Building capacity for sustainable fisheries management through science and tradition: Micronesian Outer Islands
Our Supporters
Summary
This section summarizes the deliverables, products and outreach efforts of this project, and provides links to the many reports and products we have developed.

Deliverables
- We surveyed 72 sites across 9 atolls in the Federated States of Micronesia (Yap State). These sites were surveyed for fish and benthic community structure
- We analyzed over 400 samples from 7 atolls for identification and connectivity assessments (genetic tools)
- We have collaboratively developed 2 fishery databases: Ulithi Atoll (approx. 85,000 fish), and outer islands (approximately 12,000 fish)
- 58 local fishery scientists/data collectors from 6 atolls/islands have been trained and are collecting data for the above-mentioned databases
- We have helped develop management plans for 5 outer islands/atolls and 4 Ulithi Atoll islands

Workshops
- Outer Islands fisheries management workshop (2014) REPORT
- Yap outer islands reef management workshop (2015) REPORT
- Hawaii cultural exchange workshop-200 participants (2016)
- Yap Outer Islands Teacher workshop (Yap) 2014, 2015, 2016
- Human Dimensions of Large Scale Marine Protected Areas (Big Ocean 2016) HI
- Hawaii Conservation Congress panel workshop (2018)
- 2 youth workshops (2017-2018)
- Outer Island Fishery workshops (9) 2017-2018

Public/Academic seminars
- Café Scientifique Palo Alto (2)
- California Academy of Sciences (2)
- WISE (UC Santa Cruz)
- Seymour Center Long Marine Lab (2)
- NOAA regional Seminars (2)
- University of Hawaii (Coconut Island)
- OIA/Dept. Of Interior
- Moss Landing Marine Labs
- California State University Monterey Bay
- Oceans Film fest (SF)
- Explorers club (2)(SF/NYC)
- Palo Alto out-reach event
- Cabrillo College, CA (3)
- KSCO radio
• Bodega Bay UC Davis
• The Brando (Tetiaroa, French Polynesia)
• 2015 invited seminar, Northern Arizona University “Applying coral reef ecology and fisheries science: a collaboration with remote Pacific island communities in Yap State, Micronesia”

Symposia/conferences
• Western Society of Naturalists (3) (2014, 2015, 2016)
• George Wright Society Management conference (Oakland) (2015)
• International Coral Reef Symposium - 3 talks (HI) (2016)
• Hawaii Conservation Conference (2) (HI) (2016, 2018)
• AAAS citizen science (2017)
• International Marine Conservation Conference (2018) (Kuching)
• University of Reunion Island, Coral Reefs Conference (2018)
• 2015 American Fisheries Society (Portland, OR) “Applying traditional management practices informed by modern science”

Media and other reports
• Website: onepeopleonereef.org
• Twitter, Instagram, Facebook
• Short Film, Jessica Hamel “The Reef”
• Documentary, Kelsey Doyle “Hofagie Laamle”
• TEDx Talk, Nicole Crane “Sustainable Ocean Management, Back to the Future in Micronesia”
• Post Typhoon Maysak Assessment REPORT
• Outer Islands Trip Summary 2017 REPORT
• Outer Islands Trip Summary 2018 REPORT
• Managing Reefs For a Sustainable Future: Findings and Feedback (Best Practices) from One People One Reef, Yap Neighboring Islands REPORT
• Coral Reef Ecology Handbook for the Micronesian Outer Islands: Booklet
• Fisheries monitoring handbook LINK
• Guide to commonly caught Ulithian fish with pictures and reference to common and scientific names LINK

Peer reviewed papers/publications


**Education and Youth Programs**

- **Bluecology youth program** (24 US youth, 30 Yapese (Outer Island) youth) partnership with Bluecology.org. Coral reef research and sustainable management, and cultural exchange
- Ulithi Falalop Community Action Program (Woleai and Yap): 60 Yapese (Outer Island) youth. Coral reef research and sustainable management
- Cabrillo College Research program class 25 US undergraduate students **New Class Developed Bio 450. Genetic barcoding and phylogenetic analysis, connectivity of samples from Ulithi Atoll**
- University of California/Cabrillo College joint undergraduate class (14 US Undergraduate students). Genetic barcoding and phylogenetic analysis, connectivity of samples from Ulithi Atoll
# Table of Contents

This report documents the results of this 3-year award (2 year with an extension). Section I outlines the methods and results from benthic and fishery independent fish surveys at sites throughout the outer islands. Section II provides results from interviews and meetings with community members, and section III will address each goal stated in the proposal.

**Background**

3

**I. Benthic and Fishery Independent Surveys**

4

A. Methods

4

B. Sites for benthic and fish surveys:

5

C. Results from benthic surveys

7

i. Montipora sp. on Ulithi Atoll

7

ii. Corals of the Outer Islands from Satawal to Sorol

14

D. Results from Fish surveys

17

i. Biomass for Ulithi sites

17

**II. Results from interviews, focus groups and community meetings**

21

Major themes around community and cultural changes

22

Major themes around marine resource management

23

Specific Concerns of youth

24

**III. Results by stated goal**

25

**Goal 1:** Survey fish assemblages associated with reef habitats from 10-50 m depth using fishery-independent tools

25

BRUV results

26

Results of Scuba surveys to compare deep and shallow sites:

28

**Goal 2:** Strengthen local and regional capacity to manage marine resources through improved resource monitoring.

29

Matching between Ulithian names and scientific species names

29

Fisheries of Ulithi Atoll, Yap (FSM)

30

Biosampling (genetic monitoring)

36

Fish

36

Population genetics of Sea Cucumbers

39

Population genetics of *Montipora* Corals

Seafood consumption patterns

51

**Goal 3** Partner with local leaders and managers to co-create an adaptive management plan framework for the entire Atoll and associated islands and **Goal 5 (goal 4 follows):** Expand the program to additional outer island communities in Yap State, FSM to develop program reach and benefits (Goal 4 follows).
Goal 4: Build knowledge capacity and long-term community involvement through education and outreach

   i. Results from interviews, focus groups and community meetings
      (Ulithi Atoll): see Section II
   ii. Youth exchange program.

IV. Conclusion
Background

Managing and conserving oceans in regions where people rely directly on the reefs for their livelihoods must start with an understanding of the problems, and of the cultural, historical and ecological context of environmental and resource change. With the support and direction of the local communities, and at their invitation, we are implementing a unique approach to advance adaptive marine management and conservation in Micronesian outer islands. We work with communities to help them develop and implement needed changes by sharing the ecological knowledge we acquire from the reefs, and by listening to what they have to say about their reef resources, the history of declines, and traditional management practices. This is an approach to empower communities to lead in the sustainable management of their reef ecosystems.

We used a knowledge-based approach to facilitate adaptive management planning – flexible plans the people can alter as needed based on knowledge of the system and familiar traditional frameworks. This approach relies on a two-way exchange of knowledge to develop management plans with the best chance for success. The science team gathers information and knowledge from the community about what the main issues are, what approaches have been tried, what works and what does not, what the major barriers are, and importantly what local people see as some of the key ecological changes on their reefs over time. This information is gathered by conducting interviews and community meetings with as many different demographics as possible including leaders, men, women, elderly people, youth, fishers etc. In exchange, the science team conducts thorough surveys of the reefs to assess the ecological state, and some of the patterns that may shed light on the problems at hand. This knowledge is shared with the community to help them make informed decisions.

Our approach involves a combination of social science and ecological assessments. Our premise is that the reef management plans themselves and the implementation of the plans will come from the community, and our team of scientists will facilitate by providing scientific information and management advice where needed. We analyze the ecological data and inform fishers and leaders about key patterns we see that implicate overfishing or other human impacts such as eutrophication. We do not suggest a specific approach (such as an MPA) and we do not set benchmarks for the community to meet. Rather, we discuss these needs with the community leaders, and let them come up with the components for an effective management plan. An important aspect of our approach is to identify traditional methods and suggest incorporation of those where possible. MPAs in fact are an ancient method of marine resource management, and when presented as a traditional method, we have found communities embracing them as one of several strategies to enhance the reefs and associated resources.
The One People One Reef collaborative adaptive management model:

I. Benthic and Fishery Independent Surveys

A. Methods

Benthic characterization
Benthic community structure was evaluated using 0.25 m² quadrats placed randomly on the reef crest area at each site between 1.5–5 m depth. Twenty quadrats per site each year was the modal level of effort (sample sizes for all years and all sites are provided in S1 Table). Quadrat locations were selected by using a random number generator to set the distance between quadrats and direction of swim within the reef crest corridor. Percent cover of key organisms was determined within each quadrat (counts were used for larger mobile invertebrates and giant clams). Each quadrat was documented photographically. A total of 10 functional group categories were used to assess benthic cover: stony coral, octocorals, hydrocorals, macroalgae, algal turfs, encrusting algae, cyanobacteria, bare substrate and non-coral sessile and mobile invertebrates. Stony corals and hydrocorals were categorized into one of 12 morphological groups and identified to genus when possible (S2 Table). Instances of disease, paling, and bleaching within each quadrat were noted. Stony coral colony sizes were measured by recording maximum length, width, height, nearest live coral neighbor and coral functional group for each coral that intercepted a 50 m transect line (the same transect as used for the fish counts).

Fish community characterization
All fish were counted along 50 m transects, in the same habitat and area (1.5–5 m depth) as the quadrats, and were identified to the species level. The transect count area was along a 50 meter
long transect, and extended from the sea floor to the surface of the water column. We conducted two to three transects each year at each site. For all transects, the same diver first counted mobile fish on a 5 m wide swath, before returning along the same transect and counting cryptic benthic fishes on a 1 m wide swath. The total lengths of mobile fishes were estimated to the nearest decimeter, and nearest centimeter for cryptic benthic fishes. For analysis of fish community structure, fish species were classified into one of five trophic guilds: 1. herbivores, 2. planktivores, 3. corallivores, 4. carnivores, and 5. piscivores (S3 Table lists all of the species observed on the transects and the trophic category in which they were placed). Species that have a wider trophic range (omnivores) were categorized by their main food preference according to the 5 categories mentioned above. Biomass was estimated using the published length/weight relationships most appropriate for the region. Sharks and large rays were occasionally seen on transects, but their overall low abundance makes band transects a poor approach to estimate their actual numbers and bias their contribution to biomass. Therefore, elasmobranchs were recorded, but not included in our biomass calculations.

