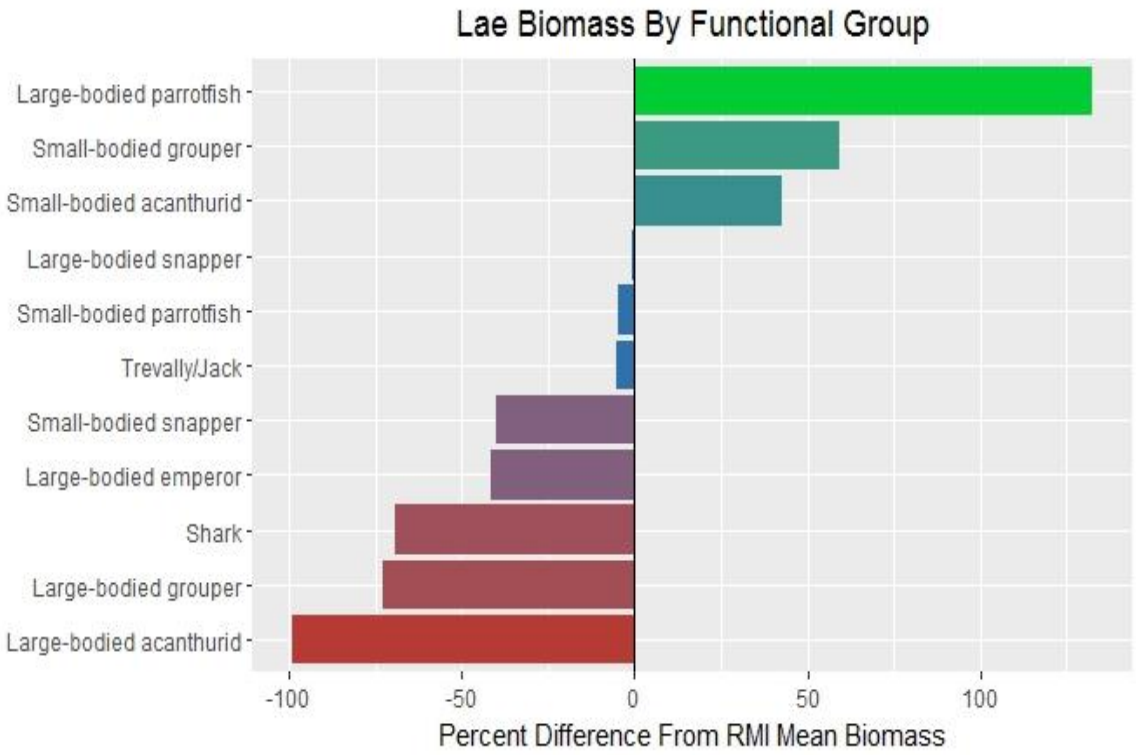

Figure 9. The distribution of Lae's fish biomass for important functional groups in comparison to the RMI average.

The fish assemblage condition score that was calculated from the suite of parameters mentioned earlier allows us to visualize how the communities are faring across the atoll (Fig. 10). It is important to note that each site's condition score is calculated in respect to other sites within that same atoll and are not comparable between islands. Within Lae wind and wave energy was a decent predictor of fish biomass, but not overall condition score, potentially due to ease of human access to one of the more exposed sites that was surveyed. On the inner reefs there was a weak positive relationship between condition score and distance to the island of Lae that turned out to be barely non-significant due to the small sample size (n=4). Outer reefs showed no indications of a distance gradient but seemed better on the Leeward side of the island (Fig. 11). Although benthic and habitat data was not included in this analysis, the two top scoring outer reef

sites had notable amounts of habitat and structural complexity that could contribute to their performance.

