Enhanced Monitoring of Grouper Spawning Aggregation at Ebiil Channel

Final Technical Report

June 2010

Palau Conservation Society and

The Society for the Conservation of Reef Fish Aggregations

Table of Contents

Acknowledgements

These 2009 grouper aggregation surveys in the Ebiil Channel Conservation Area were a collaborative effort amongst many people and organizations. The Palau Conservation Society would particularly like to thank the following organizations, individuals and governments for their assistance and support:

Ngarchelong State

Coral Reef Research Foundation

Society for the Conservation of Reef Fish Aggregations

The David and Lucile Packard Foundation generously provided financial support for the enhanced monitoring reported in the current report through SCRFA.

The following people provided support, assistance in the field, and contributed to the production of this report.

Governor Browny Salvador, Ngarchelong State

Tiare Holm, Palau Conservation Society

Dr. Elizabeth Matthews, Palau Conservation Society

Dr. Pat Colin, Coral Reef Research Foundation

Dr. Yvonne Sadovy, University of Hong Kong, SCRFA

Murphy Wasisang, Ngarchelong State

Einer Kebekol, Ngarchelong State

Matsuda Renguul, Ngarchelong State

Leslie Ngiramolau, Narchelong State

Scottie Kiefer, Palau Conservation Society

Asap Bukurrou, Palau Conservation Society

Godinez Ngiltii, Palau Conservation Society

Renguul Masahiro, Palau Conservation Society

Summary

From 2008-2009, the Palau Conservation Society (PCS) and the Society for the Conservation of Reef Fish (SCRFA) worked together to develop a robust sampling protocol for Ebill Channel spawning aggregation in western Palau. Efforts were also directed towards increasing awareness and understanding of the importance of reef fish aggregations for targeted fish species and for the fisheries they support, as well as the need for consistent and accurate monitoring of reef fish spawning aggregations for effective conservation and management in Palau. SCRFA provided technical support and information for the project, assisted in the development and production of educational materials and provided additional funding to support PCS's participation in the project. PCS dedicated personnel to implement and coordinate project activities.

Results of the PCS monitoring in the past using single transect underestimated the overall aggregation size and composition due to fact that the sampling design did not adequately cover the entire aggregation nor did it cover all three species of groupers. The single transect was largely focused on Tiau, *Plectropomus areolatus*. As a result of this sampling design, one species of grouper, Ksau, *Epinephelus polyphekadion*, was assumed to be absent from the site for several years. However, subsequently a more comprehensive survey of the Ebiil site showed the species to be aggregating in a deeper area of the channel that had not been previously surveyed. A third species of aggregating grouper at Ebiil, the brown marbled grouper, Temekai, *Epinephelus fuscoguttatus*, was also under reported due to the placement of the original transect. Based on a better knowledge of the distribution of the three aggregating species, an improved monitoring protocol was developed and conducted. The results provide a baseline of the grouper aggregations site on the southern part of Ebiil channel and allow recommendations to be made regarding monitoring and possible uses of the site on a long-term sustainable basis.

1. Enhanced Monitoring of Ebiil Conservation Area

1.1 Introduction

Ebiil Channel is considered to be one of the most important fish aggregation sites in Palau. Many species of reef fish use Ebiil as a spawning aggregation habitat and many species of groupers migrate from surrounding waters to spawn here. The Ebiil Conservation Area is located at approximately 7°27' N; 133° 56' E within the jurisdictional waters of Ngarchelong State of the Republic of Palau. Approximately 15 km^2 in area, the Conservation Area includes the Ebiil channel and adjacent coral reef areas of Erengoll, Oubedbad, Uchulamengbokb and Ochimer, inclusive of reef slopes. Results of previous studies suggest that approximately 50 different species of fish use Ebiil Channel as a reproduction habitat, and migrate there from surrounding waters. (Johannes 1994; Johannes et al. 1999). Since the passage of the Palau Marine Protection Act in 1994, five species of grouper are protected during part of their spawning season (from April 1 to July 31) and when they cannot be bought, sold or fished (MPA 1994). These grouper

species are: Tiau, *Plectropomus areolatus*, Mokas, Katuu'tiau, *Plectropomus laevis*, *Bekerkard l'* Tiau, *Plectropomus leopard*, Kesau or Ksau'temekai, *Epinephelus polyphekadion* and Temekai or meteungerel'temekai, *Epinephelus fuscoguttatus*

In recent years, Ebiil channel has come under increasing pressure from illegal fisherman coming from all over Palau, not just from Ngarchelong, to fish for the vulnerable grouper species during the periods of aggregation. Concerns over overfishing of these vulnerable grouper aggregations as well as a general decline in fish populations in the area led Narchelong State government to close Ebiil Channel to all fishing activities and it prohibited unauthorized entry in February 2000 for three years. In 2003, the state law was reauthorized to extend the closure period permanently and this was based on a strong consensus from state leadership with support from the majority of the local fisherman.

The Ebiil Management Plan was approved by the state government in November 2009. Within this plan, the stated goal of the Ebiil Conservation Area is to "Allow for the conservation and effective management of the natural resources of Ebiil, including its special spawning aggregations and exceptional coral habitats, for the continued benefit of the present and future generations of Ngarchelong, Palau, and the world." (Ebiil Management Plan) The purpose of the management plan is to provide guidance for the implementation and evaluation of management activities of the Ebiil Conservation Area. As such, the Ebiil Management Plan intends to help identify and develop operational management goals, objectives and work plans for the management of the Ebiil Conservation Area in the future.

Background to long-term monitoring at Ebiil

There is a long history of monitoring of the aggregation site at the southern portion of the Ebiil Channel, commencing in 1993 and continuing intermittently until the present day. The earliest project was headed by Dr. Robert Johannes with data regularly collected using underwater visual census surveys, monthly year-round from 1993-1995. Based on these initial surveys, fish numbers were counted starting 10 days prior to new moon, the period most likely to include peak numbers of three species of grouper, Tiau, *Plectropomus areolatus*, Kesau or Ksau'temekai, *Epinephelus polyphekadion* and Temekai or meteungerel'temekai, *Epinephelus fuscoguttatus.* The sampling method centered around metal stakes between which divers swam collecting data. The metal stakes were assumed to lie within a central area of the aggregation but its placement was not made relative to the outer boundary of the aggregation site. The results of these haphazard surveys, supplemented by accounts from fishers, Johannes' study identified the months of aggregation for the three species and recommended complete closure of grouper aggregation areas throughout Palau and for all aggregating months (Johannes 1994; Johannes et al. 1999). Although there was already a 'bul' (protection of aggregations) in place during April to July, inclusive, of particular note was the finding that aggregation also occurred in August, a month not protected. However, because the boundaries of the grouper aggregation survey area at

Ebiil was not documented it was not known what proportion of the total aggregation site, and hence total number of fish present during the aggregation period, was covered by the staked transect. Moreover, only one species, *P. areolatus*, was the main focus of the surveys.

Between 2000 and 2003, PCS sporadically sampled the same area as that monitored by the Johannes study and modified earlier sampling approach by establishing a permanent transect of 200 m. This transect involved installation of a more permanent set of metal stakes which were surveyed in a linear rather than zigzag fashion, although the boundary, and hence spatial extent, of the grouper aggregation site had still not been surveyed. Data were collected by 2-3 observers SCUBA diving along the rebar-staked transect. The size of the area being monitored was approximately 200 m long with a swath (width) of 10 m, resulting in a total survey area of 2000 m². Divers counted fish using a standard Underwater Visual Census technique, similar to a 'Belt-Tansect' (Mersai 2008).

Figure 1. Geo-referenced image with appropriate scaling of the permanent rebar transect used by PCS to monitor the grouper populations in part of the Ebiil aggregation site 2003-2007.

From 2003-2007 PCS consistently monitored the grouper aggregation 4 and 3 days prior to the new moon along the rebar transect. The overall trend from these data resulted in a decreasing number of Tiau, *P. areolatus*, at the Ebiil aggregation site along the rebar transect line. However, the meaning of the data was in question because it was not clear how well the data represented the total number of Tiau at the aggregation site as a whole (Figure. 1).