B. Sites for benthic and fish surveys:

Sites on Ulithi Atoll:

Sites in the Outer Islands from Satawal westward to Woleai atoll:
C. Results from benthic surveys
These results will focus on the *Montipora* coral. For a more complete analysis of benthic and fish community structure across Ulithi Atoll see Crane et. Al 2017.

i. *Montipora* sp. on Ulithi Atoll

Reef surveys of Ulithi Atoll 2012-2014 reveal spatial variation in benthic composition of reefs, with some reefs having a high cover of what appears to be an outbreak species of coral (Fig 1). We genetically identified this coral to genus, but the *Montipora* species that is overtaking several reef areas on Ulithi Atoll has not yet been identified to species. We will refer to it here as *Montipora spO*. The sites where Montipora sp0 was abundant were all lagoonal sites near villages, and most of them were areas that were used as boat landings. There were only 2 lagoonal unpopulated sites where Montipora sp0 was observed, and it was at a much lower cover than the populated sites (less than 10% compared to over 30% at village sites). We saw no Montipora sp0 on any of the unpopulated oceanic-facing sites.

Figure 1. Benthic composition at all sites in Ulithi Atoll 2012-2014.

*Montipora spO* appears to outcompete other stony coral species (Fig. 2). Reefs with very high covers of *Montipora* sp0 have very low cover of other stony corals and reefs with high cover and diversity (Fig. 2) of stony corals have low abundance of *Montipora* sp0.

Figure 2. Percent cover of *Montipora* sp0 relative to other live stony corals on Ulithi Atoll.
While we cannot yet determine definitively whether *Montipora* sp0 is a cause or an effect of the low cover of other stony corals, the observation evidence suggests that a) is more abundant on reefs susceptible to disturbance (ie, boat landings) and b) it is outcompeting other corals. We can clearly see many instances of *Montipora* sp0 growing over and killing other corals (Fig. 4). When *Montipora* is removed from the surface of the other coral, dying and newly dead tissue is visible.

Figure 4. Close-up photo showing *Montipora* sp0 overgrowing *Porites lobata*. 
Ulithians are concerned about the overgrowth of *Montipora* sp0 because they observe that reefs that have been overtaken by this coral have lower fish abundance. Our data shows a trend in some groups of fishes, particularly corallivores and piscivores, who have lower biomass on reefs that have higher cover of *Montipora* sp0 (Fig. 5). These groups of fishes have an increasing trend of biomass on reefs where coral cover is higher (Fig. 6).

Figure 5. Cover of *Montipora* sp0 relative to fish biomass by trophic group.
Figure 6. Percent cover of all other live stony corals (with the exception of *Montipora* sp0) relative to fish biomass by trophic group.

*Montipora*

We began surveys of Ulithi Atoll in June 2012 and continued surveys annually until 2016, and again in 2018. In the first two years we saw an increase in *Montipora* sp0 at most sites in which it was present (Fig. 7).

Figure 7. Change in percent cover of sp0 at sites along Ulithi Atoll from 2013 to 2014.

In April 2015, Super-typhoon Maysak made a direct hit to Ulithi Atoll (Fig. 8)

Figure 8. Weather map showing Super Typhoon Maysak over Ulithi Atoll.
We visited Ulithi Atoll two months after the storm and surveyed the reefs. *Montipora* sp0 is a fast-growing coral that grows as sheets, plates, and grows upright into foliose and small columnar structures. It is brittle and easily broken. We observed the shallow reefs to be heavily scoured by wave action and *Montipora* sp0 to have experienced a decline in cover at all sites, in some areas being almost completely scoured off (Fig. 8).

Figure 9. Change in cover of *Montipora* sp0 from June 2014 to June 2015 (2 months after Super Typhoon Maysak).
We continued to monitor reefs in 2016 and observed some recovery of *Montipora* sp0 (Fig. 10). The timeline of average cover indicates general atoll-wide stability in cover (although as seen in Fig 6, there is site-wise variation with many experiences increases). There is a decline in *Montipora* sp0 following Typhoon Maysak in 2015, and a slight recovery in 2016. Unfortunately, due to circumstances outside our control, we were unable to survey Ulithi in 2017. We were able to visit briefly in 2018 and do a rapid assessment using photo quadrats which are still being analyzed.

Figure 10. Average cover of *Montipora* sp0 among Ulithi Atoll sites for each year.

This trend differs for other stony corals, which seem to have fared relatively well after the Super Typhoon (Fig 11). We observed some breakage of branching Pocillopora colonies, but the bases of those corals were often intact, so overall cover at most sites remained steady post-typhoon. One site on the north side of Ulithi Atoll, Lamor, experienced full-reef bleaching after the storm, with total mortality of corals.

Figure 11. Annual average percent cover of other stony corals at Ulithi Atoll sites.

In 2017, a grid was set up on one site at Ulithi Atoll (Falalop Men’s House) to examine the spatial and temporal dynamics of *Monitipora* sp0. We observed a concentration of *Montipora*
sp0 in front of the Men’s House, and low cover to the south (toward Ulithi Adventure Lodge) (Fig. 12).

Figure 12. *Montipora* sp0 at Falalop Men’s House to UAR sites June 2017 (red dots) and 2018 (green dots). Dots are sized with larger dots being higher percent cover.

It is clear that *Montipora* sp0 is a coral species that is acting differently from other coral species on Ulithi Atoll. It is fast-growing, capable of overtaking other species, and appears to negatively impact not just the other stony corals, but also the abundance of fishes and invertebrates. We are continuing to track this coral and investigate causative factors, such as temperature variation, dispersal capability, and human impact.

In 2017 we surveyed 33 sites on the Outer Islands of Yap. We found *Montipora* sp0 at one site, a shallow lagoonal area on Woleai. This site differs from the Ulithi sites in that it is bordered by
seagrass. We observed *Montipora* sp0 to be in low abundance and in isolated colonies. Local residents were trained in 2018 and are now tracking this site regularly.

ii. Corals of the Outer Islands from Satawal to Sorol

**Yap Outer Islands Benthic Summary**

In 2017, 33 sites were conducted across Yap State, with shallow (2-4m) and deep (12-15 m) sub-sites when possible. In 2018, five additional shallow sites were surveyed.

<table>
<thead>
<tr>
<th></th>
<th># sites shallow</th>
<th># sites deep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pisarach</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Satawal</td>
<td>4+2 (2018)</td>
<td>5</td>
</tr>
<tr>
<td>Lamotrek</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Elato</td>
<td>4+2 (2018)</td>
<td>3</td>
</tr>
<tr>
<td>Ifalik</td>
<td>6+1( 2018)</td>
<td>2</td>
</tr>
<tr>
<td>Woleai</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Eaurapik</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sorol</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Total #</strong></td>
<td><strong>35</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

There was a general trend of decreasing live stony coral cover from east to west (Fig 1).

Figure 1. Total live stony coral cover at all Yap Outer Island sites surveyed in 2017 & 2018. Note that sites are arranged in an east to west order.
At all sites, the total amount of algae (macroalgae, turf, and encrusting algae) exceeded the total coral cover (Fig 2), ranging from 2-45 times more algae than coral (average 7.5x more algae). There was no trend with depth or with longitudinal spread. Three sites at each of 3 different atolls had very high cover of algae (ranging from 78-96% cover). Sorol lagoon had the highest coral cover.

Figure 2. Ratio of total algae (macroalgae, turf, and encrusting algae) to coral for all 2017 and 2018 Yap Outer Island sites.

Cluster analysis of all of the outer island sites surveyed in 2017 shows that sites overall have high similarity in coral morphotype composition, with a few sites showing particularly high coral cover, and on the other end of the spectrum, very high algal cover (Fig. 3).
Analyses are still in the initial stages, but a look at how these sites compare to Ulithi Atoll sites using cluster analysis based on coral morphology shows that Ulithi and the Outer Island sites group almost completely separately from each other (Fig. 4 – note that all of the sites on the left cluster are Ulithi sites, with only 2 outer island sites, from Satawal, clustering with them).
D. Results from Fish surveys

Fish Biomass is presented for all Ulithi sites (section i) that had sampling continuously from 2013 through 2018 (with the exception of 2017 when we were unable to sample Ulithi but sampled the other outer islands. Following section i, section ii presents data from the other outer islands beyond Ulithi. We break out herbivorous fish due to their preference in the fishery for human consumption. For more analysis on fish community structure, see Crane et. al 2017.

i. Biomass for Ulithi sites

In the following figures, ULAR (Falalop island), MGMG (Mog Mog), FMHO1 (also Falalop), and ASOW1 (Asor Island) are inhabited islands while LOOS1 (Loosiep Island) GEIL1 (Geilob Island) and BULB1 (Bulbul Island) are uninhabited. An important event to note when interpreting these results is Typhoon Maysak which occurred in 2015 just prior to our sampling season.

Figure 1 shows that the biomass is highest at two of the three uninhabited sites, and the third (BULB) is overall higher than the inhabited sites though not as clearly so. The same trend can be seen in the herbivorous fish (Fig 2). We focused on the herbivorous fish guild since herbivorous fish make up a large percentage of the catch and is a favored food fish by many people.
We looked more closely at the inhabited islands (Mog Mog, Asor, Falalop and Federai) to try and identify trends in biomass over the years, possibly indicating effects of management. Falalop Island was the first to implement management in the form of a marine protected area (late 2012). They were followed by Mog Mog and Asor (late 2013), and lastly by Federai (late 2014). Fig 3 shows the total biomass changes over the years, and in all cases the effects of management (primarily areas closed to most fishing around the inhabited islands) are evident in an increased biomass. Fig 4 shows herbivores only, for Falalop. Figure 5 is of herbivore biomass on the
inhabited islands. Figures 6 and 7 show biomass for surgeonfishes and parrotfishes. Surgeonfish and parrotfish are both caught mostly with spears, which is a method used for a large percentage of the fish catch (see section III goal 2). The effect of Typhoon Maysak (2015) seems evident, in particular for Falalop. The reefs are customarily opened for fishing after an event such as a typhoon. Although this did not appear to have an immediate effect, the resulting increase of people (especially on Falalop) from the many AID agencies and rebuilding efforts might have had an impact. Spearfishing appears to have increased, and the additional pressure might has resulted in the decrease in biomass of all fish (seen in figures 3-7). The rebuilding was finally completed in 2018. The population on Falalop, and the population of visitors in particular, reached a peak in 2017-2018.
II. Results from interviews, focus groups and community meetings

The feedback here is from approximately 60 individual interviews, 10 focus groups (approximately 90 people total), and community meetings with approximately 250 people from 4 islands (Ulithi). We have conducted additional interviews on the outer islands beyond Ulithi and many of the themes are similar.