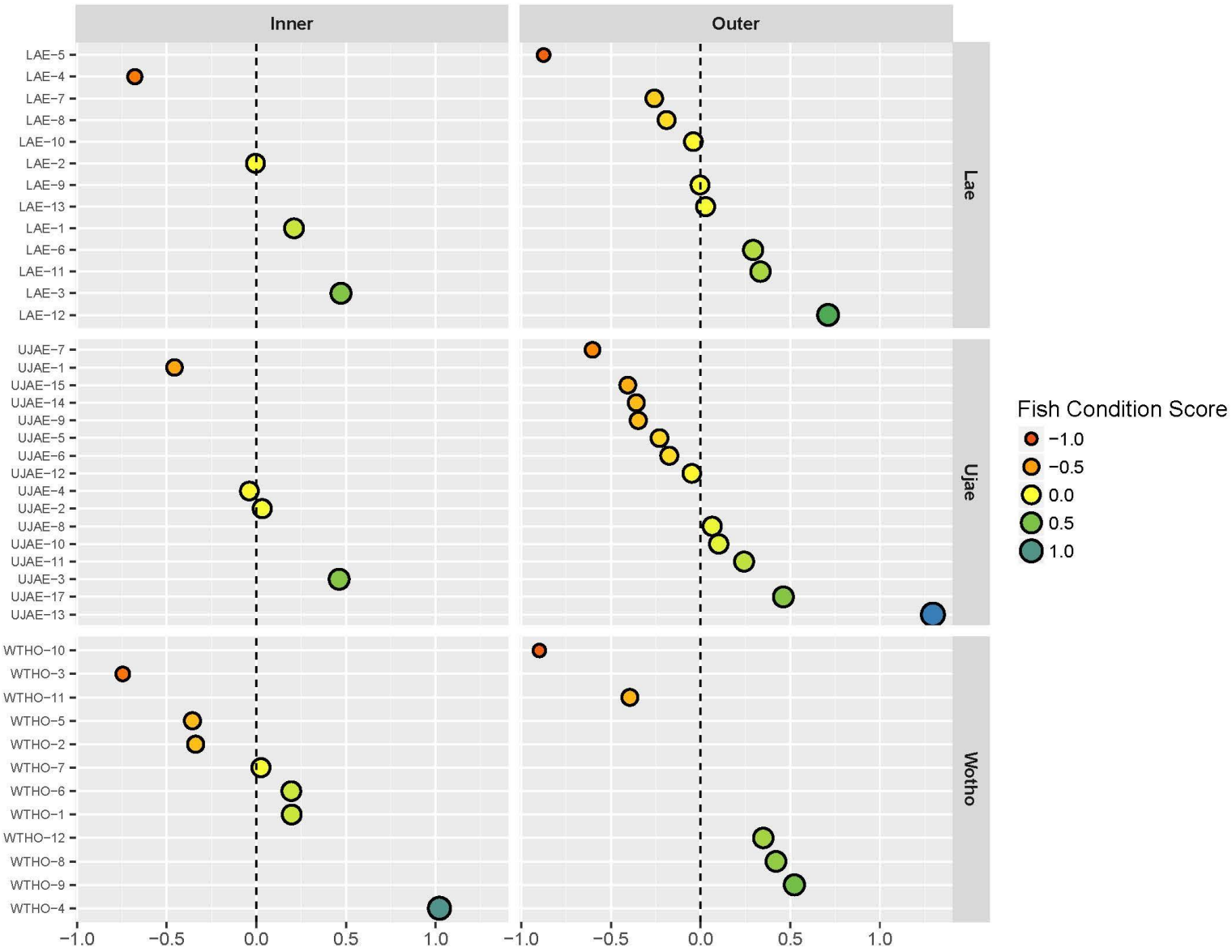

Figure 10. Calculated fish assemblage condition scores based on a site's (1) total biomass, (2) mean fish size, (3) species evenness, (4) assemblage heterogeneity, and (5) predator biomass. Sites are only compared to other sites within the same atoll and of the same reef type. Values are standardized to have a mean value of zero.