In 2003, the Ebiil aggregation site was surveyed by SCUBA by Jason Kuartei and Pat Colin leading, finally, to an understanding and mapping of the boundary of the aggregation area used by two of the three species (Fig. 2). Aware of challenges in the survey of grouper numbers at the

Ebiil site, because a single rebar transect was being used that was an unknown proportion of the entire aggregation area used by groupers, PCS collaborated with the Society for the Conservation of Reef Fish (SCRFA) to improve upon the existing monitoring techniques and apply a robust and practical sampling protocol for efficient and long-term monitoring of the Ebiil grouper aggregation. Further survey of the site subsequently revealed the presence of *E. polyphekadion* in deeper waters (Fig. 2) – thus three grouper species were found to use the site in large numbers for spawning.

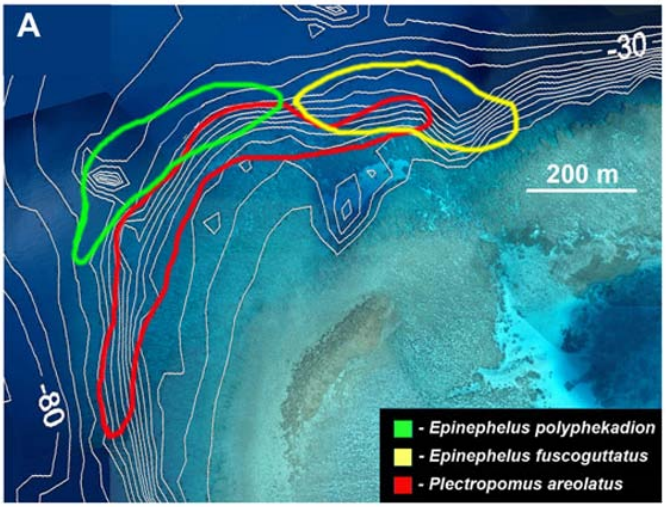


Figure 2. Original survey of grouper limits at the aggregation site in 2003 identified only the yellow and red areas for *E. fuscoguttatus* and *P. areolatus*, while a more recent GPS-based survey revealed the deeper (green) aggregation area of *E. polyphekadion* (Patrick L. Colin).

The sampling protocol adopted as part of the PCS/SCRFA collaboration was a modification of the 'belt transect' method that was adapted to the realities and challenges of sampling fish numbers at a large site where SCUBA diving time is limited because of depths and where currents can make underwater surveys particularly challenging. The method was developed by Dr. Pat Colin and depends on the use of a GPS 'virtual' transect instead of a physical belt transect. Given the size and conditions of the aggregation site belt transects were considered to be impractical for sampling at the spatial scale needed (see Methods below).

SCRFA formed in 2000 to promote responsible stewardship of reef fish spawning aggregations. The core of work implemented through SCRFA focuses on public education regarding the vulnerability of reef fish spawning aggregations to unsustainable fishing practices, and the need for their better protection and management based on a foundation of good science. In 2003, SCRFA Director, Dr. Sadovy, worked with PCS to study the historical knowledge of reef fish aggregations throughout Palau. The objectives of this study were to document local Palauan fisher knowledge and understanding of reef fishes that aggregate to spawn and of the status of their fisheries over the last few decades. Specifically, information on the knowledge of the timing and locations of aggregations, fish species involved, catch rates both past and present,

opinions, and attitudes of fishers regarding their fishery and its use and management. The results of the peak catch rates from this survey are depicted in Figure 3. Peak catches per trip taken at spawning aggregations of groupers (*E. polyphekadion, E. fuscoguttatus and P. areolatus*) as reported from fisher interviews conducted in July 2003 from the 1960s, 1970s, 1980s and 1990s at different aggregations sites in Palau (Sadovy, 2007). For each decade, different symbols represent a separate estimate but the same symbol across decades may not represent estimates from the same fisher. There is a significant decline in landings over the 1960-2000 time periods.

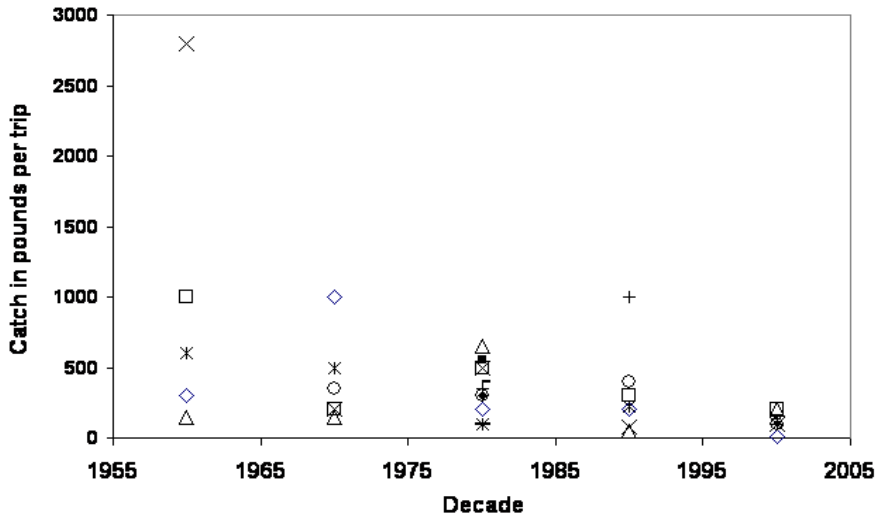


Figure 3. Peak catches taken at spawning aggregations of groupers (*E. polyphekadion, E. fuscoguttatus*, and *P. areolatus*) at multispecies aggregation sites as reported from fisher interviews conducted in July 2003 in Palau. For each decade different symbols represent independent estimates by different fishers, although the same symbol in different decades may not represent estimates from the same fisher (Sadovy 2007: http://www.scrfa.org/server/studying/reports.htm-Palau*)*.

In June 2008, PCS in collaboration with SCRFA began to conduct underwater GPS surveys over the entire spatial extent of the grouper aggregation site at the southern entrance to Ebiil Channel. These surveys confirmed that there were large areas of the aggregation site with considerable numbers of groupers present that had not previously been accounted for in the original PCS transect survey design (Figure 4). The following month, July 2008, the survey team capture a geo-referenced image of the density of groupers aggregating at the area (Figure 5).

Sampling of the entire site was important for several reasons: to establish a solid baseline of the grouper species and numbers aggregating at the site for future reference. This is important because the communities of Ngarchelong wish to know how the population of groupers is changing overtime. Having a good baseline of grouper numbers and species present at the site enables recommendations to be made in relation to future use of the grouper resources that use the site. Moreover, a robust sampling protocol that can be applied more widely to other aggregation sites in a representative and efficient way is applicable to other aggregation sites.

For example, the Protected Areas Network and the Micronesia Challenge are currently using spawning aggregations areas as indicators of marine system health. Having accurate and precise information on the health of these aggregations depends heavily on a reliable and solid monitoring methodology.