Open ended questions were used, and careful listening of community dialog. Analysis was by grounded theory (finding themes within the recorded comments and coding all themes). All focus groups and meetings (where there were multiple people involved) were conducted with a goal of consensus building for information recording.

Overall, from Ulithi and the neighboring islands, there were common concerns around:

- Loss of resource abundance (eg. Fish)
- Reef Health/degradation concerns
- Lack (loss) of management
- Loss of traditional management
- Disconnect with the youth
- Breakdown in leadership
- Desire to improve the situation
- Strong interest in combining traditional and western science

Over the period of this work an additional concern that has been raised in plastic pollution and garbage (especially plastic) disposal.

The following data were collected from people representing 14 outer islands of Yap, including Ulithi Atoll. It shows how the people rank major areas of concern or areas needing improvement/addressing.

Fig. 1: community feedback regarding issues of major concern:
Major themes around community and cultural changes

**Cultural changes from more modern practices.** There is a concern that some of the changes brought on after World War 2, and especially since the war claims money came in the mid 1970’s, have had negative effects on community cohesion, health, and diet, and marine resource management. These include the introduction of motor boats and freezers. Both of these have changed the way fishing is conducted. Motor boats allow for fishing even in poor weather and facilitate access to sites that used to be accessible only occasionally. It also allows for repeated access to some sites, resulting in overfishing there. Importantly, as fuel became more expensive, motor boats would only be used to go to closer sites (near inhabited islands), resulting in overfishing there. Compounded with stressors such as human and livestock nutrient pollution and physical disturbance, this has led to habitat degradation. Our benthic and fish transect data corroborate this. Newer fishing gear has also changed fishing, resulting in fewer types of fishing used and catching a less diverse community of fishes. Freezers too affect the way fish are caught and distributed. Rather than only catching what can be eaten at a given time, freezers led to storage which led to catching more than needed at a given time. This meant that not as many needed to be distributed (since families with freezers could keep more fish), resulting in a breakdown of traditional sharing and distribution frameworks. Funds from war claims, government jobs and other sources created similar inequities, which redistributed the power structure. People with money became decision makers in addition to traditional Chiefs.

**Introduction of Chemicals and new products.** There is a concern (especially among women) about the use of some products and what it might do to their limited water (especially to the water in the ground used for growing crops, and used for bathing etc. In particular they wanted to know about the use of cleaning products which government health officials encourage (such as
Clorox and chemical cleaning agents). Shampoos, soaps and detergents were also of concern. Other products include food products which are causing serious health and diet problems. White rice, spam and canned meats and sugar are among the products people mentioned. Heart disease and diabetes were major health problems (and cancer).

**The loss and lack of traditional knowledge.** People are concerned that traditions and knowledge about culture, management, canoe building, navigation etc. are being lost, and that this knowledge is important to their survival. They feel a disconnect with the youth, yet an understanding that informing the youth is key. There was a general concern that the western education system is contributing to that. Many felt that more traditional knowledge and cultural practices ought to be taught in the schools. Some of the school lessons use valuable time but do not fit with their community needs and empowering the youth to contribute and preserve communities and culture. Another factor mentioned that is likely contributing to the erosion of cultural integrity and knowledge is Christianity. Christian influence can interfere with community needs/traditional practices. As quoted by one member: “The Bible says to not worry about tomorrow, and that's hurt us”.

Collectively these changes and influences are resulting in a degradation of marine resources and the knowledge and leadership structures to manage them well. There was a general concern that resources suffer when leadership and community cohesion weaken. People talked of cheating on rules for fishing (not historically common), people talking behind each others’ backs, a general lack of respect for Chiefs and leaders, and Chiefs not exercising their leadership and authority. There was broad consensus that there was a lack of education/public awareness about marine management, its importance, and the role of traditional knowledge in preserving both the resources and the knowledge to manage them.

**Major themes around marine resource management**

The people of the Yap outer islands expressed a desire to learn more about the resources they manage, and to work with western scientists to integrate new knowledge into their existing traditional systems. In particular they wanted to know more about the life histories of the fish they catch, the impacts of the more modern fishing (such as spear guns and nets), and the role aquaculture could play. They were also very interested in the impacts of export fisheries such as reef fish and sea cucumbers. They were very thankful in general for the support that our One People One Reef team offered, and our method of working closely with them and integrating them into data collection, rather than dictating management schemes. There was a general skepticism of western ‘projects’, which often come and go without long-term support, and there was specific skepticism towards conservation projects and the establishment of prescribed Marine Protected Areas. This seems particularly important to recognize, as outer islanders have been managing their resources for a very long time and have the legal and legislative autonomy to make their own decisions. This was a common theme expressed by people.

They are aware of shared problems with marine resources across the region, as well as common successes. They want to address the issues and recognize that current management is not always successful (since One People One Reef has been working with outer island
communities they have been addressing these and have been seeing successes – they also recognize this). On Ulithi, there is a recognition that the turtle project has been a success, including increasing people’s awareness of the importance of that resource and the need to manage it. Some of the solutions people mentioned included new management, better dissemination of information about management, reefs, and fish, using alternative technologies such as FADs, limiting community fishing to special occasions, and setting up moorings for all boats to limit benthic destruction. They agreed that sharing successes in management (such as has been seen on Falalop and some other islands) is important. They express a desire to work together as an island chain to improve marine resource management and food security. They agreed that area closures, gear restrictions, species bans and by permission only fishing as part of renewed traditional management is working well, and in addition to enhancing the resource is also working to strengthen leadership. They would like the science teams (OPOR) to help provide the data to help them justify management.

One man from Satawal said, “Seems like little to no attempt by the government to do anything about changes in the fish population, coral, etc. As a kid I saw lots of very colorful corals, now it’s all brown.” - Wants to learn what’s happening and what can we do to save the island for future generations.

Specific Concerns of youth
Based on individual interviews with 12 boys and 8 girls aged 13-25.

Girls
The girls have more household responsibility than the men in their families. Once the men got back from fishing, the women were essentially in charge of all the meal prep – from cleaning the fish to cooking the meals. They felt the Men’s houses are too exclusive. There was a consensus that girls often do better in school and so they know more, yet they have less say in the fishing area closures and other decisions. Girls and women should be trusted more in decision making.

The youth, regardless of gender, should have more of an opinion in the affairs of the elders. They thought that the women should have more say in affairs outside the household, while men should have a bigger share of family responsibility. They thought that the current “top-down and male dominated” system limits both youth and girls from becoming active members of the community. They want to preserve the historical traditions but change the culture that limits the voices of the younger generations that are “more aware of current events and technology.”
From one girl: “I want to update those old customs that limit women and clothing options. They aren’t fair to everyone.”

Boys
Although some youth want to leave for the US for higher education, they do want to return to their home island and become leaders in their own community. They feel the elders don’t give them enough credit. Although they understand that the elders criticize them for lacking responsibility, they consider it an unfair assumption. Some specific points:
• While they enjoy fishing, it becomes a chore if it is forced upon them as a “right of passage” task given to them by the adults. The youth want to learn more about the old traditions but also expand their horizons with Western ideas and culture.
• The elders want them to stay in and sit and learn through only talking but that isn’t interactive enough – they want hands-on learning WITH the elders.
• They think the elders are threatened by the Western customs and thus don’t want them to experience both and blend them together.
• The youth want the elders to be more receptive of what they learn in school.
• They know that other islands don’t allow the youth to talk or teach the elders.
• They currently teach close family about Western customs.
• They want to bring that idea to the other islands to build a dialogue.
• They don’t think it’s a good tradition that the youth don’t have a voice on some islands.
• They want there to be a more even balance between traditional customs and Western ideas.
• They don’t think the old customs are as progressive as they need to be to compete with the modern world.
• They want to preserve the old traditions while still moving forward.
• When they are adults they want to teach their kids a mix of old and new to survive in the modern world but not lose their values.
• They don’t like the slowness of the traditional fishing
  ○ Like the speed of spear fishing – able to feed the population fast.
  ○ But they want to limit the amount and size of the fish taken by spear fishing to maintain a stable management.

Quotes

“Everyone should have equal access to all the fish caught, nothing just for the chiefs.”

“I think the chiefs should talk to each other more on other islands so the traditions are more even for everyone.”

“Old traditions that don’t help everyone should be improved into new, better ones that include everyone.”

III. Results by stated goal

**Goal 1:** Survey fish assemblages associated with reef habitats from 10-50 m depth using fishery-independent tools (i.e., BRUVS—Baited Remote Underwater Video Stations)

BRUV results
Our goal was to compare deep and shallow fish species assemblages and biomass to better understand fishing pressure, and fish community structure. Although we developed and tested Baited Remote Underwater Video Systems (BRUVS) at multiple sites, ultimately the method was not successful, and the desired analysis was achieved using standard underwater visual
surveys on scuba. The rationale for using BRUVs was that scuba facilities were not available in these remote islands, and we hoped that BRUVs would provide an efficient, low cost alternative to count and size fish. We were successful in developing a modified design for the BRUVs (details below), and deployed them at 12 sites (Table 1). However, we learned that there is a local tabu against using oily fish bait inside of the lagoon and at prime fishing sites generally. The use of high oil content fish as bait facilitates attraction via olfactory senses and is standard practice in BRUV deployments world-wide. We wished, however, to be sensitive to local traditional practices and tabus, and deployed BRUVs using reduced quantities of reef fish (comparatively much less oily). The bait used was not effective at attracting fishes, our trials comparing baited and unbaited stations indicated no discernable difference over relatively short time periods (<30 minutes), and we attribute poor results from the BRUVs to this.