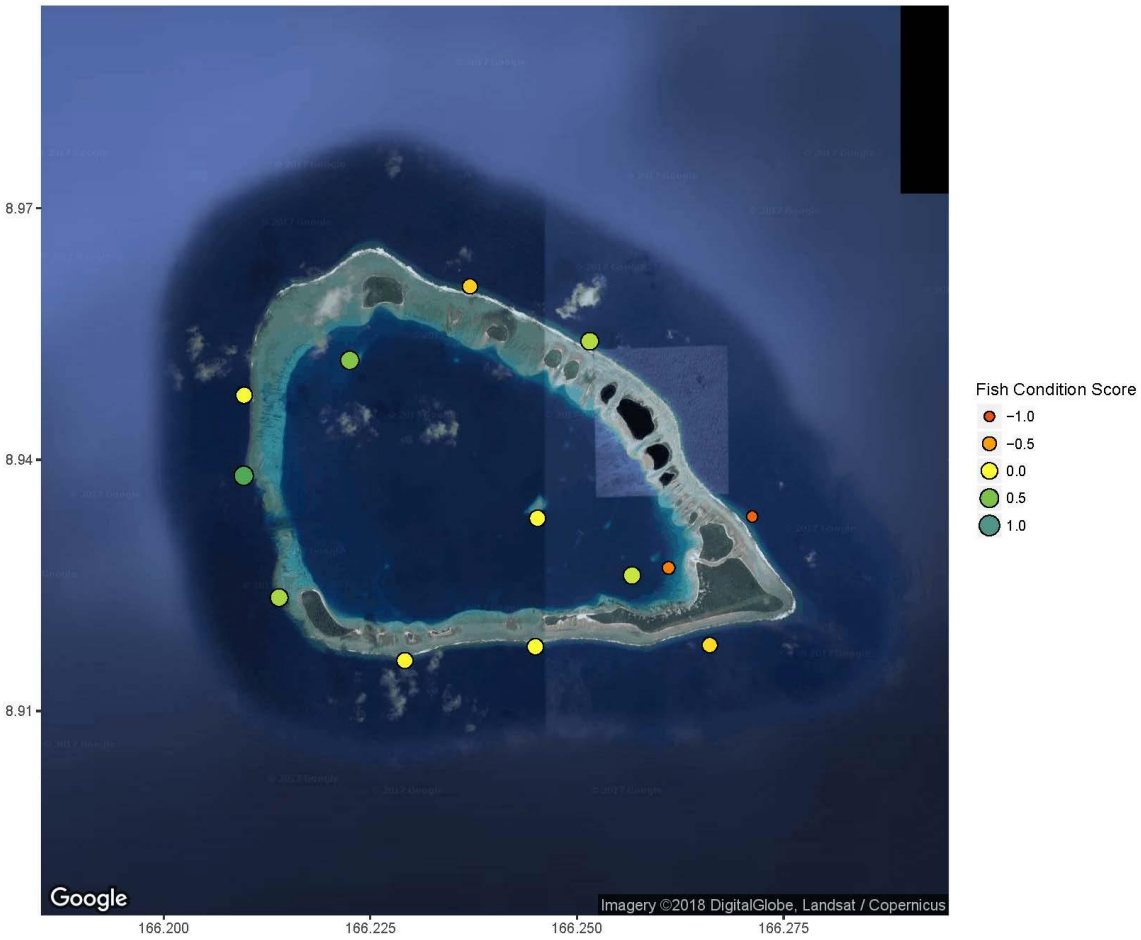

Figure 11. A map of each site surveyed on Lae, marked with the corresponding fish condition score.

Ujae Atoll

Ujae's fish communities are doing very well and seem much more productive than average. Large piscivores have exceptionally increased biomass (Fig. 12). This is a good sign for the health of the system as a whole but may not translate into fishery value due to the risk of ciguatera within the atoll. Of course public safety is a priority, so before any predators can be commercially harvested from this atoll it is strongly recommended that formal surveys and testing be performed to fully understand the risk associated with consuming each target species from Ujae. Spatially, Ujae's reef didn't show any

relationship with wave energy. This could be due to the small sample size of exposed sites surveyed (n=2). There also wasn't any significant distance gradient from the populated island of Ujae but due to the natural concentration of fishing pressure near the southern end of the atoll, spatial management should still be considered to protect local food resources (Fig. 13).

