SUBMITTAL DATE : March 25, 2010 –edit May 22, 2010

TO: NOAA

FROM: Ann Kitalong, Biologist
The Environment, Inc.
Tel: 680-587-3451 email: kitalong@palauent.com

RE: NA08NMF460452
Final Reporting Period 01/01/2008 to 03/31/10
Title: Community based management of the mangrove crab, *Scylla serrata* and the mangrove clam, *Anodontia edulenta* in Airai State, the Republic of Palau.

The Environment, Inc. in partnership with Ngarameliwei and Ngarabrekork has the following accomplishments to report in this final report:

- Over 40 field trips were conducted in Airai State
- Data was collected and analyzed for the water chemistry, soil plots, tree plots, tagged mangrove crabs and harvested mangrove clams.
- 12 Ngarameliwei members were training on building and setting crab traps, techniques to harvest, tag, release and recapture mangrove crabs. Ngarameliwei members learned how to set up mangrove forest plots identify species of trees and measure diameter and estimate heights. They also learned how to set soil plots to measure soil accretion and elevation. The women of Ngarabrekork exchanged knowledge about clam harvest and learned how to sample areas and measure and weight clams for a comparative study.
- Finding were presented at the annual Airai Women's Conference on February 26, 2009 including over 100 people including the Governor, Legislatures, chiefs and female counterparts and women clubs throughout Airai. The Presentation was televised and is regularly aired on the local network. The presentation was presented at the 15th Educational Conference in July 2009
- A simple management plan was developed based upon the findings and community discussions
- An oral Presentation was given at the 11th Pacific Science Inter-Congress held March 2-5, 2009. A publication was accepted for the 11th Pacific Science Inter-Congress and The US China Public Administration Journal in August 2009.

Administration and Financial Reporting

As of Dec 31, 2009, all Federal funds have been spent to implement this project.

Overview

The study sites were within mangrove conservation areas were chosen after the conservation areas were surveyed and boundaries delineated with the assistance of Airai State Conservation Officers and PALARIS. During the following months, crab traps were built with assistance from the crab fishermen and Ngarameliwei group. Forest plots were set within the inner middle and outer zones of these four conservation areas. The water quality and forest structure and number of crab fishers or crabbing effort varied between sites. Interviews with the crab fishermen in the field to determine the best locations to set traps and to document temporal harvest peaks and reproductive periods. This information was used to determine placement of traps and when possible optimal times to set and check traps.

The traps were usually set near the forest plots and within smaller channels that crabs normally are found as near as possible to the forest plots. The TEI team together with experienced crab fishermen and clam gleaners trained the younger members of the Ngarameliwei and Ngarabrekork team how to harvest crabs and clams. New methods and skills for tagging and releasing crabs and measuring sizes of crabs and clams were shared between the trained team and community members. The team learned together how to set up the soil plots and measure soil elevation and accretion.

Most of the equipment was purchased and sent within 6 months of the start of the project. The exception was the REDOX probe and the standards to calibrate it which didn't arrive until March 2009. Then the probe was not functioning properly during tests with the standards. Therefore we did not do REDOX measurements for this project as planned and refocused our efforts on water quality. During the Airai State women's meeting presentation of our results, the more questions and concerns were raised about the high level of bacteria in the water. The governor and the community requested more sampling of bacteria and further investigation of the source of this pollution. Therefore we refocused our effort to work with EQPB more closely on water quality. The supplies Permanent water monitoring sites are now established with EQPB as a result of this study.

During our field surveys of the conservation sites found only one clam at the study sites after 4 harvesting trip with the Ngarabrekork women. Based upon interviews and field work, it was found that the compactness of the soil and whether or not the soil was "worked" or not was what determined if an area was productive for clam harvests. The women did a timed search at all the

sites and while searching loosened the soil and inserted mangrove leaves into these areas. The team will revisit these sites to determine if more clams where found there after the reworking of the soil. The presence of crocodiles at three of the four study sites was considered to great a risk to continue the mangrove clam study. Women must go waist deep into the mud to harvest and crocodiles can move very quickly.

Trapping and tagging crabs was a success with much cooperation from the crab fishers. We underestimated the number of field trips and level of participation by crab fishermen to complete all the work required for this project. The fuel budget from federal funds has been exhausted. The results of this project were presented and an evolving power point presentation that we have now presented at the Annual Airai Women's Conference, the Pacific Science Inter-Congress and Presented July 23rd at the Annual Education Conference for the Republic of Palau. At each meeting we recorded comments. We were invited by Airai State to talk about water pollution during meeting with EQPB. Currently EPQB initiated an Integrated Watershed Management Program in the Ngerikiil Watershed that will continue monitoring water quality in the Ngerikiil Bay and other sites. A positive outcome is that EQPB has transferred set up two additional water quality monitoring stations in Airai Bay for regular monitoring as a result of this study. During the last quarter of this funding cycle, the team has focused on the development of a simple management plan and interviewed individuals about the plan. The plan incorporates new information obtained from this project on water quality, mangrove forests, and crab and clam harvests. In addition comments from the key stakeholders- the crab fishers were incorporated into the plan.

Habitat Mapping

During the first three months of this project the team worked with the Airai Conservation Officers and the Palau Automated Land and Resources Information System (PALARIS) to survey and maps the locations of the four conservation sites. Based upon this work a map was produced of the four sites (Figure 1).

Figure 1. The four main sites were Ngeruluobel (Site 1), Ngerusar (Site 2), Oikull (Site 3) and Ngchesechang (Site 4).

Coliform Bacteria and water chemistry

The results from bacteria analysis and water chemistry analysis (Table 1 and Figures 2-4) show that Ngeruluobel had the highest coliform counts and significantly higher mean turbidity and lower temperatures and pH than the other sites. There are homes and an auto repair shop adjacent to the inner mangrove. There is a water treatment plant upstream of Ngeruluobel Channel also suggesting more impacts. The Environment Inc and EQPB will be conducting more studies of the bacteria as part of an ongoing monitoring program. The mean dissolved oxygen concentration was lowest at Ngerusar which was a smaller channel with homes upstream but not immediately adjacent to the stream. The highest mean oxygen levels, and lowest mean salinity were measured at Ngchesechang suggesting more freshwater input.