The BRUVS were designed and tested with the assistance of Dr. Steve Moore and his students (California State University Monterey Bay), initially

Figure 1: BRUV design.

in 2015, and refined extensively in July, 2016. The goal of this project was to develop and implement a simple, low-cost, portable undersea camera system that could be operated at depths between 1.5 and 40 meters. The design was intended to be potentially useful anywhere an inexpensive tool would aid in surveying and, particularly, monitoring coral reef fish populations. The design has potential to provide useful data, but needs to be tested with adequate bait—1+ kg of oily fish.

The BRUVS design is a monopole with an arm to hold a mesh bait bag in front of a GoPro video camera (fig 1). The single camera does not allow for photogrammetry to measure fish captured in the video, but does allow for species identification and for comparative measures of abundance. The BRUVS are held upright by a float at the top and rebar ballast inserted into the PVC pipe frame at the bottom. The BRUVS are lowered from the surface and tethered to a surface float for subsequent retrieval (line and surface float not shown in the figure). They are positioned by a swimmer at the surface; the compass direction in which the camera points is largely determined by the direction of the prevailing current. This usually results in the camera “looking” downstream.

We placed BRUVS (see table below for locations) in depths ranging from about 2-23 meters (depth estimated by the amount of line paid out) and sought locations on the reef where the field of view for the camera included an unobstructed perspective of open water beyond the bait bag. Deeper sites were not used because depths greater than ca. 25 meters were generally on very
steep slopes where deployment and retrieval would be difficult or at depths well beyond the maximum allowed by our technology (40 meters). We sought locations with a broadly unobstructed perspective so as to identify fishes in the vicinity that were not definitively responding to the presence of the BRUVS or were wary of approaching the gear closely. Deployment duration was a minimum of 10 minutes (mean = 14:11), based on published species saturation curves and preliminary data of our own.

Table 1. BRUV deployments in 2016.

<table>
<thead>
<tr>
<th>site</th>
<th>code</th>
<th>GPS (N, E)</th>
<th>date (2016)</th>
<th>depth (m)</th>
<th>n</th>
<th>notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asor Protected</td>
<td>ASOP1</td>
<td>10 1.452, 139 45.515</td>
<td>June 28</td>
<td>16-28</td>
<td>3</td>
<td>high tide, ebbing; bait: <em>dilhoul</em> &amp; <em>padi</em> (atherinid &amp; carangid)</td>
</tr>
<tr>
<td></td>
<td>ASOP2</td>
<td>10 1.530, 139 45.428</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASOP3</td>
<td>10 1.665, 139 45.394</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asor Landing</td>
<td>ASOR1</td>
<td>10 1.842, 139 45.618</td>
<td>June 28</td>
<td>20</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASOR2</td>
<td>10 1.881, 139 45.596</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASOR3</td>
<td>10 1.943, 139 45.575</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federai South</td>
<td>FEDS1</td>
<td>9 53.723, 139 39.510</td>
<td>June 29</td>
<td>10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FEDS2</td>
<td>9 53.750, 139 39.478</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FEDS3</td>
<td>9 53.687, 139 39.541</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federai Landing</td>
<td>FEDE1</td>
<td>9 54.221, 139 39.283</td>
<td>June 29</td>
<td>8-10</td>
<td>4</td>
<td>along edge of reef—deeper was sand, only</td>
</tr>
<tr>
<td></td>
<td>FEDE2</td>
<td>9 54.258, 139 39.269</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FEDE3</td>
<td>9 54.320, 139 39.258</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federai North</td>
<td>FEDN1</td>
<td>9 54.600, 139 39.389</td>
<td>June 29</td>
<td>10-12</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FEDN2</td>
<td>9 54.564, 139 39.397</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FEDN3</td>
<td>9 54.611, 139 39.381</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Falalop, UAR2</td>
<td>UAR21</td>
<td>vicinity of 10 0.759, 139 47.279</td>
<td>June 30</td>
<td>28 &amp; 1.5</td>
<td>2+2</td>
<td>shallow and deep deployments</td>
</tr>
<tr>
<td></td>
<td>UAR22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>UAR23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mogmog Landing</td>
<td>MOGC1</td>
<td>10 5.096, 139 42.487</td>
<td>July 1</td>
<td>8-10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MOGC2</td>
<td>10 5.080, 139 42.462</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MOGC3</td>
<td>10 5.077, 139 42.422</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghloi</td>
<td>SOHL1</td>
<td>10 4.616, 139 44.114</td>
<td>July 1</td>
<td>10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SOHL2</td>
<td>10 4.547, 139 44.155</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SOHL3</td>
<td>10 4.499, 139 44.182</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maas Outside</td>
<td>MASO1</td>
<td>10 0.581, 139 43.460</td>
<td>July 1</td>
<td>12-15</td>
<td>2</td>
<td>on edge of slope/drop-off; lost bait from MASO2</td>
</tr>
<tr>
<td></td>
<td>MASO2</td>
<td>10 0.505, 139 43.460</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAAS3</td>
<td>10 0.545, 139 43.439</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yealil Outside</td>
<td>YEAL1</td>
<td>9 51.334, 139 37.357</td>
<td>July 2</td>
<td>13-15</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>YEAL2</td>
<td>9 51.322, 139 37.400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>YEAL3</td>
<td>9 51.311, 139 37.439</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilegei</td>
<td>PIGL1</td>
<td>9 59.311, 139 37.159</td>
<td>July 2</td>
<td>3-6</td>
<td>3</td>
<td>deep channels in reef</td>
</tr>
<tr>
<td></td>
<td>PIGL2</td>
<td>9 59.284, 139 37.166</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PIGL3</td>
<td>9 59.248, 139 37.177</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Songh</td>
<td>SONG1</td>
<td>10 0.201, 139 36.803</td>
<td>July 2</td>
<td>18-23</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SONG2</td>
<td>10 0.241, 139 36.768</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SONG3</td>
<td>10 0.246, 139 36.747</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The sites for BRUVS placement were selected to correspond to shallow water visual surveys conducted previously in June of 2016, and to paired fished and unfished sites. Persistent local power outages limited our ability to recharge camera batteries and, therefore, the number of BRUVS deployments during this field season.
Meta-data from all deployments were compiled, including placement depth, bait consumed, video duration, time of day, and field of view (categories). Nearly 30 species are readily identified from the BRUVS video, but species accumulation curves for each deployment and comparisons between shallow-set BRUVS and our visual transects showed that the BRUVS were extremely limited in their potential analyzing differences between sites. Ultimately, scuba facilities were available to us in the outer islands, and, as mentioned above, we resorted to scuba surveys.

Results of Scuba surveys to compare deep and shallow sites:
Our goal was to evaluate potential differences in fish biomass between deep and shallow sites, and, ultimately, to distinguish between the effects of environment (i.e., depth) and the effects of fishing. We have not completed these analyses yet, but have the data to do so. The methods were identical for both shallow and deep to allow for comparison (see above section on methods). We conducted paired scuba surveys (fish and benthic transects) at 17 deep and shallow sites throughout the outer islands, as well as several additional shallow surveys. Deep surveys were at 15 meters, and shallow surveys were at 1-5 meters. This section will focus on the results of the (fishery independent) fish surveys at these two depths.

Deep and shallow sites across a broad geographic range (approximately 600 kilometers west to east, show that all deep sites had higher biomass than their shallow counterparts (Figure 2), without accounting for fishing pressure. These results support our use of visual surveys by free diving (i.e., Ulithi Atoll), where and when scuba is not available. These shallow water surveys do not present a complete picture of total biomass for fishery independent surveys (since the comparisons over years on Ulithi are from shallow sites) and there are emerging differences in species composition, but these results demonstrate our trends are representative.

Fig. 2: Comparison of total fish biomass at 16 sites throughout the outer islands
**Goal 2:** Strengthen local and regional capacity to manage marine resources through improved resource monitoring.

Fishery landings database and matching between Ulithian names and scientific species names.

We developed a collaboration with 8 local fishery scientists from Ulithi Atoll. They were trained to collect landings data and have collected data for approximately 80,000 fish from Ulithi. Over the course of this project we trained an addition 50 local scientists from 6 additional islands/atolls to the east of Ulithi Atoll. They are currently expanding the data collection effort and have collected data from approximately 15,000 fish. This expansion of fishery landings data will be invaluable as we continue to expand this work and assist communities in the outer islands.

Mario Dohmai, one of the local scientists, has created a list of local names matched to common and scientific names, and a pictorial guide to naming (see links to these products in the first section under ‘Media and other reports’). He has spent the past two years refining the naming and creating a key for the database.

The large fishery database has been quality controlled, modified, and tested for analysis with the help of Donna Miller. This database is available to view upon request.

*Fisheries of Ulithi Atoll, Yap (FSM)*
Data on fisheries landings in Ulithi began in June of 2012, but a concerted effort including all four island communities based on training workshops conducted by One People One Reef, began in June of 2014. OPOR has returned to Ulithi each summer with the exception of 2017. These tables and figure provide a summary of data collected by each community between June 2014 and December 2017. Note that the data collection is on-going. The entire database contains records for approximately 85,000 fish.

Table 1. Catch and effort by community.

<table>
<thead>
<tr>
<th>Community</th>
<th># of trips surveyed</th>
<th>Total # fish recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asor</td>
<td>609</td>
<td>17,390</td>
</tr>
<tr>
<td>Falalop</td>
<td>134</td>
<td>2,719</td>
</tr>
<tr>
<td>Federai</td>
<td>129</td>
<td>8,892</td>
</tr>
<tr>
<td>Mogmog</td>
<td>229</td>
<td>20,586</td>
</tr>
<tr>
<td>other</td>
<td>36</td>
<td>3,061</td>
</tr>
<tr>
<td>Totals</td>
<td>1,137</td>
<td>52,648</td>
</tr>
</tbody>
</table>

Table 2. Catch and effort by year.