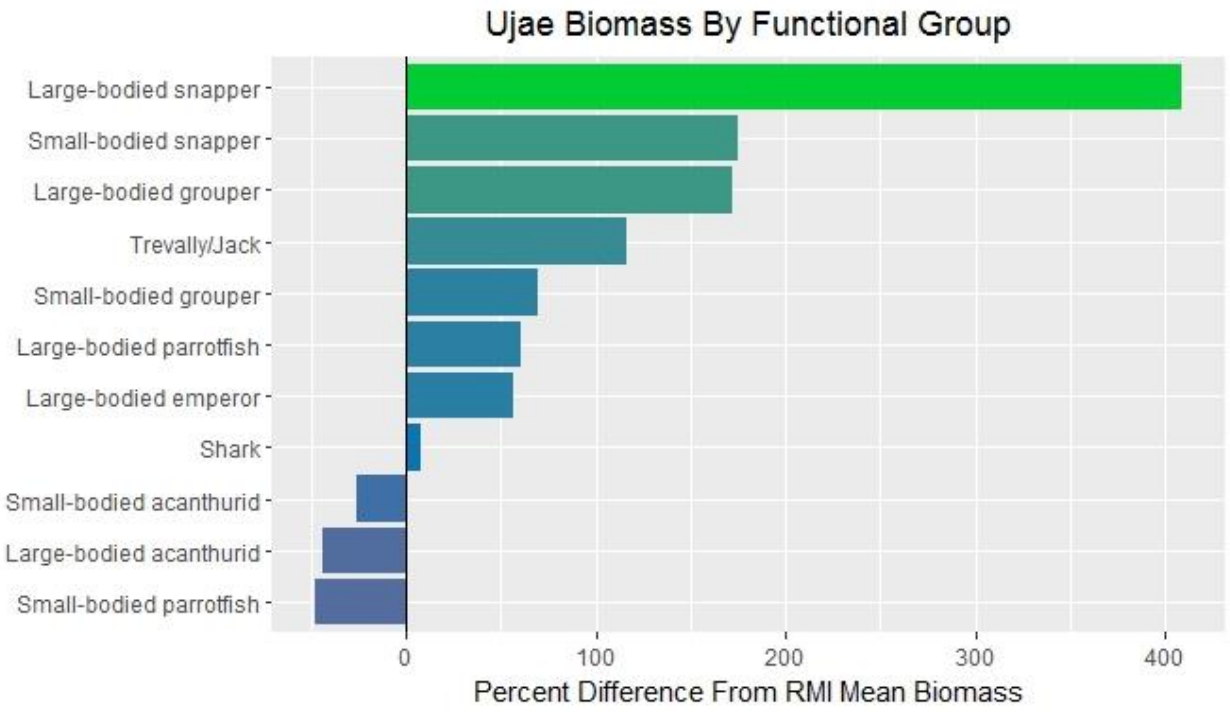

Figure 12. The distribution of Ujae's fish biomass in several key functional groups.

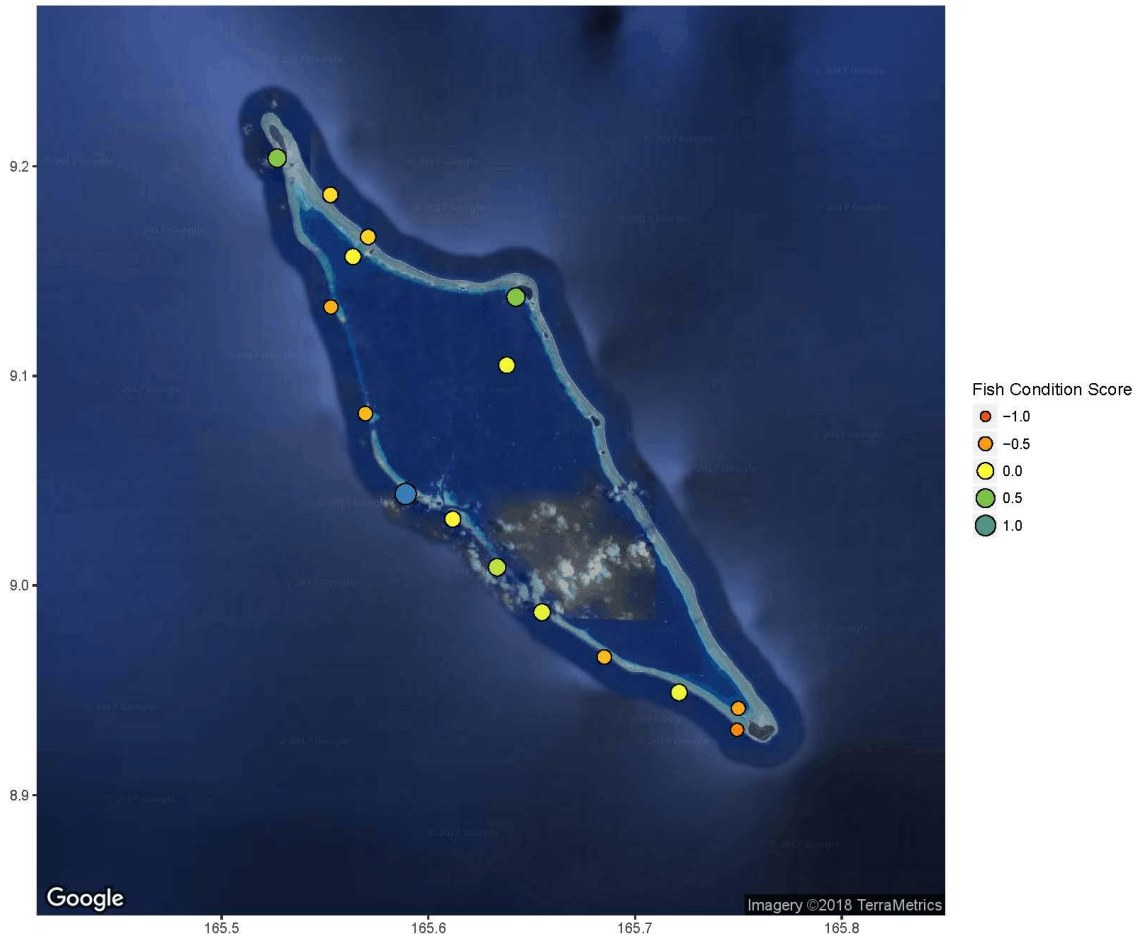

Figure 13. A site map of Ujae with markers that correspond with calculated fish condition scores.