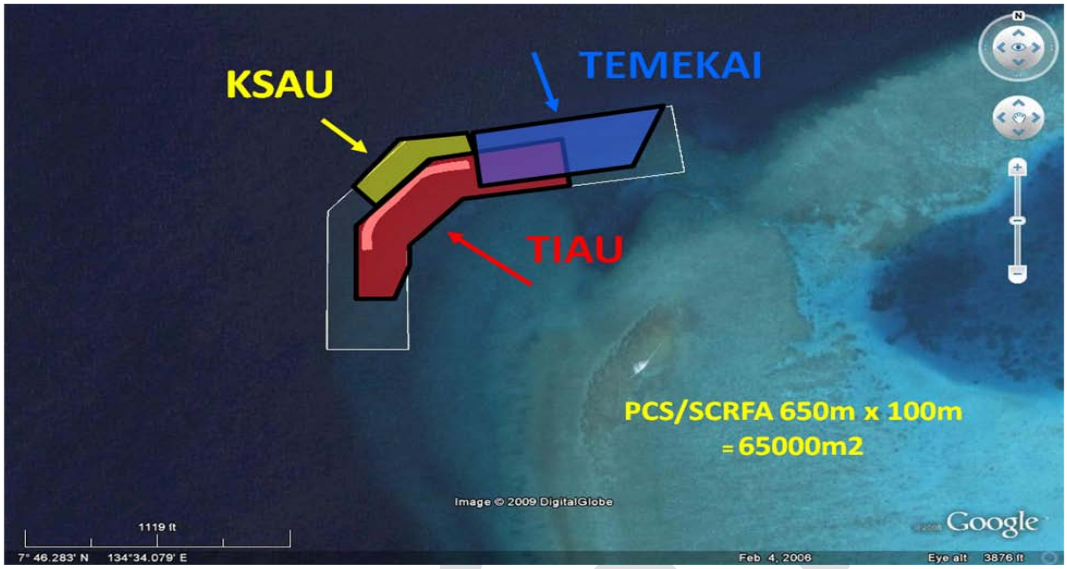


Figure 4. Shows the entire areas surveyed in 2009 with the original PCS 200M transect and the 3 corresponding areas of fish aggregation areas: KSAU *(E. polyphekadion)*, TEMEKAI *(E. fuscoguttatus)*, and TIAU *(P. areolatus).*

1.2 Objectives

In 2008, SCRFA and PCS signed a Memorandum of Understanding to cooperate and work together to increase awareness about spawning aggregations and the practice of protecting reef fish spawning aggregations in Palau and to develop a scientifically robust UVC sampling technique for spawning aggregations, using Ebiil as a demonstration sites. The primary objectives for this work are:

1. To characterize the Ebiil spawning aggregation (south entrance to the Channel) in terms of area and grouper species and numbers aggregating in order to establish a baseline for future work.

2. To develop a robust and practical sampling protocol for efficient and long-term monitoring of the Ebiil, or aggregation areas in general, to assess the outcomes of its conservation for groupers.

3. To facilitate future validation of other possible grouper spawning sites in Palau for conservation and management purposes.

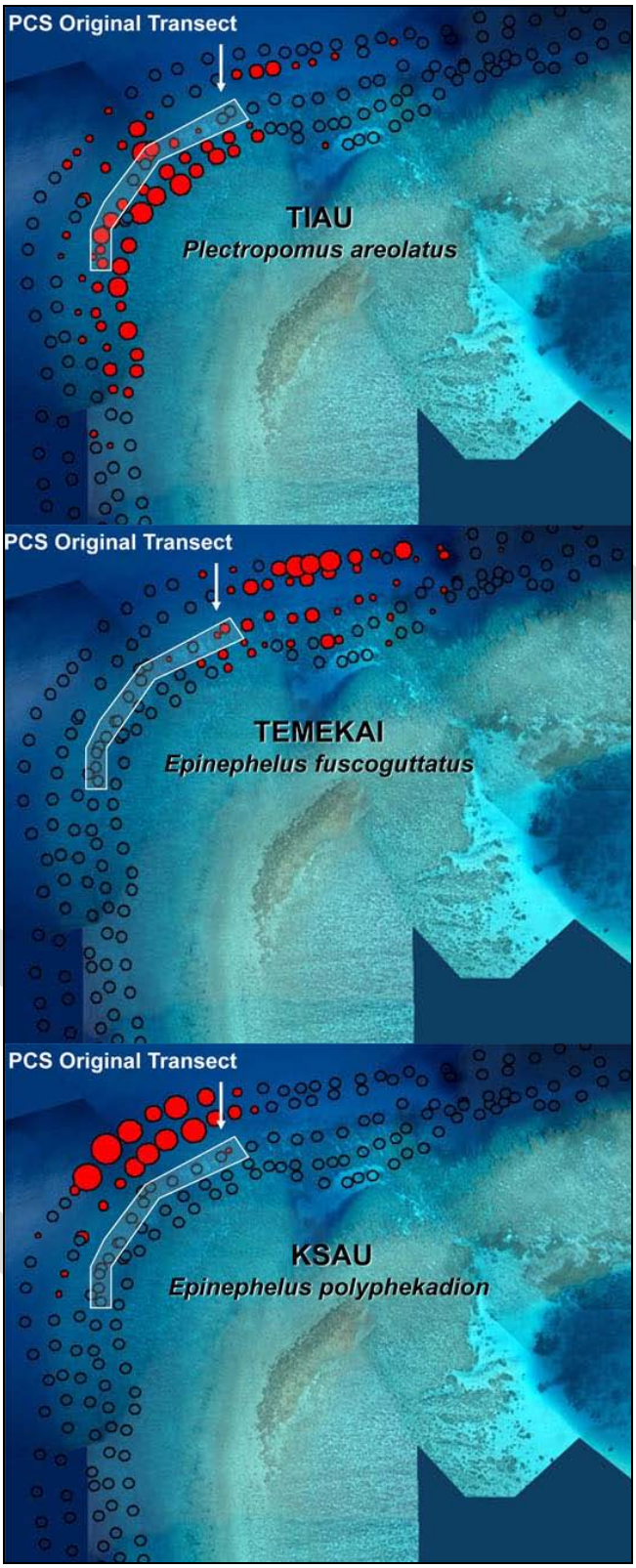


Figure 5. Geo-referenced PCS permanent transect in relation to the location and density of grouper species *P. areolatus*, *E. fuscoguttatus and E. polyphekadion*, within the aggregation site from preliminary surveys conducted in July, 2008.

4. To evaluate retrospectively, if possible, the significance of historical sub-sampling of the Ebiil site for groupers i.e. the rebar transect used 2003-2007.

5. To evaluate whether current seasonal closure measures are adequate for protecting spawning groupers.

6. To provide recommendations on options for the sustainable use of grouper resources at Ebiil as part of the conservation and management of the protected area and for the benefit of the community

1.3 Methods

The "GPS (Global Positioning System) Density Survey" method was used for the Underwater Visual Censuses (UVC) during this project (Colin et al. 2005). Conventional UVC techniques (typically 50 or 150 m long transects) are not feasible for documenting the spawning aggregations of reef fishes. The UVC technique is based on transects that allow observers to cover specifically marked areas of reef to collect quantitative data at known geographic locations that can be replicated over time. The method used for the PCS/SCRFA study at Ebill utilized a modified form of line or belt, the GPS Distance Survey. This is a technique that is in principal the same as the standard line transect survey in which a physical line is laid on the substrate and forms the basis for the counts. In the GPS approach, a virtual line is consistently followed by swimming along a familiar area of the reef where by the ‘line’ is ‘traced’ by a towed GPS rather than a physical line. This technique, developed by Dr. Pat Colin, is the most practical approach to surveying where long rope transects are impractical and can be considered as a virtual belt transect. The GPS approach provides quantitative information in the same way as a belt transect since the location and length of the transect can be determined from the GPS trace. Fish are counted either side of the transect in a prespecified width (i.e swath) exactly as for the belt/strip transect approach. The GPS method is ideally suited to measure the distribution and density of fish over large areas, such as fish aggregation areas, and also provides the precise location of areas of interest such as aggregation of fishes, ship/plane wrecks, distinctive coral growths and species of interest, such as giant clams, etc. The GPS density survey method uses a "track logging" GPS receiver in a waterproof floating housing, which is towed on the surface by the observer (Figure 6).

Figure 6. Equipment used (GPS receiver, waterproof PVC housing-handmade-towline) for the survey (left) and divers at the beginning of a transects with equipment.