Table 1. Summary of mean pH, turbidity, salinity, dissolved oxygen, temperature and coliform bacteria with standard error in parenthesis and sample size for each site

Site	1	2	3	4
pH	7.14 (0.06) 29	7.61 (0.06) 23	7.67 (0.05) 38	7.60 (0.05) 52
Turbidity (NTU)	25.8 (5.7) 39	10.5 (1.5) 33	9. 5(2.0) 38	13.0 (1.9) 52
Salinity (ppt)	18.5 (0.82) 117	25.2 (0.91) 65	18.6 (0.93) 106	13.8 (1.03) 82
Dissolved Oxygen (mg/l)	4.50 (0.19) 51	3.80 (0.22) 41	4.33 (0.14) 39	4.84 (0.14) 38
Temperature (^{0}C)	28.8 (0.23) 51	29.6 (0.28) 36	30.2 (0.28) 36	29.5 (0.33) 38
Coliform bacteria per 100ml	338 (102) 3	54 (38) 3	0 (n/a) 2	116 (75) 3

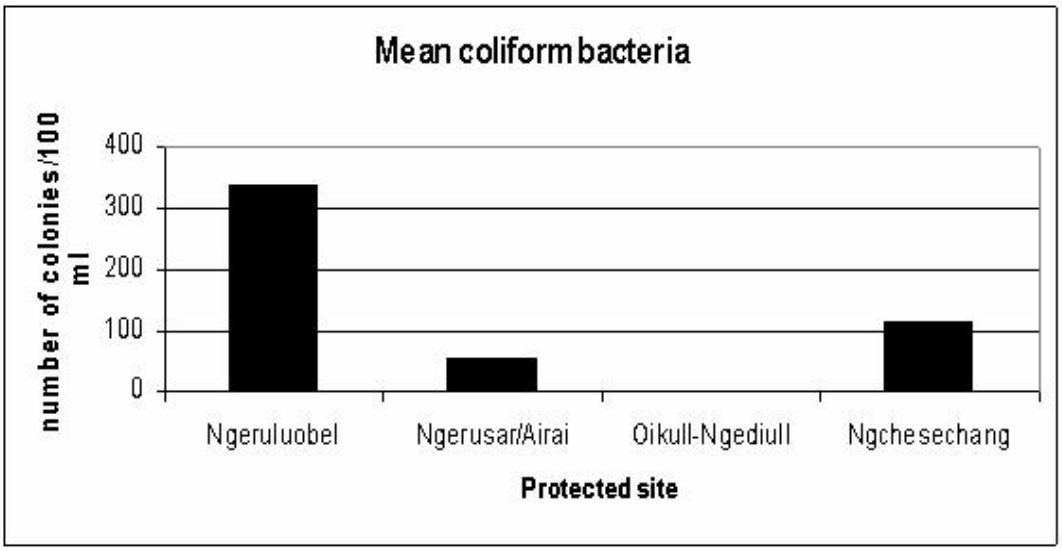


Figure 2. Mean Coliform Bacteria Counts per Site.

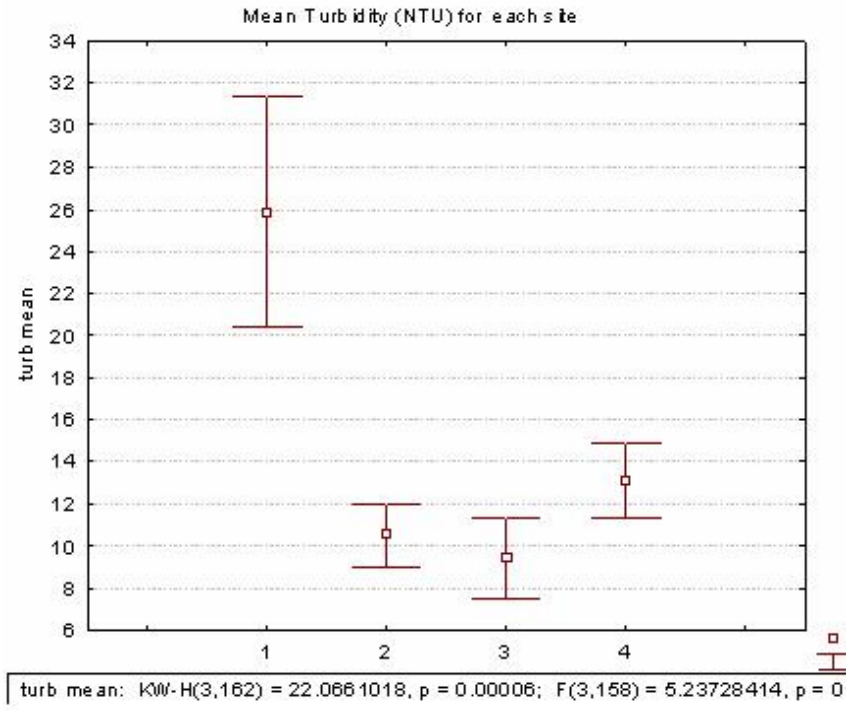


Figure 3. Mean Turbidity (NTU) per site.