Wotho Atoll

The fish community on Wotho is also faring well. Like Ujae, piscivores are leading the production of biomass (Fig. 14). There are similar concerns with ciguatera toxicity around the atoll so verifying which species in the atoll are inedible is important before commercial harvesting can begin. Parrotfish biomass production is also increased within Wotho which make them a prime candidate as a target species for the fishery.

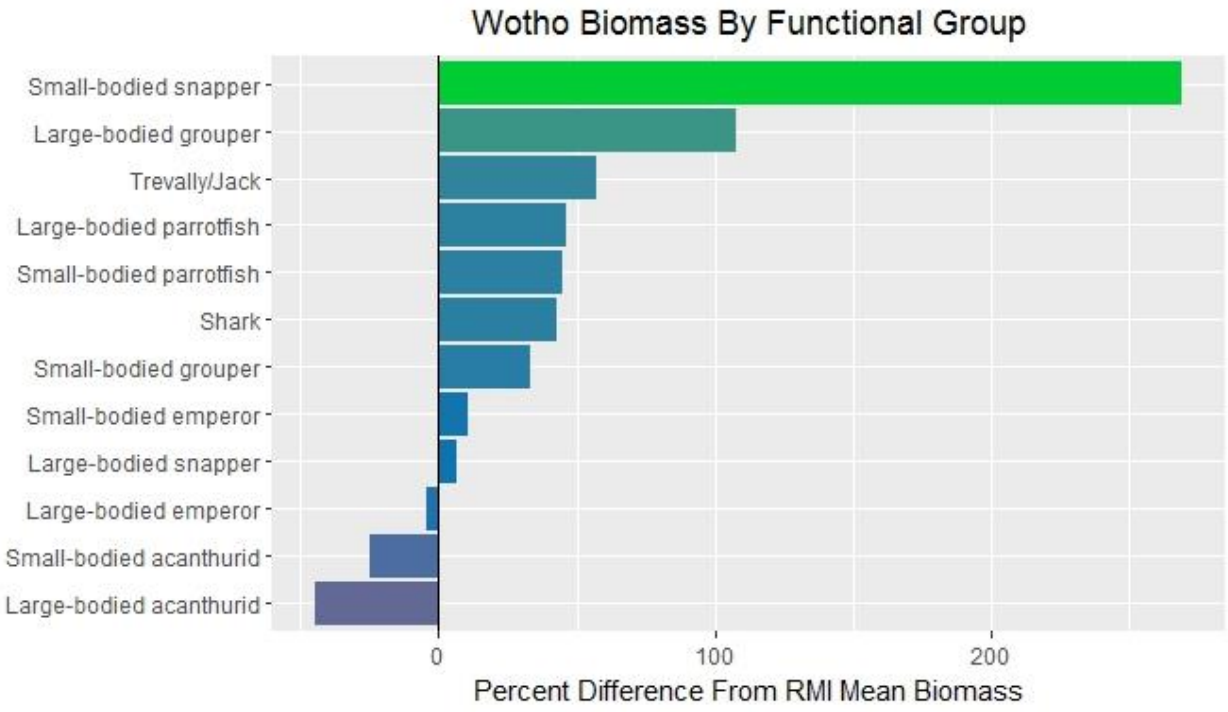

Figure 14. The distribution of Wotho's fish biomass across several key functional groups.

Across the inner and outer reefs of Wotho there were no significant spatial patterns associated with wave energy or distance to the human population. However, there is evidence that the traditional protected area, *mo*, is working with increased the fish biomass within the protected area (Fig. 16). This could be a good opportunity to expand the boundaries of the traditional protected area, with the permission of community leaders, or border the, *mo*, with a traditional MPA.