<table>
<thead>
<tr>
<th>Year</th>
<th># of trips surveyed</th>
<th>Total # fish recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>83</td>
<td>8,410</td>
</tr>
<tr>
<td>2015</td>
<td>498</td>
<td>25,695</td>
</tr>
<tr>
<td>2016</td>
<td>402</td>
<td>12,493</td>
</tr>
<tr>
<td>2017</td>
<td>154</td>
<td>6,050</td>
</tr>
<tr>
<td>Totals</td>
<td>1,137</td>
<td>52,648</td>
</tr>
</tbody>
</table>

Each island has jurisdiction over different areas within Ulithi Atoll, and each has created unique management plans as explained in section III under Goal 3. Fishing pressure and commonly fished sites vary by season and year, but Figure 1 below shows some of the main sites (the larger red circles) between 2014 and 2018. We are lacking data in this map for lagoonal sites and sites to the south west. Nevertheless it shows that reef crest sites (generally not in the lee of an island) and sites in the northern reefs are important fishing areas.

Fig 1. Map of sites where the most fish were caught by number of fishing trips

The types and diversity of fishing gear used are important, as each gear type targets different groups of fish/invertebrates in different ways. OPOR has found that several traditional fishing gear are no longer or rarely used on many islands. Some islands are working on reviving traditional fishing practices, such as traps, and reducing, removing or regulating use of new, high impact gear such as spear guns and gill nets.

The relative importance of different gear types is shown in Figure 2, below.
Figure 2a. Landings by gear category. The category ‘multiple’ refers to fishing trips where multiple gear types were used (e.g., hook & line and spear).

Figure 2b. Hook & Line and Cast Net are used to target a comparatively limited range of species; Speargun is used for broad variety of fishes, mostly herbivorous fish. (data through 2017; figure from Crane et al. 2017).

Fig 3. Comparison of hook and line vrs. Spear gun for islands of Ulithi
Spearfishing is the most favored method to catch fish on Ulithi Atoll, and the majority of fishes caught with this method are herbivorous fish. Interestingly, although it ranks as highest for effort for three of the four islands (Fig 4a-d), it is generally not the gear with the highest CPUE (Table 2), which falls to nets and hook and line. This could mean that the fish that are targeted with spearguns are favored and are not as available using the other techniques. It could also mean that spear guns are more readily available, and/or that hook and line fishing is restricted by season. This will be an important area of focus for the future. Critical to this information will also be better life history information for the fish that are targeted, including size at maturity and reproductive cycles.

Data show that there are substantial differences in catch-per-unit-effort (CPUE) among gear types and among communities. Effort was recorded in hours using the ‘start time’ and ‘end time’ recorded for fishing trips; catch was measured by the total number of fishes landed, irrespective of size. Effort and catch differed across gear and community too, but, because different communities joined the fisheries monitoring program at different points in time, inconsistencies in data recording efforts, and logistical and cultural differences between communities, the number of hours or the number of fishes landed cannot be compared directly. The ratio of catch and effort, CPUE, however, can be compared:

<table>
<thead>
<tr>
<th>Asor</th>
<th>effort hrs</th>
<th>catch #</th>
<th>CPUE (#/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falalop</td>
<td>Spear or Speargun</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federai</td>
<td>Spear or Speargun</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mogmog</td>
<td>Spear or Speargun</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2:
<table>
<thead>
<tr>
<th>Method</th>
<th>Total Effort Hrs</th>
<th>Catch #</th>
<th>CPUE (#/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Net</td>
<td>55</td>
<td>2178</td>
<td>39.6</td>
</tr>
<tr>
<td>Gillnet or Block Net</td>
<td>8</td>
<td>2436</td>
<td>304.5</td>
</tr>
<tr>
<td>Fishing Pole</td>
<td>6</td>
<td>87</td>
<td>14.5</td>
</tr>
<tr>
<td>Hook &amp; Line</td>
<td>22</td>
<td>553</td>
<td>25.1</td>
</tr>
<tr>
<td>Spear or Speargun</td>
<td>423</td>
<td>6880</td>
<td>16.3</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>178</td>
<td>17.8</td>
</tr>
<tr>
<td>combination</td>
<td>1</td>
<td>30</td>
<td>30.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Falalop</th>
<th>Catch #</th>
<th>CPUE (#/hr)</th>
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<tbody>
<tr>
<td>Cast Net</td>
<td>1</td>
<td>12</td>
<td>12.0</td>
</tr>
<tr>
<td>Gillnet or Block Net</td>
<td>4</td>
<td>482</td>
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<tr>
<td>Fishing Pole</td>
<td>57</td>
<td>495</td>
<td>8.7</td>
</tr>
<tr>
<td>Hook &amp; Line</td>
<td>9</td>
<td>488</td>
<td>54.2</td>
</tr>
<tr>
<td>Spear or Speargun</td>
<td>43</td>
<td>664</td>
<td>15.4</td>
</tr>
<tr>
<td>Other</td>
<td>combination</td>
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</table>

<table>
<thead>
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<th>Method</th>
<th>Federai</th>
<th>Catch #</th>
<th>CPUE (#/hr)</th>
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</thead>
<tbody>
<tr>
<td>Cast Net</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Gillnet or Block Net</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Fishing Pole</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Hook &amp; Line</td>
<td>22</td>
<td>2504</td>
<td>113.8</td>
</tr>
<tr>
<td>Spear or Speargun</td>
<td>68</td>
<td>2847</td>
<td>41.9</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>441</td>
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<td>combination</td>
<td>1</td>
<td>52</td>
<td>52.0</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Mogmog</th>
<th>Catch #</th>
<th>CPUE (#/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Net</td>
<td>4</td>
<td>210</td>
<td>52.5</td>
</tr>
<tr>
<td>Gillnet or Block Net</td>
<td>4</td>
<td>241</td>
<td>60.3</td>
</tr>
<tr>
<td>Fishing Pole</td>
<td>1</td>
<td>11</td>
<td>11.0</td>
</tr>
<tr>
<td>Hook &amp; Line</td>
<td>9</td>
<td>403</td>
<td>44.8</td>
</tr>
<tr>
<td>Spear or Speargun</td>
<td>112</td>
<td>3134</td>
<td>28.0</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>6</td>
<td>6.0</td>
</tr>
<tr>
<td>combination</td>
<td>1</td>
<td>30</td>
<td>30.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>CPUE (#/hr)</th>
<th>Hook &amp; Line</th>
<th>Spear or Speargun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asor</td>
<td>25.1</td>
<td>16.3</td>
<td></td>
</tr>
<tr>
<td>Falalop</td>
<td>54.2</td>
<td>15.4</td>
<td></td>
</tr>
<tr>
<td>Federai</td>
<td>113.8</td>
<td>41.9</td>
<td></td>
</tr>
<tr>
<td>Mogmog</td>
<td>44.8</td>
<td>28.0</td>
<td></td>
</tr>
</tbody>
</table>
We suspect that community-level differences in CPUE are primarily related to each community’s access to reefs with varying levels of productivity, but there are also differences in the relative effort each community ascribes to particular gear types:

Fig 4 a

Asor: Effort by gear type (hrs)

- Cast Net
- Gillnet or Block Net
- Fishing Pole
- Hook & Line
- Spear or Speargun
- Other
- combination

Fig 4 b

Falalop: Effort by gear type (hrs)

- Cast Net
- Gillnet or Block Net
- Fishing Pole
- Hook & Line
- Spear or Speargun
- Other
- combination

Fig 4 c
Additional detailed analyses are currently being prepared. For example, reef fish, particularly emperors, surgeon, parrot and unicorn fishes comprise the majority of the landings, although monthly totals are highly variable (Figure 5). This variability is likely a reflection of the reporting, rather than inconsistent fishing effort.

Figure 5. Monthly landings; reef species only.
Our fisheries landing data also include length information. Efforts to screen these data for consistency in collection methods are still underway. Our expectation is that these will, at a minimum, provide a longitudinal record of maximum size, which will be informative for monitoring the effects of management efforts. We also expect that a substantial portion of the data will allow for an estimation of mean size and variance, which we plan to compare to published estimations for size at sexual maturity. The latter results will be particularly important for management.

**Biosampling (genetic monitoring) of fishery landings for connectivity assessments – collection by fishermen of fin-clips and other genetic samples**

**General background**
The genetic portion of our project dealt with two aspects of the biology of Ulithi and outer islands organisms. The first aspect includes species identifications and fisheries, the second aspect deals with genetic connectivity between reefs.

**Species identifications and fisheries**

This portion of the project involved collaboration with local science teams from Ulithi and the Yap outer islands, the One People One Reef science team and a classes at Cabrillo college and University of California Santa Cruz that included 48 students, Teaching Assistants, graduate students and faculty.

Samples were collected in Ulithi and the outer islands (FSM) by local people as well as local and US students. These samples included fish, sea cucumbers and corals. A total of over 300 samples were collected and analyzed.

DNA was extracted and PCR amplified resulting in approximately 240 samples. This represented 20 species of fish, 90 sea cucumbers and 10 corals.

PCR amplifications were then DNA sequenced (Sanger sequenced), sequences were cleaned and analyzed using different bioinformatics tools including phylogenetic, phylogeographic and population genetic analyses.

General results: We obtained 106 different DNA sequences, 8 of coral, 12 of fish, 86 of sea cucumbers. These included 3 new species of fish. We performed population genetic analysis of the sea cucumbers of the Yap outer islands and looked at genetics of *Montipora* corals.

**Population genetics of Sea Cucumbers**

Sea cucumbers play an important role in filtering sediments and recycling nutrients back into the food web. In addition to their ecological value, cucumbers are also the focus of artisanal or commercial fishing efforts. It is of great value to understand the demographics and genetic characteristics of sea cucumber populations, and see how individuals of different islands are related. If each island has populations that are unique genetically, then these populations are
more sensitive to fishing, and management needs to be locally focused. On the other hand, if cucumber populations from the outer islands are related, it means that the populations are larger in scale and management could be more regional in scope.

*Holothuria atra* is one of the most common and widest ranging sea cucumbers in the world. This sea cucumber is not harvested in the Yap outer islands, but in other parts of the world it is utilized, mainly in artisanal fisheries (additionally, people eat them in Chuuk –personal communication). We examined population genetic structure based on the mitochondrial COI gene. This marker, commonly used as a barcoding gene, in some cases, can be used to detect population level differences in organisms. It has been used for *H. atra* around the Pacific, but the Micronesian islands had never been sampled. Our project, therefore, fills that gap (in addition to providing valuable connectivity information at this regional level).