The GPS is set to log its position 30 or 60 seconds and the observer carries a waterproof watch exactly synchronized with the time displayed by the GPS receiver. Fish within a 10m distance to either side of the swim track are recorded while swimming along a reef feature, or reef slope (Figure 7a). Need to be sure that divers recalibrate estimated 20 m separation from each other from time to time by actually measuring this in water. When the logged data from the GPS are downloaded using Garmin Map Source World Map software), this provides a continuous track of the survey swim and, within the accuracy limits of the GPS, a permanent record of the area surveyed, allowing for replication in the future. Using the concurrent time log and the time of fish observations, the position on the track where any fish was observed can be closely (within a few m) determined from the time and position data. The distance (and thereby the area depending on swath width) covered during a given survey is documented and the number of fish observed provides a density (fish per unit area) value (Figure 7b). The survey track and positions of individual fish along that track can be plotted on habitat maps, satellite images or other backgrounds to provide a visual display of fish numbers and dispersal against a habitat image providing insights into the relationship between the fish and the environment.

For fish counts, divers line up in parallel and swim slowly along the transects keeping aligned. Counts are noted every 30 seconds or 60 seconds (depending on the GPS log setting) in terms of species and numbers seen. To effectively survey the entire area at Ebiil, five transects must be completed. In the present study, three divers would organize the diving as follows: observers would complete 2 dives each, For Dive 1, a single reference transect, or the ‘middle’ transect (Transect 3) would serve as the ‘guiding transect’ for the other two observers to line-up with. This transect is permanently demarcated and each subsequent observer would position themselves 20 m apart from the ‘middle’ observer, covering a linear distance 60 m perpendicular to the reef slope. (Figure 8). The permanent transect is an extension of the earlier transect surveyed by PCS in 2003-2007 and all transects run the full length of the aggregation site.

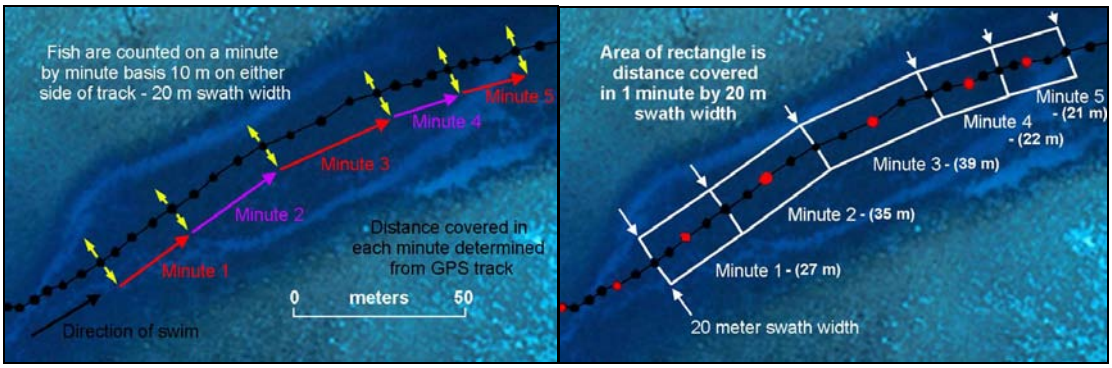


Figure 7. a-b. Geo-referenced transects from GPS units on aerial photograph with direction and times indicated. Geo-referenced transects from GPS units on aerial photograph with direction, distance and times indicated. In addition, b. the swath of the observers transect has been added to show the quadrant that was used to calculate fish density (Pat Colin).

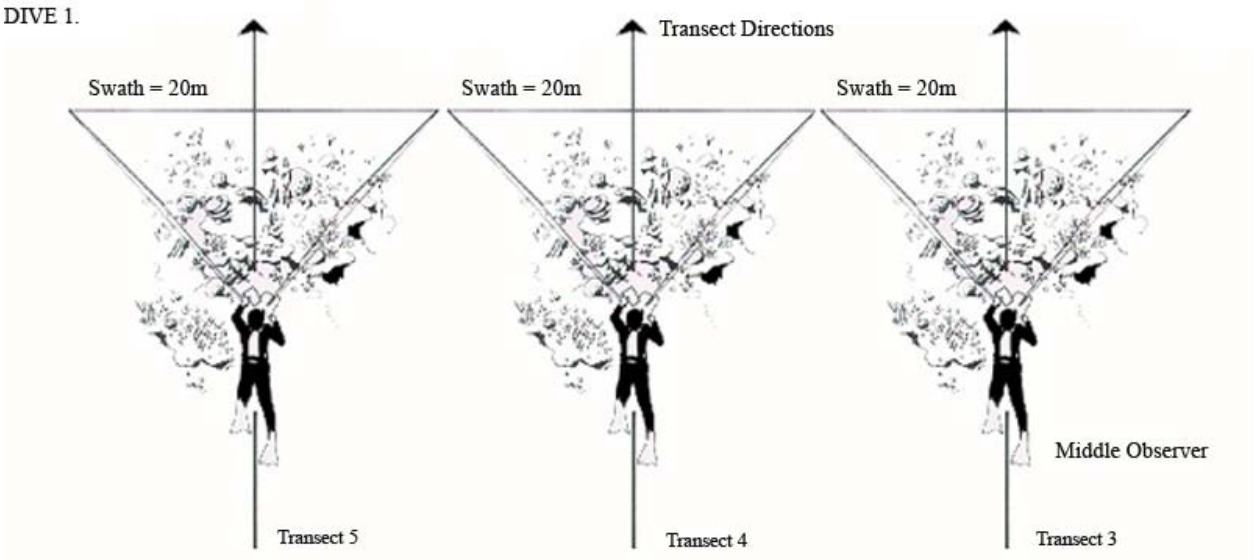


Figure 18. Observers lined up perpendicular to the reef slope on respective transects for the first dive, covering transects 5 (substrate approximately 30 m deep), transect 4 (substrate app. 25 m deep) and transect 3 (substrate app. 20 m).

The entire aggregation site for the groupers can be achieved by completing a total of 5 transects (1-5). This is most efficiently done by having three diver/observers conducting two dives each, with one of the divers (in the central transect, 3) swimming the same transect twice. This central diver acts both as a visual anchor for the other transects (see below) and also provides a duplicate fish count on each survey day. The three observers synchronize their start time and begin to swim. Maintaining the respective 20 m distance from each other (this can be done following measuring with a tape and practice) perpendicular to the reef slope, the three

observers begin swimming through the aggregation, starting at a point where none of the three species of groupers are present. Gradually, more and more grouper species are detected, until the numbers of individuals present stated to decline, to the point where no more groupers were present at the end of the transect. This would mark the completion of Dive 1 (Figure 8); this dive was conducted first because it involved the deeper areas of the site. Dive 2 would be completed using the same technique as Dive 1, with the observer from Transect 3 completing a replicate of Transect 3, the observer from Transect 4 would switch to Transect 2, to the immediate right side of Transect 3, and the observer from Transect 5 would shift over to Transect 1 (Figure 9). The survey would commence and be completed the same way as in Dive 1. The combined transects, inclusive of 20 swath widths (i.e. divers counting up to 10 me either side of the transect line), 1-5, covered the full length and width of the aggregation. The aggregation ranged in substrate depth from 6 m to about 30-35 m. The full area survey area was 100 m wide by 650 m long for a total survey area of 65,000 m² (Figure 10).