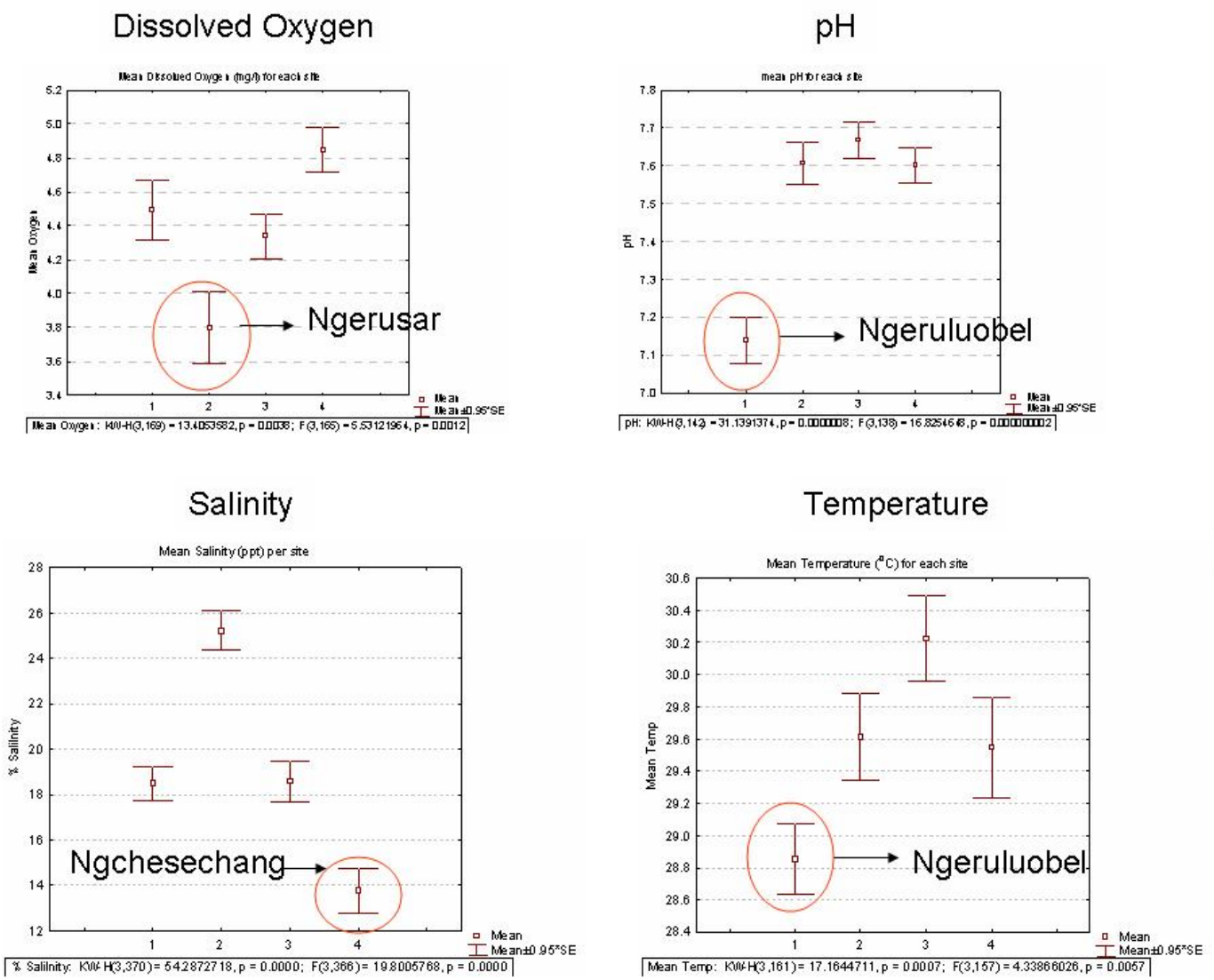


Figure 4. Mean dissolved oxygen, mean pH, mean salinity and mean temperature per site.

Soils

During December 2008, three plots were placed at each site within the three zones. Four 100cm long rebar were placed at each corner at a depth of 70cm. Five gallons of sand was spread over each plot as evenly as possible (Figure 5). The team measured the height of the rebars and the horizon of the soil during January, April and July of 2009. The change in the height of the rebars reflect changing in soil elevation which is related to the degree of packing and subsidence of the soil. The width of the soil horizon reflects the amount of soil deposition or accretion at each site. The mean soil packing rate or increased depth around the rebar was greatest at the more sheltered and shallow channel of Ngerusar (Site 2). The soil deposition was variable with the least deposition at Ngchesechang (Site 4) (Figures 5-6). The mean daily soil elevation or packing rate was the least at the outer mangrove zone and the mean soil deposition or accretion was significantly higher in the middle zone of the mangrove. No significant difference was found between sites for soil packing rates or soil build up rates between sites. However, there was a tendency for the no take site of Ngerusar (Site 2) to have higher packing rates than the other sites and Ngchesechang to have the lowest soil deposition rates. No significant difference was found between zones for soil packing rates. There was a tendency for the soil packing rates to decrease from the inner to outer zones of the mangroves. There was a significant difference (KW-H (2, 36) =5.9, p=0.05) between zones for soil deposition rates between sites. The highest deposition rates occurred within the middle zone of the mangroves.

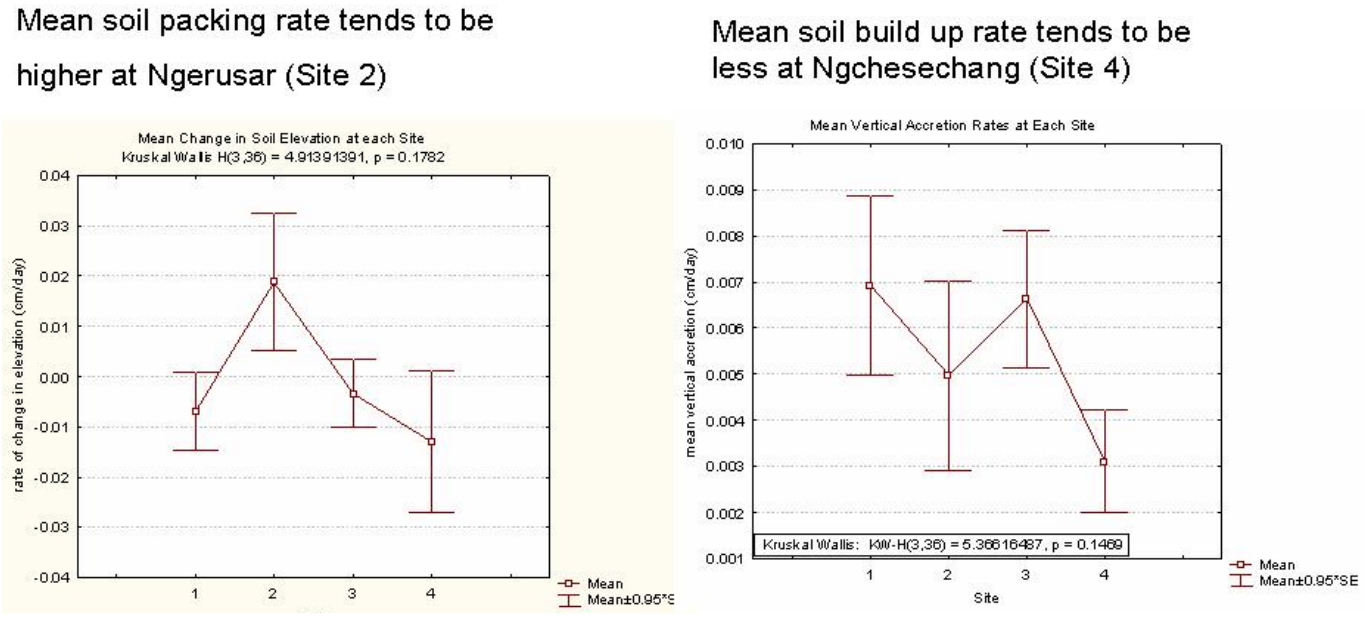


Figure 5. Mean change is soil elevation and soil deposition or buildup per site.