**Results**

We sequenced 378 bp of the COI gene, of 85 *H. atra* individuals from 13 locations of seven Yap outer islands (Fig. 1). We calculated nucleotide and haplotype diversity (Table 1), and generated haplotype networks to assess genetic similarity among locations (Fig. 2). In addition, we compared our results to other *H. atra* sequences available in Genbank, using haplotype networks (Fig. 3). We found that haplotypes are widely shared among the Yap islands, and in the rest of the Pacific Ocean, suggesting that strong barriers to gene flow may be absent. Our results, however, rely on a marker that provides a coarse assessment of population structure. We recommend using additional genetic markers to obtain higher resolution.

**Figure 1.** Map of the seven Yap Outer Islands where sea cucumbers were collected. FAL= Falalop, Ulithi atoll. FED= Federai, Ulithi atoll. EUP= Euripik. WLI= Wooleai. IFA= Ifaluk. ELA= Elato. SAT= Satawal. Sampling sites within FAL island were UAR and UARM; within EUP were EUP1 and EUP2; within WLI were WLI1 and WLI2; within IFA were IFA1 and IFA2; within SAT were SAT1, SAT2 and SAT3. In FED and ELA there was only one site.
Figure 2. Haplotype network of *Holothuria atra* of the Yap outer islands

![Haplotype network of *Holothuria atra* of the Yap outer islands](image)

Figure 3. Haplotype network of *Holothuria atra* of the Yap outer islands compared with COI sequences of other *Holothuria atra* found in Genbank

![Haplotype network of *Holothuria atra* of the Yap outer islands compared with COI sequences of other *Holothuria atra* found in Genbank](image)

Table 1. Haplotype and nucleotide diversity of sea cucumbers found in Yap Outer Islands.
Population genetics of Montipora Corals

On Ulithi atoll there is a species of coral that we previously identified as belonging to the genus *Montipora*, that is taking over some reefs, overgrowing other corals. The *Montipora* corals found on Ulithi seem to belong to a single species. During 2017, we had the opportunity to visit several Yap outer islands, and a similar-looking *Montipora* was found in Woleai and Satawal islands. We collected samples from these colonies and compared genetically using the COI mitochondrial gene.

**Results**

As seen in Fig. 1, an early study by OPOR shows that the *Montipora* of Ulithi atoll (samples in red) groups as a unique species. Comparisons with newly obtained COI data show that the *Montipora* collected in Woleai is genetically identical (with the exception of one sample) to the one from Ulithi, and that the Satawal *Montipora* samples differ by 1 base pair. We recommend using additional genetic markers to further compare genetic structure.
In order to positively identify fish that were caught by local fishermen, as well as to definitively associate scientific names with local names, we started a collection of samples directly from local catches and used cytochrome oxidase 1 (CO1, a barcoding molecular marker) DNA sequences.

Overall, local scientists and ourselves collected over 300 fish fin clips. DNA from these fin clips was then extracted, PCR amplified and sequenced. Newly obtained sequences were compared to Genbank and in some cases analyzed using phylogenetic approaches, when clear cut identifications were found to be problematic. In addition, we also collected fish samples from nests on the island of Yealil, where booby birds nest and leave or reject freshly caught fish by the parents.

Below is a table that describes the fish identified by our students, and a few examples of phylogenetic trees resulting from the analyses. We are currently building a database of all the species of fish that are commonly caught in Ulithi and the Yap outer islands. This approach has
been, thus far, very successful in both teaching students molecular biology skills, as well as providing invaluable information regarding the fisheries of Ulithi and the Yap outer islands.

Table 1. List of Ulithian fish identified to date by the students involved in the research class.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Semester found</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convict surgeonfish</td>
<td><em>Acanthurus triostegus</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Lined surgeonfish</td>
<td><em>Acanthurus lineatus</em></td>
<td>Spring 17, Fall 17</td>
<td></td>
</tr>
<tr>
<td>Black jack</td>
<td><em>Caranx lugubris</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Bigeye trevally</td>
<td><em>Caranx sexfasciatus</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Fringelip mullet</td>
<td><em>Crenimugil crenilabis</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Blue sea chub</td>
<td><em>Kyphosus cinerascens</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Spotcheek emperor</td>
<td><em>Lethrinus rubrioperculatus</em></td>
<td>Spring 17, Fall 17</td>
<td></td>
</tr>
<tr>
<td>Yellow-edged lyretail</td>
<td><em>Variola louti</em></td>
<td>Spring 17, Spring 18</td>
<td>Phylogenetic tree revealed a cryptic species in French Polynesia</td>
</tr>
<tr>
<td>White-edged lyretail</td>
<td><em>Variola albimarginata</em></td>
<td>Spring 17, Spring 18</td>
<td></td>
</tr>
<tr>
<td>Blue striped snapper</td>
<td><em>Lutjanus kasmira</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Humpback red snapper</td>
<td><em>Lutjanus gibbus</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Blotcheye soldierfish</td>
<td><em>Myripristis berndti</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Ringtail maori wrasse</td>
<td><em>Oxycheilinus unifasciatus</em></td>
<td>Spring 17</td>
<td></td>
</tr>
<tr>
<td>Yellowfin tuna</td>
<td><em>Thunnus albacares</em></td>
<td>Spring 17, Fall 17</td>
<td></td>
</tr>
<tr>
<td>Blacksaddled coralgrouper</td>
<td><em>Plectropomus laevis</em></td>
<td>Spring 17, Fall 17</td>
<td></td>
</tr>
<tr>
<td>Flowery flounder</td>
<td><em>Bothus mancus</em></td>
<td>Fall 17</td>
<td></td>
</tr>
<tr>
<td>Dogtooth tuna</td>
<td><em>Gymnosarda unicolor</em></td>
<td>Fall 17</td>
<td></td>
</tr>
<tr>
<td>Brassy chub</td>
<td><em>Kyphosus vaigiensis</em></td>
<td>Fall 17</td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Genus and Species</td>
<td>Date</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------</td>
<td>----------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Dash-and-dot goatfish</td>
<td><em>Parupeneus barberinus</em></td>
<td>Fall 17</td>
<td>Phylogenetic tree revealed that it may be a cryptic species</td>
</tr>
<tr>
<td>Goldspotted spinefoot</td>
<td><em>Siganus punctatus</em></td>
<td>Fall 17</td>
<td></td>
</tr>
<tr>
<td>Brown-spotted spinefoot</td>
<td><em>Siganus stellatus</em></td>
<td>Fall 17</td>
<td></td>
</tr>
<tr>
<td>Andhra anchovy</td>
<td><em>Stolephorus andhraensis</em></td>
<td>Fall 17</td>
<td>Closest fish match, not enough data in genbank. To be investigated (extract DNA again, repeat PCR, use additional marker, ask Ulithi to take specimen samples of anchovies)</td>
</tr>
<tr>
<td>Skipjack tuna</td>
<td><em>Katsuwonus pelamis</em></td>
<td>Fall 17</td>
<td>Found on <em>Sula leucogaster</em> (booby) nest, Yeali, June 2017. Juveniles. To be investigated if it has been reported as <em>Sula</em> catch in the literature</td>
</tr>
<tr>
<td>Spinycheek lanternfish</td>
<td><em>Benthosema fibulatum</em></td>
<td>Fall 17</td>
<td>Found at night in Falalop, June 2017. Might be a different species or distinct population. Additional specimens will be required</td>
</tr>
<tr>
<td>Abe’s flyingfish</td>
<td><em>Cheilopogon abei</em></td>
<td>Fall 17</td>
<td>Found on <em>Sula leucogaster</em> (booby) nest, Yealil, June 2017</td>
</tr>
<tr>
<td>Rainbow Runner</td>
<td><em>Elagatis bipinnulata</em></td>
<td>Spring 18</td>
<td></td>
</tr>
<tr>
<td>Blue and gold fusilier</td>
<td><em>Caesio caerulaurea</em></td>
<td>Spring 18</td>
<td></td>
</tr>
<tr>
<td>Whitemargin unicornfish</td>
<td><em>Naso annulatus</em></td>
<td>Spring 18</td>
<td></td>
</tr>
</tbody>
</table>
**Fish trees:** Ulithian fishes

Figure 3. Neighbor Joining tree for *Caesio caerulaurea* (4.13) found in Ulithi, compared with other COI sequences of *Caesio sp* found in Genbank.
Fig 4. Neighbor Joining tree for Variola found in Ulithi, compared with other COI sequences of Variola sp? found in Genbank.
Fig 5. Neighbor Joining tree for *Naso annulatus* (4.12) found in Ulithi, compared with other COI sequences of *Naso annulatus* found in Genbank.
Fig 6. Neighbor Joining tree for *Cheilopogon sp* (5.59) found in Ulithi, compared with other COI sequences of *Cheilopogon sp* found in Genbank.
Fig 7. Neighbor Joining tree for *Elagatis bipinnulata* (5.51) found in Ulithi, compared with other COI sequences of *Elagatis bipinnulata* found in Genbank.

**Genetic connectivity**

For this portion of our project, we focused on two groups of marine organisms: for fish we decided to work on clownfishes, and for corals we focused on the weedy species of *Montipora*.

Since genetic connectivity requires fine-scale genetic analyses, we chose to use RAD sequencing, which is a method that analyzes at once thousands of genomic markers.
Clownfishes
We mostly worked with *Amphiprion chrysopterus*, the orange-finned anemonefish, but also obtained some sequences from *A. clarkii*, *A. melanopus*, and *A. perideraion*. In Ulithi and the outer islands, anemonefishes tend not to be very abundant.

Our goal was to determine if any individuals were found to be related, either as parent/offspring, or as siblings or half siblings. This would allow us to understand the potential ecological connections between reefs.

We found that pairs of sibs or half-sib individuals were found on the east side and on the west side of the atoll of Ulithi, with relationships going north to south. For example, we found two pairs of full sibs in Federai and Falalaop (a connection north-south on the east side of the atoll), and pairs of full and half sibs between Yealil and MogMog (a connection north-south on the west side of the atoll). Thus far, we have not found connections between the east and the west, although further sampling will be necessary to fully uncover the general picture of connectivity in Ulithi.