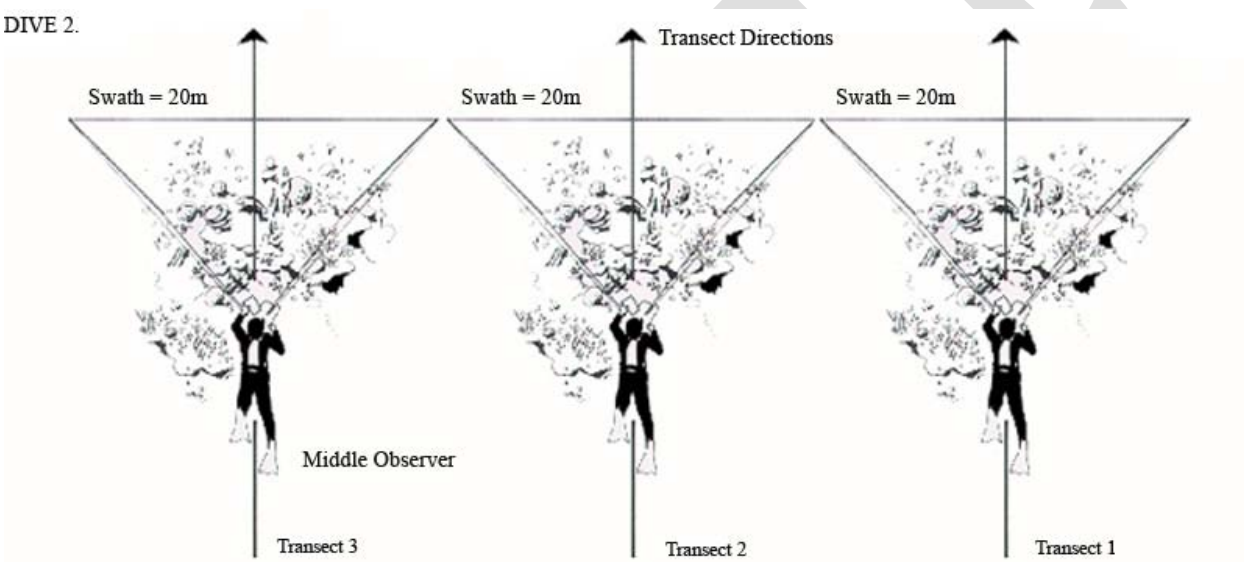


Figure 9. Observers lined up perpendicular to the reef slope on respective transects for the first dive, transect 3 (substrate app. 20m), transect 2 (substrate app. 15 m) and transect 1 (substrate app. 6-10 m).

When the logged data from the GPS units are downloaded using Garmin Map Source World Map software, a continuous track of the survey swim and area surveyed are recorded. Using the time log recorded from the observers wrist watch and the times of fish observations, the position on the track of any fish, or any area or other item of interest was observed, can be determined from the time and position data. The distance (and thereby the area depending on swath width) covered during a given survey is documented and the number of fish observed provides a density (fish per unit area) value. The survey track and positions of fish, aggregations or areas of interest along that track can be plotted on habitat maps, satellite images or other

backgrounds (Figure 10, 11) (Colin, 2006). Plots can also be made of fish densities and locations on the site. Notes were taken opportunistically on Maml, *Cheilinus undulatus*.

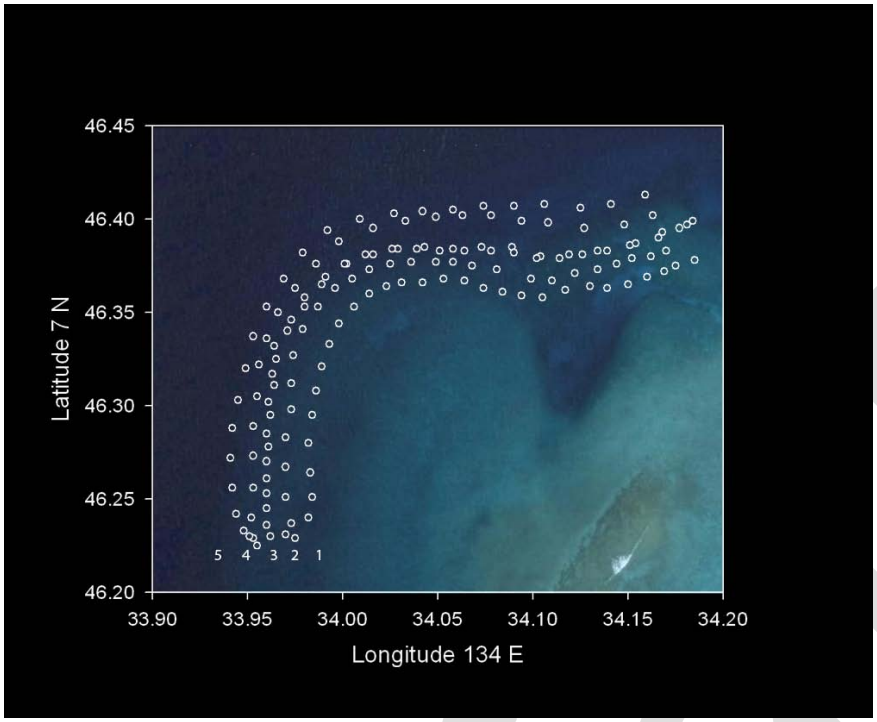
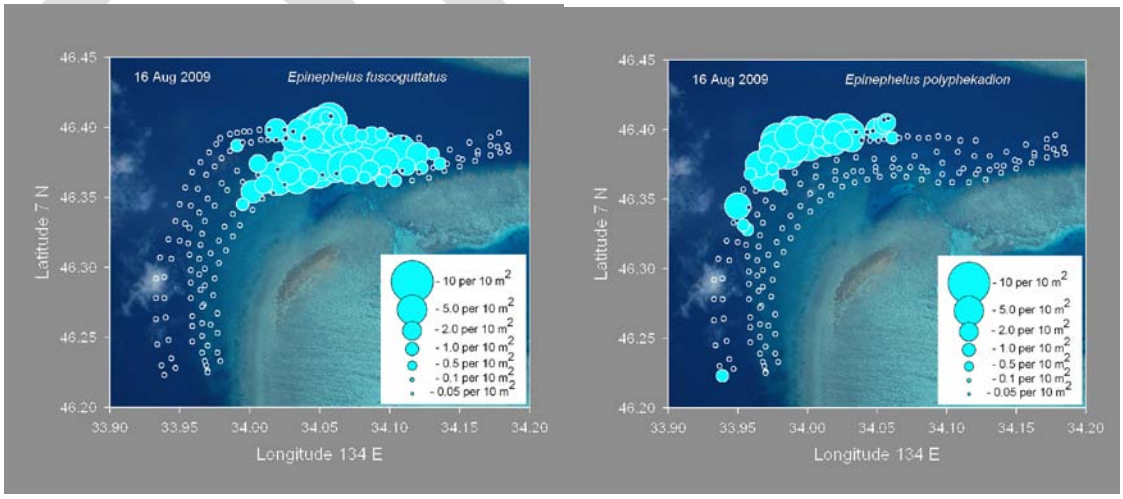


Figure 10. All 5 transects, geo-referenced on a satellite image depicting the entire area surveyed on one day by 3 divers and two dives – note that transect 3, the middle transect, is duplicated.



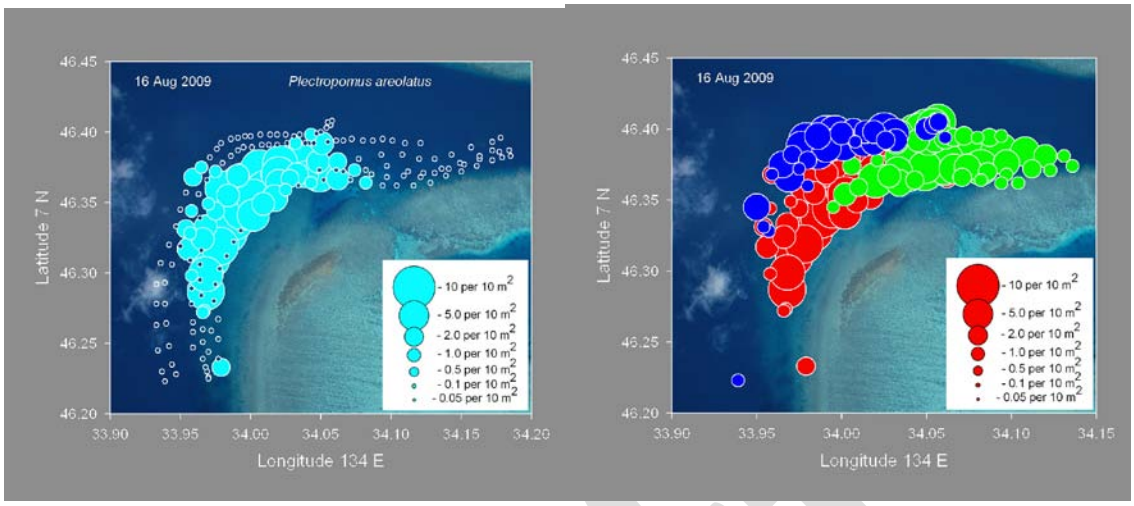


Figure 11. The 3 target species monitored at the Ebiil site (upper two images and lower left); composite picture (lower right) *P. areolatus* (red), *E. fuscoguttatus* (green), *and E. polyphekadion* (dark blue). Individual species are also shown individually in the light blue images. The circles indicate fish density as depicted by the diameter (see legend) of the circles. The blue circles