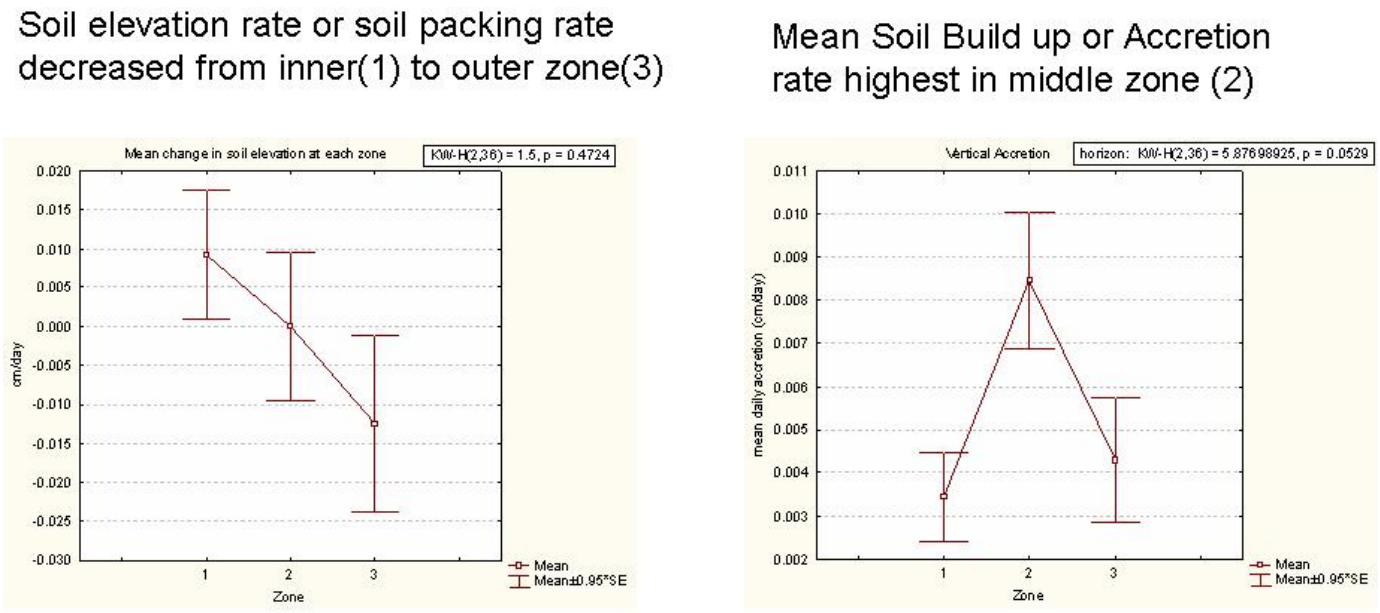


Figure 6. Mean daily soil elevation or packing rates and vertical accretion or build up per zone

Mangrove Forests

Nine circular plots were set within each site, three plots within the inner, middle and outer zones. Therefore a total of 36 plots were set. Permanent aluminum tags were placed on the center tree. The main mangrove species found at the sites are shown in Figure 7.

Figure 7. Mangrove species from upper left counter going clockwise: *Rhizophora apiculata*, *Xylocarpus granatum*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Sonneratia alba*, *Nypa fruticans*, and a *Rhizophora mucronata* flower.

Ngchesechang had more trees and saplings than the other conservation site (Table 2, Figure 8). The most common tree at all sites was *Rhizophora apiculata* (called tebechel but is actually bngaol). *Ceriops tagal* (biut) was common in Ngchesechang (Figure 9, Table 2). The total mean density of all trees was 2,077±225 stems ha^{-1} and differed significantly between sites (KW-H=9.3; df=3, p<0.02). The total mean basal area was 18.9±2.76m^2ha^{-1} and differed significantly between sites (KW-H=36.2; df=3, p<0.000). The total mean volume of all trees was 679 m^3ha^{-1}±201 m^3ha^{-1}. The total mean density of saplings was 1,234 ±297 saplings ha^{-1}. Nine mangrove plant species were recorded within the four sites. *Rhizophora apiculata* (443 trees) was predominant at all sites. *Ceriops tagal* (210 trees) was predominant at Ngchesechang (Site 4). *Bruguiera gymnorrhiza* (118 trees) and *Xylocarpus granatum* (55 trees) were more common along the inner and middle zones. *Sonneratia alba* (32 trees) was found along the outer zones and predominant at Site 2 (Ngerusar) and accounted for the large mean basal area. The volume of *Rhizophora apiculata* trees differed significantly between sites (KW-H=49.0; df=3, 439; p<0.000) and zones (KW-H=8.8; df=2, 670; p<0.01). Tree volumes for *Bruguiera gymnorrhiza* (117 trees) differed significantly between sites (KW-H=12.5; df=2, 115; p<.006). Tree heights for *Ceriops tagal* differed significantly between sites (F=4.7; df=3; p< 0.003) and zones (F=7.8; df=2, 205; p<0.0005). Tree basal area for *Bruguiera gymnorrhiza* differed significantly between zones (KW-H=6.88; df=2, p<0.03). *Xylocarpus granatum* differed significantly between sites for mean basal area (KW-H=9.8; df=2, 64; p<0.008), mean tree height (F=7.8; df=2, 52; p<0.001), and mean tree volume (KW-H=14.2; df=2; p<0.001) between sites (Table 2).

Table 2. Summary of forest area, vertical soil change, mean tree and sapling densities, basal area and mean percent canopy cover with Standard Error in parenthesis and total sample size for each site.

Site	1	2	3	4
Mangrove area (ha)	44.4	39	23.4	138
Mean Densities stem ha^{-1}	1,583 (382) 9	1,917 (283) 9	1,966 (257) 9	2,841 (700) 9
Mean Basal Area m^2ha^{-1}	12.4 (2.7) 9	43.8 (11.3) 9	11.7 (1.08) 9	11.3 (2.5) 9
Mean volume m^3ha^{-1}	216 (45) 9	1,898 (670) 9	238 (46) 9	363 (64) 9
Mean Density of saplings ha^{-1}	1,111 (382) 9	884 (326) 9	471 (141) 9	2,468 (995) 9
Mean Percent Canopy Cover	93.2 (1.5) 9	93.4 (3.0) 9	99.1 (0.1) 9	98.6 (0.3) 9
Elevation Change (cm day^{-1})	-0.006 (0.008) 3	0.018 (0.014) 3	0.003 (0.007) 3	-0.013 (0.015) 3
Vertical accretion (cm day^{-1})	0.007 (0.002) 3	0.005 (0.002) 3	0.007 (0.001) 3	0.003 (0.001) 3