At the scale of the outer islands, we found that islands east of Sorol were more connected to each other than any of them were connected to the west of Sorol (Yap and Ulithi). The large ocean gap at Sorol might give a plausible explanation for the lowered gene flow levels between these two regions.

Montipora coral
RAD sequences were obtained for populations of *Montipora* around the Ulithi Atoll, as well as in smaller plots at the islands of Asor and Federai. The latter experiment was specifically designed to see if Typhoon Maysak played a role in breaking coral branches, spreading them far from the parent colony, that could potentially reattach and thus effectively disperse.

Our results show that *Montipora* is not a clone (a single genetic entity that would spread by human activity for example). Below is a figure of a structure plot of *Montipora* individuals. In this plot, each column represents an individual and its genetic makeup. If these individuals were all identical, a single color would be present. The fact that each individual looks different is consistent with sexual reproduction as opposed to asexual dispersal.

![Figure 1: structure plot of *Montipora* individuals from Ulithi, based on RAD sequences.](image-url)
As mentioned above, we sampled fragments of *Montipora* that were presumably produced by Typhoon Maysak, to determine if the typhoon might play a role in asexual dispersal of the coral (sampling occurred a few weeks after the Typhoon). These samples were sequenced and relatedness assignments were performed to determine if fragments were genetically related to each other or to attached colonies.

The figure below shows a grid, on the seafloor, where we searched for fragments. Numbers indicate spots where fragments were collected and their genotypes. Colors indicate genotypes that were found more than once. As shown, several fragments were found to be genetically identical, indicating that fragmentation may have resulted from Maysak’s passage. Furthermore, one line in our grid was only focused on large colonies (potential parents). The orange genotype, for example, shows one parent and four fragments that are genetically identical, possibly indicating that typhoon Maysak broke off fragments from that parental colony and spread the fragments on the seafloor.

Further analysis will allow us to determine the extent of the spread and the success of such fragments.
Seafood consumption patterns
Through community meetings and interviews, we introduced the concept and anticipated outcomes of a seafood consumption calendar to all four communities. We hoped to have a minimum of 8 households participating on the island of Falalop, 4 from Asor, 4 from Mog Mog and 4 from Federai (for a total of 20 households), but ultimately had 53 Ulithi households participate in 2015 (13 from Asor, 15 from Falalop, 3 from Federai, and 22 from Mogmog). For 2017, we received 46 completed calendars from three islands (Ifalik, Satawal, Elato). Three other islands received calendars during the summer of 2017, but have not yet returned them to us for analysis.

We provided blank calendars to individual households for tracking the source location, type (reef, open water, etc.) and quantity of seafood consumed by each participating island family. These were intended as an indirect means for monitoring fishing activity and as a point of comparison for the landings data collected. Also, these seafood consumption calendars offer a chance to educate the community about their fishing traditions as well as their nutritional health.

A portion of one these 11 x 17” calendars is reproduced here:

Each calendar represented the seafood consumed by a single household for 4 weeks (28 days). Households ranged in size from 1 to 16; the median household size was 6. The calendars represent the seafood consumption for one month during summer (2015) for 343 people. The data from the calendars have been digitized, and we present some analyses.
<table>
<thead>
<tr>
<th>Atoll</th>
<th>Community</th>
<th>Households</th>
<th># of persons</th>
<th>median</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulithi</td>
<td>Asor</td>
<td>12</td>
<td>83</td>
<td>6.5</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Ulithi</td>
<td>Falalop</td>
<td>15</td>
<td>119</td>
<td>7</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Ulithi</td>
<td>Federai</td>
<td>3</td>
<td>24</td>
<td>10</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Ulithi</td>
<td>Mogmog</td>
<td>22</td>
<td>117</td>
<td>5</td>
<td>1</td>
<td>12</td>
</tr>
</tbody>
</table>

The Ulithi communities differed in their level of dependency on seafood. Frequency of seafood consumed at each meal—partitioned between reef fish, blue fish (i.e., pelagics), or canned fish (imported)—varied amongst them as shown below:
Generally, we interpret a high percentage of meals with seafood as indicative of a high dependency on marine resources. This is complicated by the differing levels of access to imported foods, including canned fish. On Ulithi Atoll, Falalop is the sole island with an airstrip, where flights between the island and Yap take off and land at least twice per week. The other Ulithi communities can access these goods, but this requires a boat ride (duration ranges from 10 to 60 minutes, or more depending on ocean conditions).

The frequency of consumption for ‘blue fish’ (pelagic species, generally caught by trolling in open water, sometimes in the vicinity of a FAD) is partially dependent on the availability of gas for outboard motors, an expensive commodity that reaches the atoll via ship, an occurrence that is both infrequent and difficult to predict. Therefore, frequent consumption of this source of seafood is generally indicative of wealth and access.

Canned seafood (and canned meats generally) are prized, but access requires cash at least at some point in the transactional process as well as opportunity. Another factor that seems to affect the consumption of canned seafood is the health and accessibility of natural marine resources. Meals on Asor included canned seafood 19% of the time. The frequencies for the other communities were: Falalop 13%, Federai 4%, and Mogmog 35%.
We received completed seafood consumption calendars (N=73) from the outer islands (4 islands, 8 communities) late this summer (2018), and representing 603 persons. These data have been digitized, but not yet analyzed.

<table>
<thead>
<tr>
<th>Atoll</th>
<th>Community</th>
<th>Households</th>
<th># of persons</th>
<th>median</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elato</td>
<td>Elato</td>
<td>9</td>
<td>83</td>
<td>7</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Ifalik</td>
<td>Ifelashig</td>
<td>6</td>
<td>55</td>
<td>9</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Ifalik</td>
<td>Iyefang</td>
<td>5</td>
<td>39</td>
<td>8</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Ifalik</td>
<td>Iyeur</td>
<td>6</td>
<td>45</td>
<td>8</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Ifalik</td>
<td>Rawaii</td>
<td>6</td>
<td>50</td>
<td>8.5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Ifalik</td>
<td>(combined)</td>
<td>23</td>
<td>189</td>
<td>8</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Lamotrek</td>
<td>Lamotrek</td>
<td>4</td>
<td>32</td>
<td>8.5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Satawal</td>
<td>Satawal</td>
<td>14</td>
<td>110</td>
<td>7</td>
<td>4</td>
<td>13</td>
</tr>
</tbody>
</table>

Across these islands generally, households reported fishing activity on 771 days out of a total of 1407 reporting days. Most activity was focused on reef fishing (618 days or 44% of their effort). Open water fishing accounted for 8%, fishing arounds FADs for <1%, and combined efforts (e.g., reef fishing plus open water fishing) for about 2% of their effort. More than 45% of their meals (out of 3 x 1408 total days reporting) included reef fish.

**Goal 3**: Partner with local leaders and managers to co-create an adaptive management plan framework for the entire Atoll and associated islands. And,

**Goal 5**: Expand the program to additional outer island communities in Yap State, FSM to develop program reach and benefits.

**Note that throughout this report we have presented data from both Ulithi and additional outer islands**

Management Planning in the Yap outer islands (Ulithi Atoll)

**History**

Based on our understanding of the region, as well as discussions with Fisheries managers, community members and leaders on the Outer Islands of Yap state, there are concerns about declining catches, food insecurity, and health issues (with more reliance on imported foods). There are also concerns around pollution, erosion and reef degradation (see section II: Results from interviews, focus groups and community meetings). In particular, across Micronesia, there is evidence that there are startlingly high numbers of herbivorous fish being caught. This may well have consequences to reefs (eg. Not enough fish to remove excess algae). Our work has focused on Ulithi Atoll, but we have also expanded to the other neighboring islands to learn more about regional trends.
Management Seascape

Marine resource management in these outer islands is culturally imbedded and includes practices that are sometimes antithetical to what western managers might consider ‘effective’. Most management can be classified as ‘partial protection’, though this may also include temporary total fishing bans. The Yap State constitution allows for autonomous governance by each community, allowing them to plan and execute management decisions per their own needs. The management frameworks can be complex and difficult to understand (from a western perspective). Each Island on Ulithi Atoll has a management jurisdiction. Often, an uninhabited island and its reefs are ‘owned’ and managed by different inhabited islands. For example an Island might be owned by Mog Mog, but Federai has jurisdiction over the reefs. Certain reefs may be owned and managed by specific families, and in some cases, the back reef, reef crest and fore-reef are owned and managed by different families. These linkages to ownership and management rights often go back many generations. A reef owner may decide to enact a management plan for any reason, but generally in consultation with the community if the area is particularly important as a resource generator. Traditionally, reef closures were put in place due to: a death, dwindling resources, traditional rotations or any reason the owner decides upon. Some reefs are only open for ‘community fishing’ – an event such as a celebration or important community event (wedding, graduation, funeral), others are only open for certain types of fishing (banning others), and still others are ‘open’ areas to all, especially on the islands with high schools, allowing for access to fishing. This complexity also makes it difficult to assess the impacts of management since each area can be different, and a closure generally means closed for some, but not all, occasions.

It is precisely due to the complex and traditionally rooted nature of this management that our team avoids recommending specific management plans. We focus on collecting data from the reefs to assess health, and data from landed fish (collected by the community) to look at impact of fishing practices on specific fish or guilds of fish. We gather community input to learn about concerns, and we encourage a return to and enforcement of traditional practices. In some instances, we have seen high use of an area lead to low fish biomass, and we share that information, suggesting that strengthened management on those reefs may help. The first island to enact management changes as a result of this work was Falalop Island on Ulithi Atoll, and they reported (and our data support) seeing an increase in biomass of herbivorous fish (and all fish) on some of the managed reefs, and they report seeing fish they have not seen in over 40 years. In addition, the community fishing in these ‘closed’ reefs yielded enough fish for the community event in just a couple of hours, compared with fishing before the management, where the reef would often have to be fished for up to 8 hours to provide enough fish for the event. However, we noticed a decrease in biomass for all fish following an influx of visitors and outside resources to Falalop for the rebuilding efforts post Typhoon Maysak (section I D).