1.4 Results

Objective 1. *To characterize the Ebiil spawning aggregation in terms of area, timing in year that aggregations occur and grouper species aggregating while establishing a baseline for future work.*

To accomplish this objective, the team counted the number of aggregating fish for each species throughout the entire aggregation area, transects 1-5, throughout April-September 2009, during the 6 days of when numbers were highest at the site, based on previous studies (i.e. day 4 before new moon to day one after new moon inclusive). In 2009, the maximum number of fish on the site, all three species combined, was in July, 2009, when about 1,300 fish were present. These counts were taken along the GPS transects and data plotted as densities to show the areas at the aggregation sites that have the highest concentration of each respective species (Fig. 11. It is clear that different species concentrate in different areas of the aggregation site and that this observation applied consistently across all survey months. It is noteworthy that aggregations continued into August for all three species, and occurred at much reduced numbers in September for two of the three species (Figure 12).

In addition to the groupers present at the site, there were consistently up to about 10 maml present, often centred in the same particular area. On a number of occasions, male courtship behaviour was seen and it is very likely that the centre of the study site accommodates a small spawning aggregation of maml.

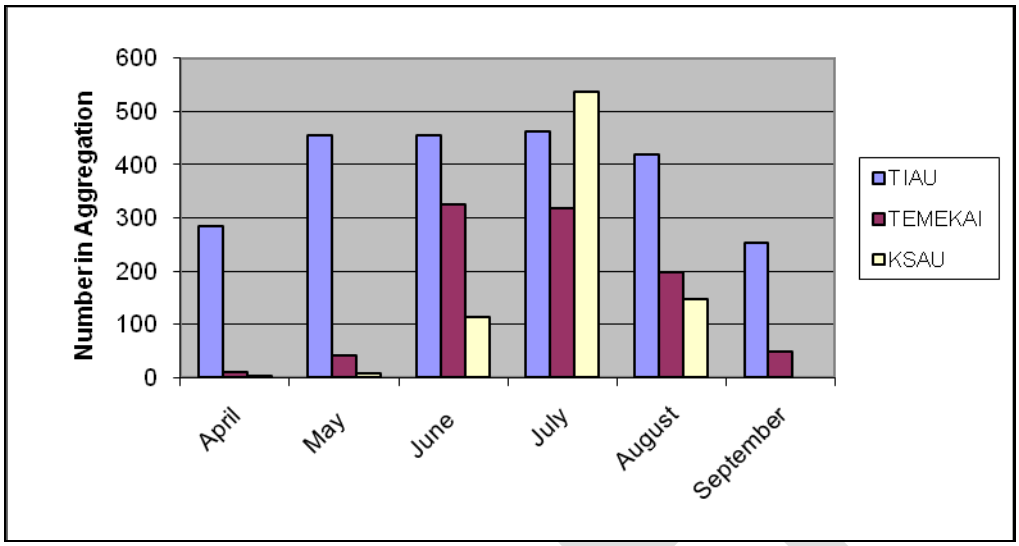


Figure 12. Number of Tiau, *P. areolatus*; Temekai , *E. fuscoguttatus, and* Ksau, *E. polyphekadion* recorded on the one day in each month that the maximum number of fish was counted within the entire Ebiil aggregation area during the 2009 survey.

Objective 2. *To develop a robust and practical sampling protocol for efficient and long-term monitoring of the Ebiil, or aggregation areas in general, to assess the outcomes of its conservation for groupers.*

Multispecies spawning sites that often contain three species of grouper throughout Palau are common; *P. areolatus, E. polyphekadion*, and *E. fuscoguttatus* and Ebiil is no exception. Although the general location and timing of the aggregations of the 3 species coincided, there were clear localized differences between species sharing the sites with respect to habitat, depth, and seasonality of spawning. (Sadovy et al. 2008) .At the Ebiil site during the 2009 sampling, highest numbers of fish overall were centred around July, with lower numbers in June and August and even lower before and after these months. Tiau had the longest spawning season, from April to September, and Ksau, the shortest one, from June to August, of the three species.

A consistent and practical long-term sampling protocol for groupers to assess their ongoing status in Palau, therefore, would need to include the following elements, assuming that 2009 is a typical year for the species:

- *Months to sample*: to ensure sampling of all three species, at least June, July and August should be consistently sampled.
- *Lunar days to sample:* at least three days per lunar cycle (i.e. days 4, 3, and 2 prior to the new moon) should be monitored to account for variability.

- *Frequency*: at least once every 3 years would be advisable to survey the site to determine numbers over time…more often if possible.

- *Area to sample*: it is advisable to survey the entire spawning site. Given the different distributions of the species, and their differing densities over the aggregation site, selection of a sub-area to sample would be problematic. Given the relatively small size of the site and that the central transect (no. 3) has now been permanently staked, monitoring of the entire site is a relatively easy exercise, using the methodology developed in this study, and does not need the GPS if just total numbers of each species is needed. If densities at different points of the aggregation site is the information required, the GPS method could be applied. For any new aggregation site to be sampled, a survey of the outer perimeter/boundary of the site should be conducted as a first step.

- *Who to sample*: it has become clear that a critical component of good monitoring of aggregations is consistency over time and comprehensive coverage of the aggregation area. Often aggregations are located in areas that are challenging to dive because of oceanographic conditions at channel sites, and that their often inaccessibility mean that close attention needs to be paid to logistics to ensure that comprehensive sampling is conducted on the correct days and in the same way over a long-time frame. Part of the current project aimed to train divers for future surveys. However, it seems likely that divers, like government employees, who are not regularly doing underwater survey work and who are not assigned specifically to such surveys do not form the basis for a long-term commitment to aggregation monitoring because: state staff are generally on low salary and may change jobs readily; staff like conservation officers have many duties, most of which would be given higher priority and hence may not be available on critical survey dates; the diver needs to be motivated and understand the purpose of surveying because diving conditions are often challenging and counts need to be carefully and consistently carried out; logistic support is not consistent.

Objective 3. *To facilitate future validation of other possible grouper spawning sites in Palau for conservation and management purposes.*

During the PCS/SCRFA project, the team visited one of the aggregation sites listed from the 2003 fisher interview surveys (Sadovy 2007) as a probable grouper aggregation site. At this site, West Entrance, team members swam a 570m transect with the standard 20m swath representing 11400m² and recorded the following (Table 1):

West Entrance 11400 m2		
500+	Black/Red Snapper	*Lutjanus niger/ L.bohar*
500+	Big eyed jacks	*Caranx sexfasciatus*
60	Rainbow Runners	*Elagatis bipinnulatus*
18	Cornet fish	*Fistularia commersonii*
60	Squaretail Grouper	*P. areolautus*
30	Brown marbled Grouper	*E. fuscogutattus*
2	Saddleback Grouper	*P. laevis*
1	Marbled Grouper	*E. polyphekadion*
7	Napoleon Wrasse	*Cheilinus undulatus*
1	Bump head Parrotfish	*Bolbometopon muricatum*
4	Sharks	
1	Manta Ray	
1	Hawksbill Turtle	

Table 1. Recorded species from validation dive of a potential grouper spawning area in July of 2008.

As this was just an exploratory single dive, more detailed information was not collected. However, given the relative abundance of target species, *P. areolatus* and *E. fuscogutattus*, this is very likely a grouper spawning aggregation site, which is not currently under any form of protection or management. Indeed, of the ten potential aggregation areas in the Northern Reefs identified by the fisher interviews conducted in 2003, only one receives legislated protection, the Ebiil Channel Conservation Area (Figure 13).