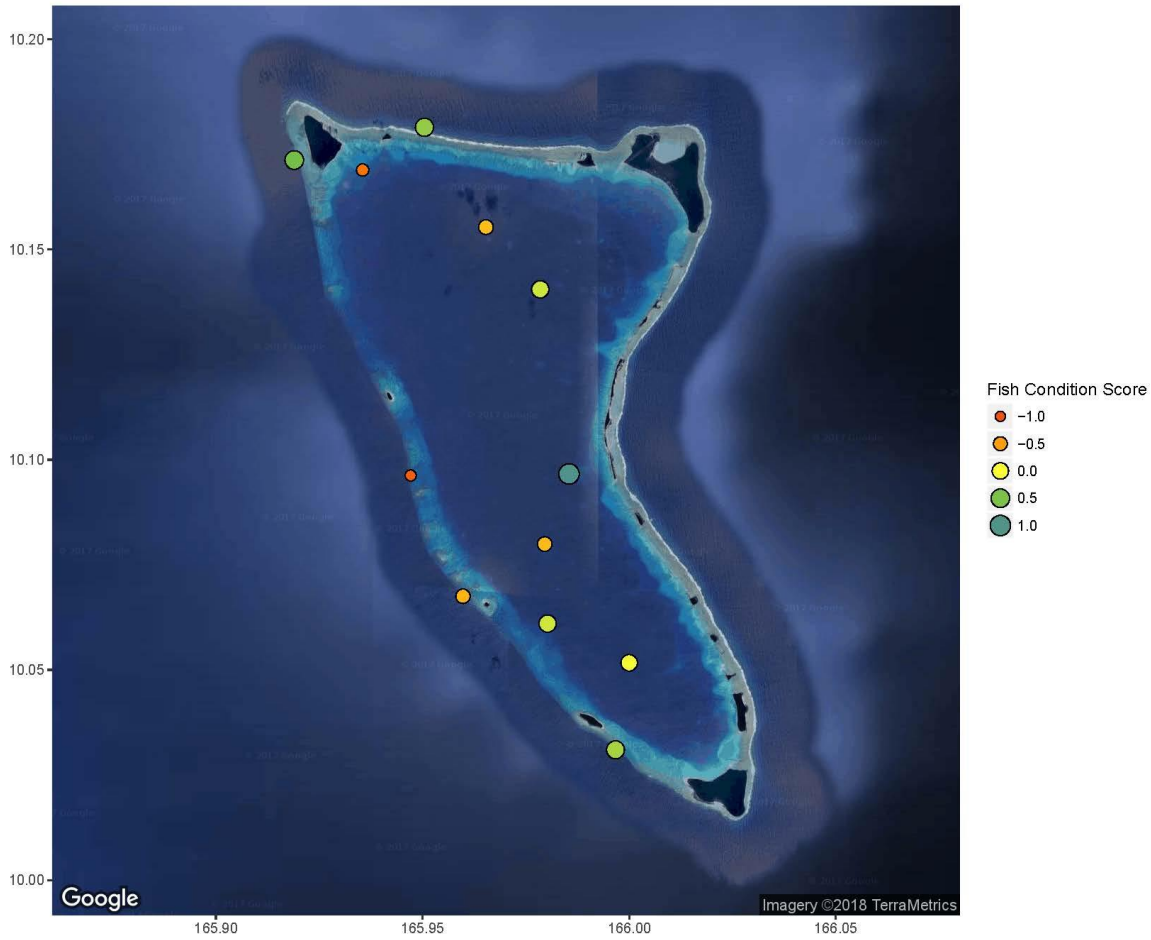

Figure 15. A site map of Wotho marked with the corresponding fish condition score.

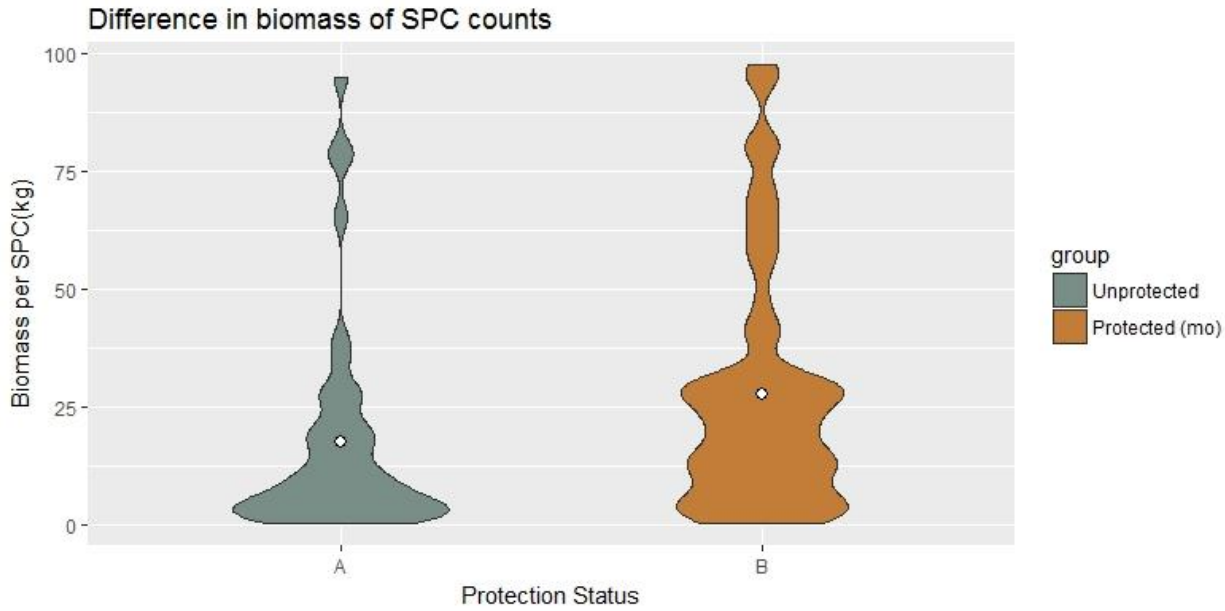

Figure 16. Biomass per SPC performed across inner reefs of Wotho, inside and outside of the traditional protected area, mo.