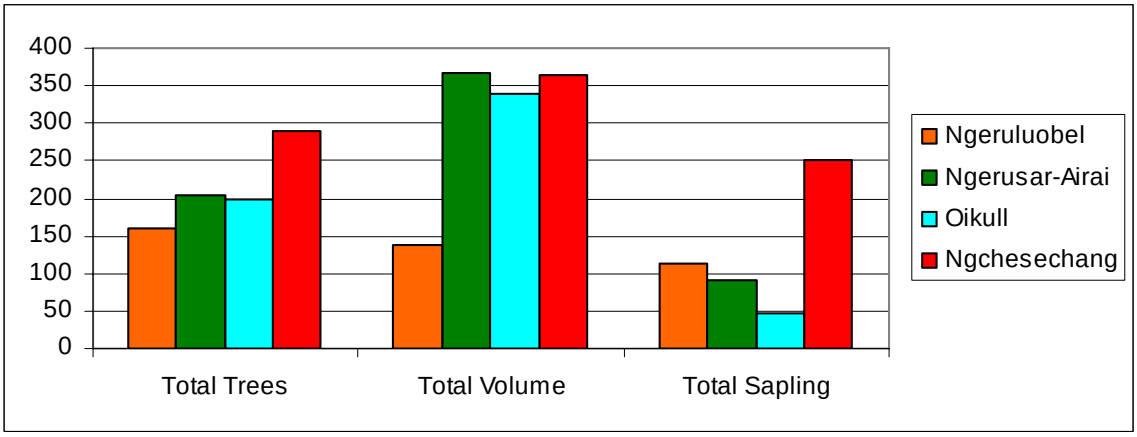


Figure 8. Total trees, Volume and number of saplings found at the four conservation sites.

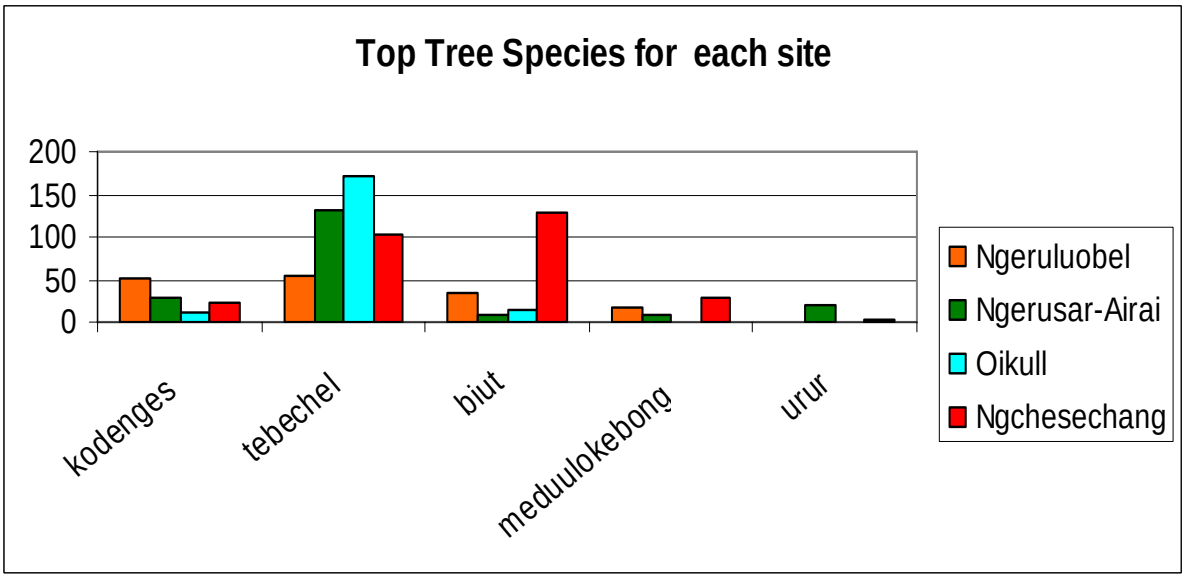


Figure 9. The five most common species found at each site including *Bruguiera gymnorrhiza* (kodenges), *Rhizophora apiculata* (tebechel), *Ceriops tagal* (biut), *Xylocarpus granatum* (meduulokebong) and *Sonneratia alba* (urur).

Fishermen and Families

Several fishermen are shown below that assisted in the project's success (Figure 10). Most are traditional chiefs from Airai. One elder, Temol Yamaguchi, was especially enthusiastic with the project and his grandchildren also assisted.

Figure 10.Crab fishermen who assisted in this project.

Fisherman Profiles

During this study, three crab fishermen were willing to be interviewed regarding their traditional knowledge of this fishery. The interviews were formal and non-formal in nature to gather information about temporal periods of optimal harvest and concerns and recommendations to better manage this fishery and ecosystem. A summary of each interview is given in the next paragraphs.

Mr. Cisco Obak was interviewed at Ngechesechang Dock where he is based for his crabbing activities. Cisco Obak is 54 years of age and started crab fishing at 18 years of age or 36 years ago. Today he has 125 traps that he baits in rotation and collects 4 to 10 crabs of harvestable size a day. His father taught him to crab fish in Airai Bay, Ngerikiil. He moved to Ngchesechang in 1982 and had lived on the nearby rock islands and other parts of Airai before that time. Therefore he has be crab fishing for 28 years in Ngchesechang. He harvest crabs in Oikull and Ngchesechang, but the best place is in Ngchesechang. Changes he has observed is that crabs were smaller and fewer than before. The largest crab he caught was

6lbs. He has seen male and female crabs joined together for mating during the slack tide. The female molts during the spring tides from full moon to slack tide through to new moon (kermarm). He has only seen two crabs together twice in his life. The last time he observed this was in February 2007. Cisco has observed more males and females during the highest tides of April and August. He has seen more small crabs during the month of October. The smallest crab he has seen was about 1 inch in carapace width during the October 9 of 2008. He sells his crabs at Happy Landing, Papago, Dragon Tei and the Sushi Bar. On average he harvests 100 crabs a month of which about 40% are female and 60% are male. The crabs are sold by weight at a unit price of $5/lb at the legal size of 6 inch carapace and above. The mean weight of his crabs is 2 to 3 lbs. His by catch is blue *Portunus* crabs (kmai), stingray (rrull), groupers (temekai) and *Lethrinus harak* (itotech). He harvests 100 crabs of all sizes in one week. The women collected ngduul at Ngerduais near the mangroves however they must work the soil. If the soil gets hard, the clams cannot grow here. He uses chicken, skipjack tuna (katsuo) and mackerel (sama). The best bait is mackerel followed by skipjack (katsuo) and chicken. Currently Cisco is not training anybody how to harvest crabs. He said it is easier to harvest betelnut. The reason he believes there are less crabs is because the people of Ngerikiil are careless about taking crabs that are too small.