Actions

One People One Reef has been working closely with communities to better understand the nature of the problems on reefs, provide information to the communities about their reefs, and work with them to understand the specific impacts of their fishing on certain guilds of fish.

Ulithi Atoll: All four islands of Ulithi Atoll are collecting data from landed fish. This database currently has over 90,000 fish in it (see analysis in section III Goal 2).
55% of the reefs of the inhabited islands of Asor, Falalop, Mog Mog and Federai are now under revised and/or new management as partial, near total and/or rotational closures. Other uninhabited but fished reefs have also received additional protection since this project began. Overall, Ulithi atoll has approximately 471 square kilometers of fishing area including reef and lagoon area and associated atolls (Turtle islands). Approximately 466 square kilometers of this area is under management today. That is 99% of the fishable area. This management includes fishing by permission only. This has resulted in enhanced communication between islands about management, sharing of plans, and the emergence of an Atoll-wide management framework. As seen in the graphs in section ID, fish biomass has increased at all managed sites since the beginning of this project.

Each of the inhabited islands within Ulithi Atoll has implemented their own management, per their customary system. Falalop has closed one area of the island to all fishing except: community fishing, and fishing from shore (primarily women). The other section of the island is closed to night spearfishing and no Gillnets or throw nets are allowed, but other types of fishing are permitted. Mog Mog has closed the section of most degraded reef in front of the island (south side) to any fishing except: community fishing, and fishing from shore. Gill nets have been banned, and take of parrotfish by spear at night has been banned. They have also implemented a traditional custom of notification of ‘first catch’ to signal the opening of lagoon fishing. Asor has implemented rotating closures on the south facing side of the island (two areas are rotated, and a third area has been closed to all but community fishing). Federai has implemented rotating closures on the west facing side of the main island, and has banned the take of bumphead parrotfish (Bolbometopon muricatum) and humphead wrasse (Cheilinus undulatus) on all reefs. All fishing in the Atoll is controlled under one of these 4 fishing jurisdictions (each main island controls a fishing jurisdiction). Thus, Ulithi is the first Atoll in Yap State to have a comprehensive, documented management plan that includes closures, gear restrictions and species restrictions. It is also the first Atoll to have implemented data collection of landed fish at all four main islands.

As of this time we can report (as the communities report), that we see the management bringing back some larger fish and more of them. See section ID for an analysis of Biomass. It appears that management has been effective but may have been negatively affected by the increase of visitors for the rebuilding effort post Typhoon Maysak (that effort peaked in 2017-2018 which is when fish biomass decreased the most on Falalop). The management on Ulithi has had several important positive outcomes: it brings more fish to eat, it keeps reefs healthy, healthy reefs protect islands, and management brings communities together and strengthens leadership. Management requires leaders to bring communities together around the management plan, and how to enforce it. It also helps younger people better understand the importance of management, and the traditions that have kept the reefs strong. Communities have told us that this work to improve management has required them to address leadership issues as well, and has necessitated the opening of dialog between islands, as well as with the COT (outer island Chief leadership council on Yap).

Fig 1 is a map of fishing jurisdictions of Ulithi Atoll (although these are fluid to a certain degree and this map may not depict them all accurately, it is an approximation).
Fig 1

Hand drawn management map of Ulithi Atoll (drawn by a community leader there):

Fig 2 A Hand drawn management map of Ulithi Atoll (drawn by a community leader there):
Additional outer islands participating in fisheries data collection and management planning:

We have worked with the islands/Atolls of: Namonuwito (Chuuk), Satawal, Lamotrek, Elato, Ifalik, Woleai, Eauripik, and Sorol (uninhabited).

We have received fisheries landings data from Elato, Lamotrek, Ifaluk, Satawal and Woleai totaling 15,653. All of these islands have established or revised protection and management, which now encompasses approximately 40% of the reefs on the islands/atolls. Two of these atolls have placed 53% and 66% of their reefs under management. This protection includes a combination of partial closure, species bans, gear bans, rotational closures and seasonal restrictions. These successes and advances in management are dramatic and noteworthy. They warrant continued monitoring to assess the efficacy of partial protection planning. Ulithi Atoll is the Atoll with the longest history of management in this project, and has shown significant positive effects from management.

We have been able to analyze fish biomass results over two summers at two locations in the outer islands beyond Ulithi, one on Satawal Island and one on Elato Atoll. Both of these locations were closed to fishing (partial protection) after our visit in 2017. Fig 3 shows an increase in Biomass at sites sampled in 2017 and 2018 for both of these locations. Community members, fishers and leaders told us they noticed an increase in fish and species they had not seen in several years – similar to what we experienced qualitatively while sampling, and corroborated by our data.

![Figure 3 - Fish Biomass - managed areas - 2017-2018](image)

Figures 4 and 5 are examples of management maps from one island (Fig 4) and one Atoll (Fig 5). We have obtained detailed management plans for Ulithi, Satawal, Lamotrek, Elato, Ifaluk, and Woleai. Each has provided maps like these, which details management over 1000 linear kilometers, or 66,000 square kilometers.

Fig 4
Goal 4: Build knowledge capacity and long-term community involvement through education and outreach, including the exchange of knowledge and experience with Hawaii Managers.
This goal involved extensive outreach and collaboration with the community, including the collection of information from interviews, focus groups and community meetings. Ewe also conducted a workshop with KUA organization in Hawaii in conjunction with the IUCN meetings in Hawaii. That workshop, involving over 200 participants (we were collaborators), was outlined in a previous report. Links to the monitoring and coral reef handbooks, and to the best practices document are provided in the first part of this report under “Media and other reports”. The distribution and explanation of the best practices document to 7 additional islands and atolls in the Yap outer islands represented a big part of the outreach effort. We met with teachers and principals at every island to discuss integration of the coral reef handbook and best practices documents into the curriculum. John Rulmal Jr. in collaboration with our teams conducted a pilot program with Woleai youth in the summer of 2018 in which over 40 youth and 4 teachers participated in data collection, data entry, discussions around management and fishery workshops.

Please see the list of deliverables in “Award summary deliverables, outreach and sampling effort” section under ‘Education and youth programs’.

i. Results from interviews, focus groups and community meetings (Ulithi Atoll): see Section II

ii. Youth exchange program.

We collaborated with Ulithi Falalop Commiunity Action Program (UFCAP) to organize 5 youth programs; 4 on Ulithi and one on Woleai atoll. US youth were paired with youth from the 4 inhabited islands of Ulithi for four consecutive summers involving a total of 29 US youth and 42 Ulithi youth. In 2018 we expanded the program to Woleai, where Ulithi youth were paired with youth from Woleai. Over 50 youth participated in this program in the summer of 2018. Youth participants learned to conduct reef surveys, bio-sampling, data entry and analysis, and prepared presentations for their peers on the importance of management, leadership and engagement. They were powerful and influential programs and we look forward to continuing and expanding them.

We also developed a class for undergraduate students at Cabrillo community college and university of California Santa Cruz. This class focused on analyzing the data collected from Ulithi and the outer islands. Students worked on Ulithi fish and corals mostly focusing on: DNA extraction, RAD sequencing, DNA barcoding, and bioinformatics. Forty-Eight community college, university and graduate students, have participated, and we developed 2 new research courses at Cabrillo College. 58% of the students involved to date are underrepresented (ethnically and/or socioeconomically – eg. First in family to go to college). This program has received funding from the Chancellors office as part of an enhanced non-credit option for students to receive a certificate in skill achievement.

IV. Conclusion

Our goals were to enhance capacity for reef resource management in the Yap outer islands through fishery independent data, fishery landings data and information exchange with
Importantly, we sought to share knowledge with communities to empower and inform them so they could be the leaders in planning and implementing management. This project has enabled the successful implementation of these goals, and the results presented here demonstrate that. It has helped develop a legacy of new management and enhanced knowledge that we believe will last into the future. The successes on Ulithi have spread and have sparked the interest and engagement of other outer islands. We have been able to document the early successes of that expansion and look forward to receiving future funding to support that important work. This work and these results are the outcome of close collaboration with outer island communities, who are responsible for these successes. They have embraced this work and have put many hours and much effort into ensuring its success.

We have collectively:

1. Gathered Baseline data on fishery practices, landings and catch distribution and improved the quality and quantity of fishery information from the region.
2. Produce a jointly-designed reef management plan for Ulithi Atoll, and several additional outer islands.
3. Gathered baseline data on the ecological state of the reefs of Ulithi Atoll to assess management and change over time.
4. Documented traditional practices, historical trends, and local knowledge of fishes and landings patterns.
5. Developed a field training plan for on-site monitoring, and trained over 50 local scientists.
6. Conducted several workshops to introduce key managers and community leaders from Yap State to traditional management approaches in Hawaii, and each other.
7. Strengthened local capacity regarding reefs, fishes and resource management.
8. Developed a framework for Ulithi Atoll for fisheries management and reef conservation: this is already a model for the FSM.
9. Expanded efforts to establish management plans for marine resource management agencies and organizations in the region.

This project has served as a model for community-based marine management at a remote site with a permanent population of resource users, and has filled a gap in knowledge about fisheries in the region – problems, local solutions, and data from the reefs and fish. It has provided a planning approach utilizing social science as well as scientific approaches that is being scaled up for similar communities in the region. This approach can serve as a blueprint for management, and as a method for implementing management in small outer island communities. It will not protect reefs from large-scale anthropogenic impacts, such as acidification and climate change. Rather, it is helping communities utilize resources sustainably in the face of rapid ecological and cultural changes. Ultimately, the goal is to provide improved access to healthy, local and sustainable sources of protein, and to collaboratively acquired knowledge to manage them. This work can serve as a model that can extend to other regions with a similar socio-political and ecological landscape.
“We need to have a common understanding around management, so that everyone agrees and supports it. Understanding the old ways, and the impacts of the new ways, can help us protect the ocean for our children, and their children.”
Chief Ike, Asor Island, Ulithi Atoll

“For it is true that the Ocean unites us and brings us together but the Reef sustains us in so many ways.” -Sabino Sauchomal, Yap CAP and Satawal Island

One People One Reef
Hofagie Laamle