Management Recommendations

- First and foremost, data of all fish harvested from each atoll for commercial purposes needs to be recorded in order to maximize management success and recognize temporal changes in fish populations. Preferably, this would mean measuring length and identifying the species of each individual collected, however this technique would require ample training and is time consuming. As a compromise, I would suggest at least recording the combined weight, and individual counts, of each fish family collected from an atoll (ex. the tally and combined weight of all of the family Scaridae collected from Lae). Good records of fisheries data is the most powerful tool a manager can possess and could mean the difference between a successful or unsuccessful fishery.
- Next, traditional knowledge of each atoll's fisheries needs to formally recorded and taken into consideration when making management decisions. Some examples of how this could benefit managers are listing and banning the harvest of known ciguatoxic species for commercial purposes. Local knowledge of the resources may also identify spawning aggregations, or seasonality of species that may require protection.
- Any potentially ciguatoxic species need to be periodically tested for ciguatera to ensure public safety.
- Another action critical to the success of management actions is frequent and open discourse with fishermen. Input from those closest to the resource allows managers to receive frequent updates on the status of the fishery and gives

stakeholders the opportunity to take ownership of the resource and take responsibility for ensuring compliance with any fisheries regulations.

- Spatially, it is important to manage areas residents depend on for food the most.
- It is important that fishermen know to spread the additional fishing pressure across an atoll to prevent from rapidly degrading reef patches.
- It is recommended that absolutely no foreign fishing vessels be allowed to harvest reef fish within or around the atolls of Kabin Meto.
- As far as gear restrictions, I would simply suggest the following techniques be avoided for commercial harvesting:
    - SCUBA spearfishing
    - Night-time spearfishing would also be wise to avoid
    - Long gill-nets have the potential to cause a great deal of habitat damage and have high rate of by-catch
    - Dynamite or explosive fishing is extremely dangerous, kills non-target as well as target fish, and is extremely destructive
    - Chemical fishing poisons fishermen, coral and other organisms, and is dangerous for the consumer of the fish
- General species restrictions:
    - All shark species
    - *Cheilinus undulatus*, Napolean Wrasse are not a sustainable commercial species
    - All large long-lived grouper species are very susceptible to overfishing; *Epinephelus lanceolatus* & *Epinephelus fuscoguttatus*

- Parrotfish, of the genus *Scarus* and *Chlorurus*, are functionally very important to the ecosystem, making them a good candidate for size restrictions. Any size limits would require further investigation into the reproductive cycle of these species.

- Encourage the harvest of pelagic species over reef fish as they are less susceptible to localized fishing predators. This could potentially be done with a monetized incentive, making pelagic fish more valuable to harvest.

Lae Specific Recommendations

Lae's small size, accessibility, and higher human population density make it the atoll in the most danger of being overfished. The already reduced piscivore biomass means quotas or size limits should be implemented to limit harvesting. Without time-series data or knowledge of the frequency and scale of the commercial fishing efforts that are to take place, it is impossible to set definitive numbers on harvest quotas. With good data collection this may soon be possible, but at the current time, with the current data available, harvest quotas are out of the realm of possibility. To protect the subsistence fishery that is so critical to residents, areas near populated islands should be designated for subsistence fishing activities only. All areas beyond a certain boundary, which should be established with input from community members, should be open to commercial fishing. If the community is set on establishing a full MPA, closing part of the outer reef along the western edge of the atoll, for example everything south of the channel or towards the northern boundary, would be most beneficial. But as a rule of thumb, any MPAs established need to be large enough to protect the majority of the home range for the species it is aimed to benefit.

Figure 17. Map of proposed protected areas in Lae atoll, red represents areas designated for subsistence fishing only, green areas show where commercial fishing is allowed.

Ujae Specific Recommendations

Ujae is potentially the most productive atoll in Kabin Meto in terms of fishery production. As was stated previously, ciguatera is a major public safety concern and potentially toxic species need to be identified by local informants and avoided by the commercial fishery. Similar to Lae, areas closest to the inhabited island should be protected from commercial fishing. However, Ujae's narrowness limits the fishable areas which may be problematic for the proposed protection, so community input may be required to settle on a solution that benefits everyone. One example of a possible compromise would be opening up outer reefs to commercial fishing within the protected area but keeping inner reefs for subsistence purposes. If the stakeholders would

like to implement a traditional MPA, protecting a single large area near the middle of the atoll would be suggested, as the far end already receives some natural protection simply from its distance from the human population (Fig. 18). The proposed MPA would protect a wide diversity of habitat types, is large enough to benefit far ranging species, and should be far enough away from the community that it does not greatly interfere with regular fishing practices which should encourage compliance.