- For any new aggregation site to be sampled, a survey of the outer perimeter/boundary of the site should be conducted as a first step.

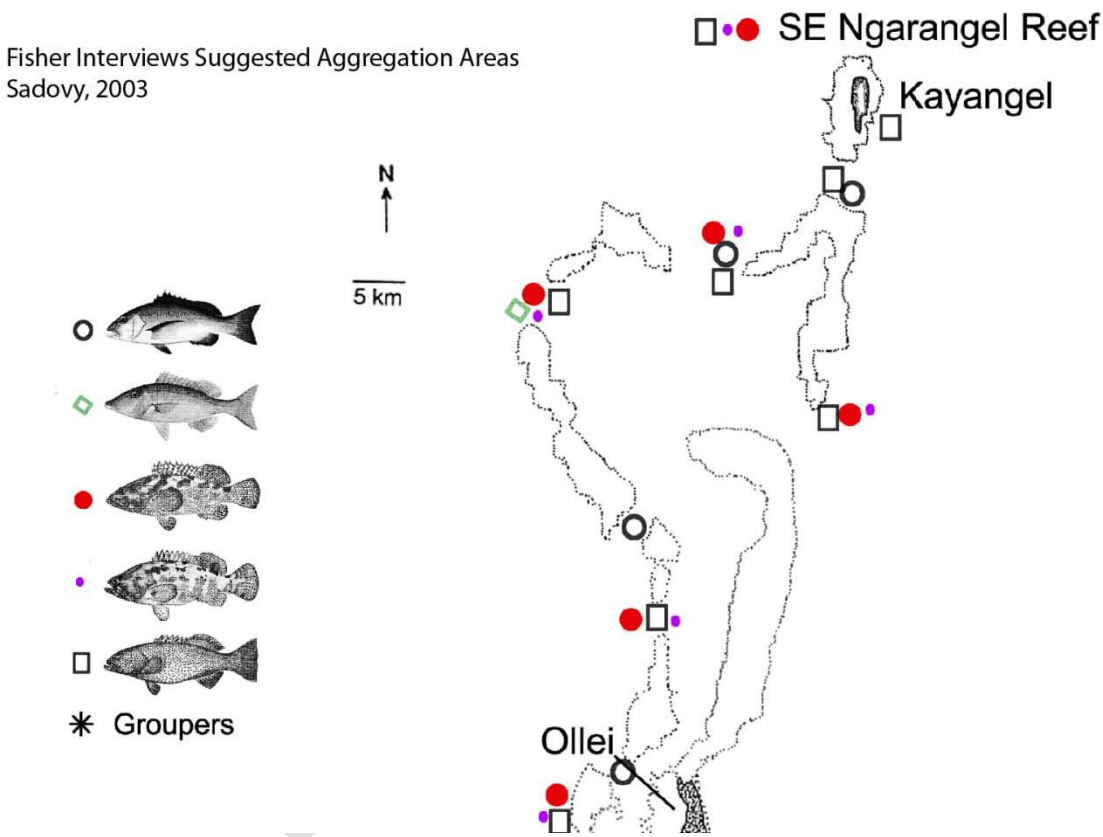


Figure 13. Map indicating potential spawning aggregation areas in the Northern Reefs reported during fisher interview surveys conducted in 2003 (Sadovy, Y. 2007; restricted version)

Objective 4. *To evaluate, retrospectively, the significance of historical sub-sampling of the Ebiil site for groupers i.e. the rebar transect used 2003-2009.*

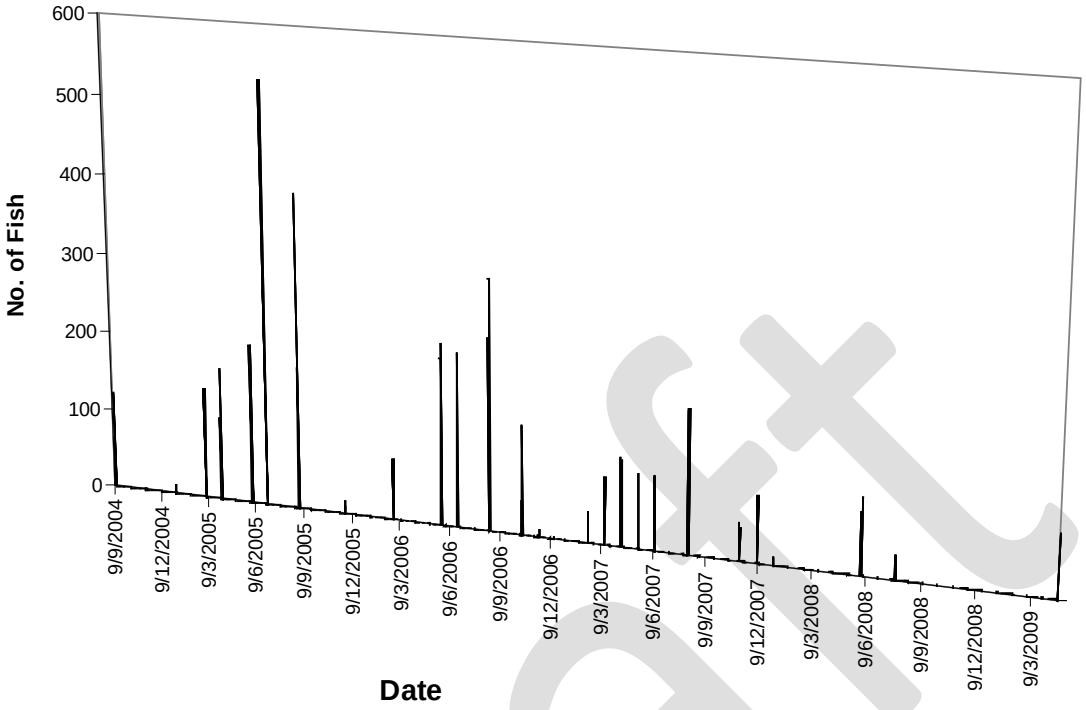


Figure 14. Data collected on numbers of Tiau, *P. areolatus* on the PCS original 200 m transect during surveys conducted monthly from 2004-2007 monthly extended to 2009 during present PCS/SCRFA collaboration for continuity (note that only the original 200 m transect data are shown in this graph). The counts depicted in the graph were all conducted by a single diver, Asap Bukurrou, from 2004-2009 inclusive, and represent the most consistent dataset from the study period. Note that this transect covers a subsample of the Tiau aggregation area at the Ebiil site.

The Ebiil site has been monitored intermittently from the early 1990s, using different methods and as part of different project. The most consistent dataset is that of PCS along a short transect (200 m) marked by metal stakes and indicated for its location in Figure 1. The data in Figure 14 strongly suggest a general and marked decline in *P. areolatus* during the period from 2005-2009, from a high of over 500 tiau in x month 2005 (the first full season monitored in the 2000s) to less than 100 in 2008/2009. Given that this short transect falls clearly within the distribution area of Tiau, if it can be assumed that Tiau typically aggregate in the same general areas each year, then this dataset strongly suggests that there has been a decline of the order of 5-fold during the 4-5 year period.

The history of Ebiil site monitoring is shown as follows and, based on the findings of the current survey in 2008/9, all approaches have fallen short of representing all species at the site of providing a comprehensive site survey. Much has been learned from these experiences over the last 20 years (Table 2) as well as about spawning aggregation monitoring in general, and it has become clear that monitoring aggregation sites can be extremely challenging. While standard survey techniques can be applied (albeit modified in the case of the GPS virtual transect in this

case), it is clear that planning of transect location is extremely important. Critically, the outer boundary of the aggregation site must be known as a first step to any survey protocol development.

Table 2

Johannes, R. 1990s

Positive Contributions

- Data was collected 10 days prior to New moon every month for 3 years
- Counts focused on only a few, select, species
- Determined the peak time of aggregations, lunar phase, annual accordance, recommendations made for complete closure of aggregation areas.