Madrabars Tadashi Belechel is a chief from Oikull where he was raised Madrabars is 68 years old and was born on August 1943. He has lived in Oikull most of his life. There was no school in Oikull when he grew up with a community of 50 people. He lived with his mother and father. He would go spearing in the mangroves. They would catch stingray (rrull) and *Epinephelus* spp. groupers (temekai). He saw a male and female crab joined together during the first new moon. Madrabars worked at Black Construction and the Palau Pacific Resort until he retired at 60yeras. He has only recently started crabbing as he is now retired. He has 10 traps and catches 5 to 6 crabs. There used to be more crabs in the pools or depressions but now there are fewer crabs today than in the past.

Temol Yamaguchi was born on May 3, 1937 in Ordmodel where he used to use the throw net to catch fish.

His mother is from Oikull at the area called Iuang. During the Japanese period he lived in Oikull at the age of 25 years old he moved to Airai. People from Peleliu lived in Oikull over 300 people. They left Oikull to attend school and there was no electricity. He used a bamboo trap for 13 years. He had 3 to 4 traps and would harvest 5 to 10 crabs per trap. The largest crab he caught was 5lbs. He would observe many small crabs during the slack tide. During this recent project he began to crab fish with 2 traps. He can catch 100 crabs with bait with 4 traps of which 80 were of legal size. He harvests mangrove crab with his grandchildren. Sometimes he catches black and white tip sharks, *Triaenodon obesus* and stingray (rrull) and the archerfish *Toxotes jaculatrix* (uloi) and the small crabs called cheled. He sells his catch at Happy Landing. Temol Yamaguchi passed away during March 2010. This study is dedicated to him.

Community comments and concerns

During the women's conference the results of this study presented as a power point that was televised and aired regularly for all the communities of Palau to watch. During this conference the following comments were made. Dirrabeluu stated that during the eastern wind when the leaves drop from the Rhizophora trees it is the time when mangrove clams are plentiful. She also found that if you touch or disturb small clams you must harvest them or they will die. She said there are many clams in Oikull. Martha Iyechad commented that she was surprised to learn so much about the mangroves during the presentation. Masashire Siksei from Ngerusar urged us to finish our study and figure out how we can prevent pollution and provide recommendations to the community. Mark Orrukem, the Ngetkib delegate was very aware of all the auto repair shops in Ngeruluobel and wants to do something about the pollution that is occurring at that site. Several asked for some clarification about the results from the crabs. Obak Clarence Kitalong restated that the no take areas work and that we need to do something about the pollution. One of the chiefs from Ngeruluobel stated that the pollution is not just from Ngeruluobel but also from the airport and new developments and that all sources of pollution need to be stopped. Marcelino Augustine from Airai State stated that if anybody observes violations they need to report it to Airai State immediately. He said that by the time they find out about a violation it is too late.

An Integrated Ngerikiil Watershed Management Program was initiated by the Environmental Quality Protection Board in partnership with the Airai Community. The Environment, Inc. was invited to attend to discuss the sources of pollution in Airai State. During this meeting it was found out that people are having problems with their septic systems and need help on correcting these problems. Airai State is sourcing funds to construct community sewage treatment systems to serve an entire village in order to alleviate this problem. The Environment, Inc. is assisting on this continued study of the water pollution problem in Airai State.

Sex Ratio, Size Structure, Harvest Effort

A total of 157 males and 56 females and were caught in baited traps (2.8:1, n=213). The sex ratio of male to females differed between sites with more males at sites 3 and 2 compared to sites 1 and 4 (Table 3). The mean carapace width for all crabs was 14.30± 0.20cm (SE). The mean carapace width (CW) for 56 females was 14.4 ± 0.35cm (SE) and differed significantly between sites ($F=4.6$; df =3, 52; $p<0.006$). The mean carapace width (CW) for 157 males was 14.3±0.21 cm. The mean weight of all crabs was 62 ± 0.04kg (SE) and significantly differed between sites ($F=3.2$; df=3, 178; $p<0.02$). The mean weight for 55 females was 0.62g ± 0.04kg (SE) and differed significantly between sites ($F=4.2$; df=3, 51 $p<0.01$). The mean weight for 157 males was 0.75±0.04kg (SE). There was no significant difference in male size or weights between sites. The mean CPUE for all sites was 0.48±0.04 crabs $trap^{-1}$ $night^{-1}$ (SE) and significantly differed between sites ($F=2.9$, df=3, 77; $p=0.04$). Overall the female crabs were larger at the no take site at Ngerusar and at

Ngeruluobel where there was only one crab fisherman. Although the catch rates were high in Oikull and Ngerusar, the sizes of the crabs were smaller at Oikull where there are more crab fishermen.

Table 3. Summary of *Scylla serrata* sex ratio, carapace size & weight of captured female and male crabs, harvest effort, percent harvestable size & number of crab fishers at each site.

Site	1	2	3	4
Sex ratio (male:female) 37	5.0:1	2.9:1 63	1.6:1 70	5.1:1 42
Mean female carapace size (cm) 6	15.6 (1.01)	15.5 (0.42) 16	14.3 (0.54) 27	11.7 (0.67) 7
Mean female weight (kg) 6	0.77 (0.13)	0.74 (0.05) 15	0.58 (0.06) 27	0.38 (0.05) 7
Mean male carapace size (cm) 31	14.8 (0.54)	14.8 (0.39) 47	13.7 (0.42) 43	14.1 (0.34) 36
Mean male weight (kg) 31	0.87 (0.09)	0.84 (0.07) 47	0.64 (0.07) 43	0.68 (0.05) 36
Crabs $trap^{-1}$ $night^{-1}$ 23	0.34 (0.06)	0.57 (0.011) 17	0.66 (0.11) 21	0.40 (0.07) 20
Percent of harvestable carapace size	47%	46%	32%	30%
Number of Crab fishers	1	0- no take site	4	2

Figure 11. Building crab traps, tagging crabs in the field and releasing tagged and marked crabs.

Figure 12. Temol with his grandchildren tagging undersized mangrove crabs for release in Oikull.

Recaptured Crabs and Other Organisms

To date 19 crabs were recaptured (2-Ngeruluobel, 8-Ngerusar, 8-Oikull and 1 in Ngchesechang). All recaptured crabs were found in the same protected area that they were tagged and 50% were caught in the same trap. Sixteen recaptured crabs had not yet molted. Three recaptured male crabs had molted with tags still intact (Table 4). A tagged crab from Ngerusar was recaptured 3 times over a 111 day period and had molted before its third recapture. The carapace width increased by 1.7cm in carapace length and its weight increased by 0.2kg. A male crab was recaptured twice over a 45 day period and had molted before its second recapture. The carapace width increased by 2.0 cm and its weight increased by 0.45kg. A male crab was recaptured in Ngeruluobel only once after a 180 day period. Its carapace width increased by 3.6cm and its weight increased by 0.75kg suggesting that it had molted twice during this period. The recapture data suggests site fidelity. The limited recapture of molted crabs indicates an average growth of 1.9 cm and weight increase of a maximum of 0.45kg within less than 45 days. A variety of fish, crustaceans and even a bull shark were captured in the crab traps.