Figure 18. Map of proposed protected areas in Ujae atoll, red represents areas designated for subsistence fishing only, green areas show where commercial fishing is allowed, and yellow represents a proposed MPA.

Wotho Specific Recommendations

Wotho's low human population and productivity mean it is probably the best suited for an export fishery. As with Ujae, ciguatera needs to be the first consideration

when deciding on fish that may be targeted by the fishermen. Besides ciguatera concerns, almost all functional groups should be open to harvest from Wotho. Again, it is suggested that there be a subsistence only designation for reefs near the main island. Outside of that, the remaining waters can be commercially harvested. If an MPA is going to be created, it seems natural to place it just north of the traditionally protected area. It could be a completely closed MPA or simply be an extension of the existing *mo*. Regardless of the strategy chosen, maximizing the continuity of the protected areas will be the most beneficial scenario for the fish community.

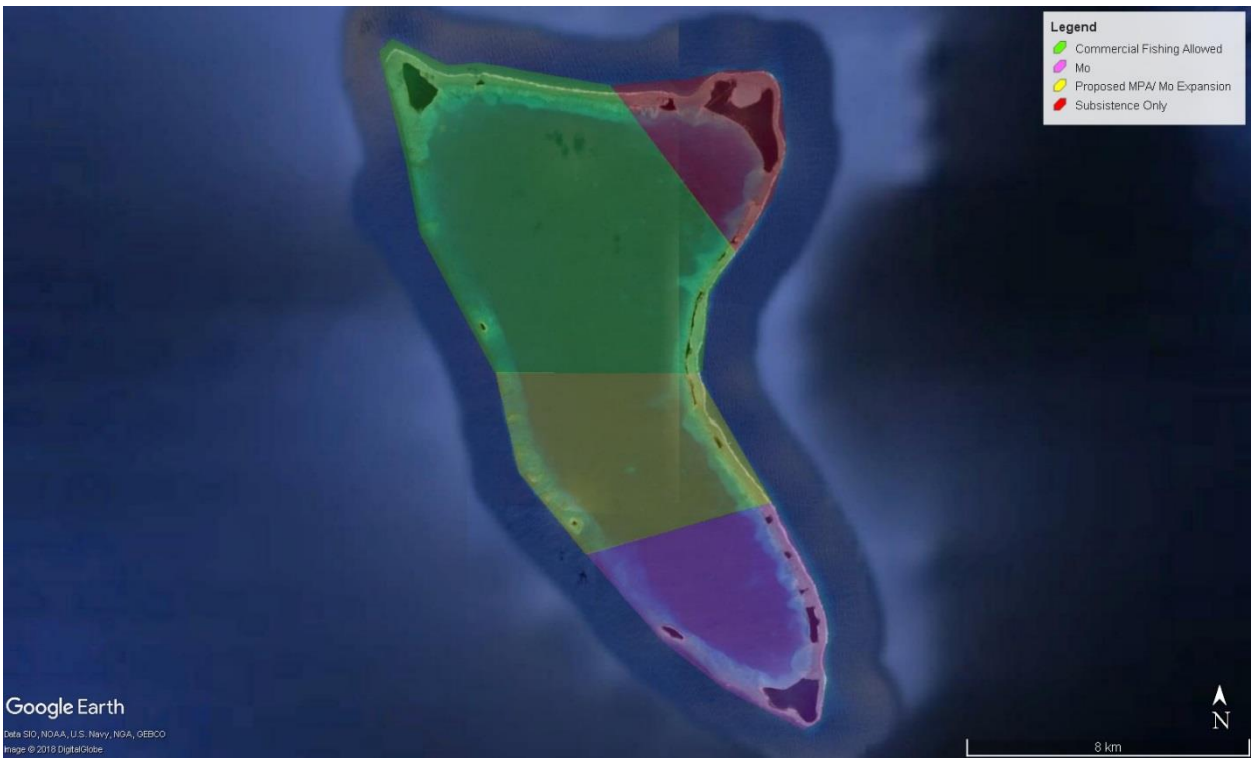

Figure 19. Map of proposed protected areas in Wotho atoll, red represents areas designated for subsistence fishing only, green areas show where commercial fishing would be allowed, purple represents the traditionally managed area, and yellow represents the proposed protected area.

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