Table 4. Recaptured and molted *Scylla serrata*

Sex	Growth increment (cm)	Weight increase (kg)	Days since first capture	Frequency of recaptures
1st Male	1.7	0.2	111	3
2nd Male	2.0	0.45	45	2
3rd Male	3.6	0.75	180	1

Crocodiles and By-catch

The endangered crocodile was found at Ngeruluobel and Ngerusar (Figure 11). Crocodiles are predators of mangrove crab. The most sightings of crocodiles occurred at Ngeruluobel (Site 1) where one large crocodile (>2m) and a smaller crocodile (1.25m) and two juvenile crocodiles (0.3m) were observed. One medium sized crocodile was found at Ngerusar (Site 2). A medium sized crocodile was also spotted in Oikull Bay. The by catch in the mangrove crab traps included a bull shark, *Carcharhinus leucas*, many small crabs called chelechd, the Portunus crab (kmai), a juvenile barracuda, *Sphyraena barracuda* (mersaod), several small groupers *Epinephelus merra* (imirchorch), a juvenile file fish (lung), and a couple moray eels (luleu). We also found a blue siponophore at one of our plots that was carried in from the lagoon within the mangrove (Figure 11).

Figure 11. By catch from the traps and fauna in the mangrove included (from top to bottom, left to right) a bull shark, *Carcharhinus leucas*, the mangrove goby, the abundant small crabs (cheleched), a siponophore from the open sea within the mangrove, the blue Portunid crab (kmai). A medium size crocodile at Site 2 in Ngeruluobel (lower left), a juvenile barracuda half way through the trap, small Epinephelus groupers and a small file fish at lower right corner.

Mangrove Clam

Only one mangrove clam, *Anodontia edulenta* was found at Ngerusar and none were found in other sites (Figures 12-13). The mangrove clams were rare at the protected sites but found outside in one area in Oikull that is regularly harvested by the women. The mean sizes of the *A. edulenta* was smaller than those measured from Ngardmau State and sold at Yano's Market. Interviews with the fishermen and fisherwomen and observations in the field indicated that the soil has to be worked and mangrove leaves added with the feet in enhance productivity of clams in a given area. The process is involves a rotational harvest with a 6-month growing period between harvests. This process enhances clam productivity according to women and fishermen in the field and also mentioned during meetings with the women during presentations. In the areas we surveyed the women did work the soil and add leaves. Our plan is to go back to "worked" and "unworked" areas within and outside the protected study sites. We planned to determine if there is a significant difference in the number of clams in worked versus unworked areas. We learned that the compactness of the soil and working the soil were considered a important factors for clam production.

The presence of crocodiles at 3 of the 4 sites raised concern among the women. We discussed this issue with the women and concluded that the study team did not want to be responsible for putting the women in harm's way. Women must go waist deep into the mud to harvest clams and crocodiles can move very quickly. Based upon these sightings, the mangrove clam study was discontinued. During the discussions, we realized that the presence of crocodiles may also explain why clam harvest was not occurring in Airai. During our initial field trips, the women said the soils were not being "worked" in these conservation areas and not found during the initial field trips with the women.

In Oikull there are several women who continue to harvest in this area dispute the presence of crocodiles. We attempted to harvest with one woman known for her skills however we were unsuccessful. Her daughters relayed that they were concerned that we would learn her "favorite spots" and did not wish to participate in our study at this time.

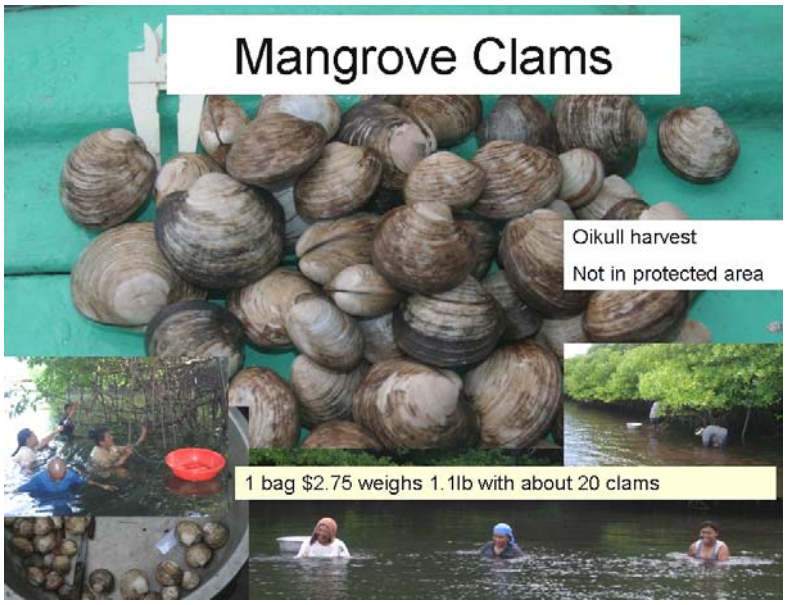


Figure 12. The mangrove clam *Anodontia edulenta* **and harvesters at work.**

Summary for Protected Areas:

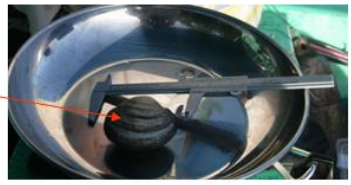
3 trips by 3 women 15-30 min minutes search at 3 areas in each protected area and we found only 1 clam:

Ngeruluobel- 0 clams

Ngerusar-Airai-1 clam

Oikull-0 clams

Ngchesechang- 0 clams



Size of clams harvested outside the protected area in Oikull (Telebekai) were smaller in mean size (4.45 cm) compared with Ngardmau (4.75)

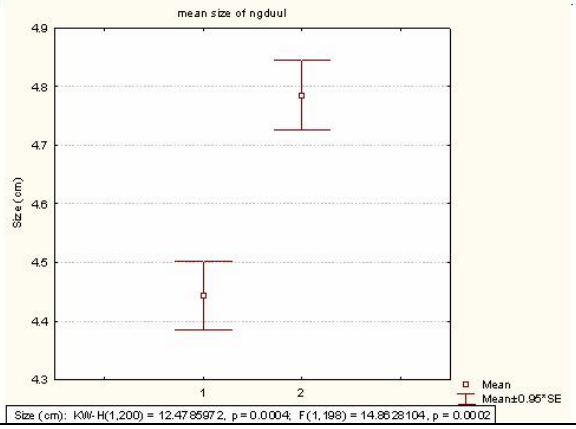


Figure 13. Mean size of clam collect at Oikull (Site 1) and Ngardmau (Site 2).

Draft Mangrove Action Plan for Airai State

During the community meetings and individual interviews with mangrove crab fishermen and mangrove tree harvesters, recommendations for management of the mangroves was either requested of given by the people. A draft mangrove action plan was composed based upon these discussions and circulated for review and comment. The people who reviewed the draft plan were supportive of it. Most were mainly concerned with improving the water quality in the mangroves and finding the source of pollution and stopping it immediately. The harvest rotations were a new concept to some. The crab fishermen did not want to be charged a fee for a permit as they could not afford it. They thought that any permit required a fee and we explained that this was not necessary if the fishers felt it was a burden. Shared information was more important than a fee. One reviewer thought the most important part of the plan was considered an education program on storm drainage and septic and pollutant management.

Future Work

Baseline information has now been collected about the mangrove forests, crabs, clams and water quality. The permanent plots established for the mangrove trees can be revisited in 5 years to determine grow and health of these forests. Ongoing water quality monitoring is a top priority Regular monitoring to determine sources of point and non-point sources of pollution is needed and the problem corrected. Recapture of tagged crabs through ongoing trapping and more tagging is recommended to increase the database on grow and movement of crabs. The presence of crocodiles established three of the sites as critical habitat for this endangered species. A study of crocodile in these sites is recommended. The crocodiles are top predators in the mangroves and may impact the crab population at these sites. The crocodiles posed a threat for the women working with the mangrove clams and may explain why so few women harvest in this areas than in the past. This clam study may be continued at sites outside crocodile habitat.

A new Airai State Legislature was elected on March 1, 2010. The newly elected Airai Congress will be installed on April 5, 2010. Clarence Kitalong is now a delegate for Ngetkib and will introduce legislation for mangroves during 2010 based upon this study. The Environment, Inc. will continue to work with the Environmental Quality Protection Board to schedule more water monitoring at the 4 protected areas to identify both point and non- point sources of pollution within the study sites. Communities meetings will be ongoing to incorporate new information into the Airai State Master Plan that is now law. The information from this study will be used to develop a Mangrove Management Plan for Airai.

Summary:

- Ngeruluobel and Ngchesechang waters are polluted with bacteria and sediments
- Soil was lost at Ngeruluobel and Ngchesechang and gained at Ngerusar and Oikull
- Mangrove Forests are healthy with many young saplings especially in Ngchesechang
- Larger female crabs were captured in the no take area of Ngerusar and Ngeruluobel where there was one crab fishermen compared to other sites.
- More crabs of legal size are captured in the no take area of Ngerusar (46%) and at Ngeruluobel where there was only one crab fishermen (47%) than in either Oikull (32%) with 4 crab fishermen and Ngchesechang (30%) with 2 crab fishermen
- Crabs exhibit site fidelity with one crab recaptured in the same area after 180 days
- Only one mangrove clam was found in all four of the protected areas. More studies are needed to examine how "prepared" clam beds especially the role of mangrove leaves and relative compactness of soil correlate with clam productivity. The hazard of crocodiles prevented further work at this time.
- Community monitoring using simple techniques work.
- Water quality was the major concern of the Airai community.
- Ongoing monitoring of 2 new permanent water quality sites were set up by EQPB as a result of this study.
- A draft management plan was developed based upon discussions and interviews with the community and reviewed.
- Mangrove management legislation will be introduced to the Airai State Congress in 2010.

Acknowledgements

We would like to acknowledge the following entities for their support of our efforts. The National Oceanographic Atmospheric Administration Coral Reef Conservation Program provided the necessary funding and technical support. The members of Ngarabrekork and Ngarameliwei implemented this project with the help of their partners at Airai State Government, the Palau Conservation Society, the Palau International Coral Reef Center, the Palau Automated Land and Resource Information System, the Coral Reef Research Foundation, and the Bureau of Marine Resources, Ministry of Resources and Development, The Republic of Palau. We especially acknowledge the assistance and cooperation of the crab fisherman that participated in this study including Cisco Obak, Madrabars Tadashi Belechel, Christopher Tkoel, Temol Yamaguchi and Jack Rengiil. The study is in special memory of Temol Yamaguchi who passed away in March 2010.

A Draft Mangrove Action Plan for Airai State

Vision

Healthy and productive mangrove forests that are sustainably managed by the Airai community for present and future generations.

Goal 1: To sustainably harvest mangrove trees in Airai

Objective:
The main objective is to accurately record the abundance and distribution of harvested and harvestable mangrove trees in Airai.

Actions:

- Assess and manage the harvest of wood through protected areas, harvest permits, size limits and regular surveys that are community driven
- Set up a permit system for mangrove tree harvest that records size, species, location and purpose.
- Set up an rapid assessment system to evaluate an area and mark each harvestable tree
- Set up a rotational harvest system whereby no more than 30% of optimum size tree be harvested within an area.
- Maintain cleared channels within mangroves for navigation and good water exchange.
- Set aside at least 25% of mangrove habitat in each hamlet as a no take area and survey and assess every 5 years.

Goal 2: To improve the water quality within the mangrove channels of Airai.

Objective: To reduce the point and non-point sources of pollutants in Airai Waters

- To conduct regular community based monitoring of water quality and identify sources of pollutants in partnership with EQPB.
- Close fisheries in polluted areas and post warning signs.
- Set up an educational program on storm drainage and septic and pollutant management

- Set up a State beautification and healthy community award.
- Set up a fine system for 3-time violators of State and National water quality regulations.
- Send crabs and clams for testing for contaminants in known polluted areas

Goal 3: To sustainably harvest mangrove crabs in Airai

Objective: To reduce the number of undersized crabs harvested in Airai

Actions:

- Require permits for the commercial harvest of mangrove crabs
- Set up a community based crab monitoring program with tagging every 5 years
- Finance training, regular surveillance and equipment for conservation officers
- Educate crab fishermen and buyers on the existing information and laws for legal harvest size of crabs.
- Set up a harvest permit system and regulate crab harvest through a rotation system within each hamlet
- Initiate a closure of a mangrove area when the majority of crabs caught are undersized.