Challenging Aspects

- Transect did not capture full aggregation as we now know it 200m x ? m = ? m2, and the actual area surveyed was not known.
- Depth between 20'-60'
- Never delineated the aggregation boundaries

Golbuu, Y. Mereb, G., Merep, A. Friedlander, A. 2005-2006.

Positive Contributions

- Surveys were conducted once a month, 2-6 days before new moon for 18 months.
- Survey counted multiple species of fish.
- 5 permanent transects used.

Challenging Aspects

- Transect did not capture full aggregation as we now know it.
- Placement of the 5 transects (50m x 5m = 1250m2) do not represent the aggregation.
- Limited in scope, 1 depth set at 30'.
- Never delineated the aggregation boundaries.
- Study focused on 10 species of valuable food fish.
- Difficult to make accurate and precise evaluation of groupers in the aggregation area.

PCS 2000-2007

Positive Contributions

- Consistent monitoring every month for 2 days.
- Data collected of large time span.
- Permanent transect used.
- Many valuable lessons learned.

Challenging Aspects

- Transect does not represent full aggregation, 200m x 10m = 2000m2.
- 2 day surveys provided limited information.
- Discrepancy in data collection from various observers.

- Never delineated the aggregation boundaries.

PCS/SCRFA 2008-2009

Positive Contributions
- Know the full extent of the aggregation area.
- The increased survey time, from 2 days to 6 days, gave a much better understanding of the time duration that the grouper used the aggregation area
- Discovered a previously unknown population of spawning groupers, Ksau, *E.polyphekadion*,
- Increased awareness program helped with public's understanding of the areas importance.
- GPS method is efficient and easier for covering such a large area.
- Established a baseline for future accurate comparisons.

Challenging Aspects
- Surveys need to be regularly repeated (every 2-3 years) in a standardized way and over the long-term.
- PCS does not have the capacity to analyze the data.
- Surveys need skilled and committed divers.
- Weather conditions.

Objective 5. *To evaluate whether current seasonal closure measures are adequate for protecting spawning groupers*

To determine whether the current seasonal closure measures (i.e. April to July inclusive) are adequate for protection of the three study grouper species during the full spawning season, PCS conducted local fish market surveys to subsample groupers on sale, for size and sexual condition. The information collected can assist in better understanding the condition of the fishery, in terms of reproductive season exploitation, and fish sizes and numbers being taken in August, 2010. Such information can be used to inform management and contribute to ensuring that valuable reef fish resources continue to be available for local coastal communities.

PCS staff visits the one remaining active fish market in Palau, Happy Fish, during the days of peak aggregation activity during the month of August, when the fishing season for groupers is open. Sampling was conducted in the morning, between 6:30-7:30 am and again in the evening, between 6:30-7:30pm, to record: (1) the number and size of *Plectropomus areolatus* (Tiau), *Epinephelus polyphekadion* (Kesau or Ksau'temekai) and *Epinephelus fuscoguttatus* (Temekai or Meteungerel'temekai) present, and (2) the state of the reproductive organs. Approximately 20 fishers sell groupers to Happy Fish market and fish had mainly been caught by spear overnight and by hook and line during daylight hours (Figures 15, 16).

The results from this survey indicate that there are many grouper in the August landings that are either ripe, with well developed gonads (Fig. 17 or were close to or below the size of sexual maturation. The number of fish being brought to the market was so high that the market was completely inundated with groupers and management would no longer purchase fish. Many groupers in the market had not yet attained the size of sexual maturation (Figure 17). Grouper sizes in the subsample: Temekai 39 fish, mean length, 33 cm; Tiau 776 fish, mean length 17 cm; and Ksau 260 fish, mean length, 21 cm.

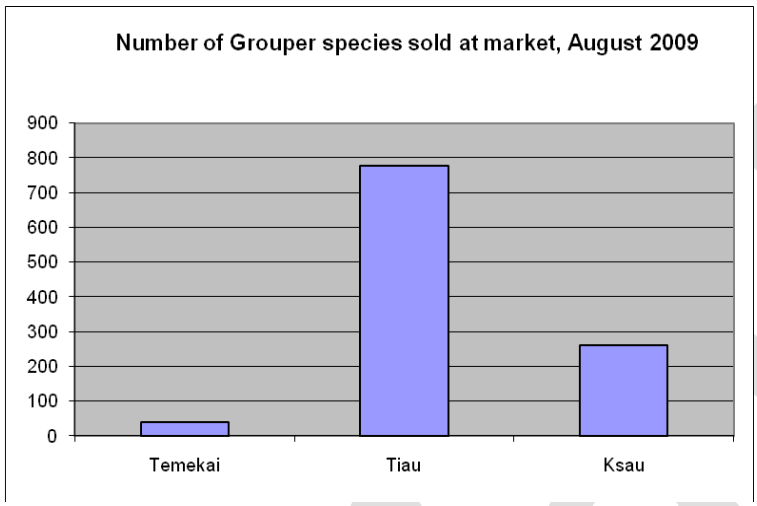


Figure. 15. Total count of groupers sampled during 14 survey days to a major fish market in Palau during August, 2009: Tiau, *P. areolatus;* Temekai, *E. fuscoguttatus* and *Ksau, E. polyphekadion.*

In the days leading up to the new moon , the time of presumed spawning, in *Plectropomus areolatus* (Tiau), *Epinephelus polyphekadion* (Kesau or Ksau'temekai) and *Epinephelus fuscoguttatus* (Temekai or Meteungerel'temekai), there was a sharp increase in the number of Tiau sold; this corresponded to the peak numbers of fish counted at the Ebiil aggregation.

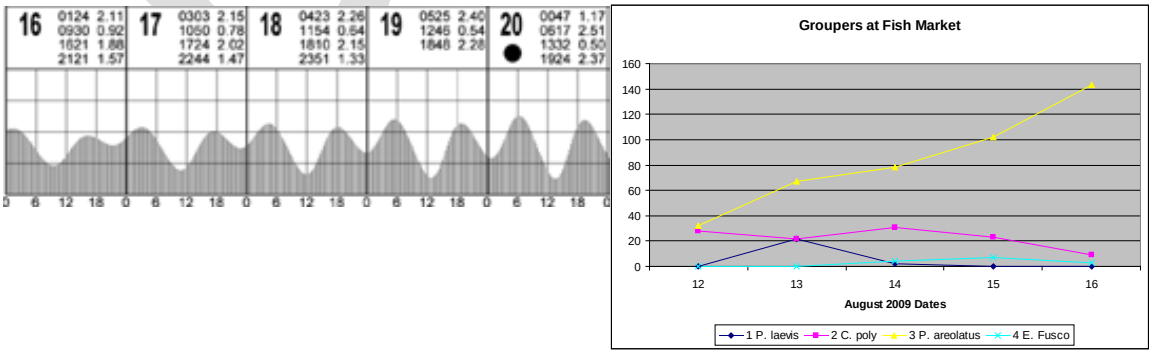


Figure. 16. Increasing numbers of Tiau, *P. areolatus*, in market in relation to the known lunar phase for peak aggregation dates in August 2009.

Figure 17. Tiau, *P. areolatus* with clearly enlarged abdomen containing ripe gonads ready to spawn August 17th, 2009, three days before the new moon.

Objective: *To provide recommendations on options for the sustainable use of grouper resources at Ebiil as part of the conservation and management of the protected area and for the benefit of the community SEE RECOMMENDATIONS BELOW*

1.5 Discussion

Spawning Aggregations used as Indicators for marine environmental health

Unchecked exploitation of aggregations will lead to negative consequences for the fish populations in question and the fisheries and livelihoods they support. Healthy aggregations indicate healthy fisheries, and aggregation loss is an important early indicator of a poorly managed fishery. One of the primary objectives of MPAs and marine reserves is to conserve spawning stock biomass. Protection of spawning aggregations is therefore essential for the maintenance of maximum spawning for a particular population. Spawning sites are also sometimes used by species attracted to prey on ripe adult spawners or on their gametes. Such include large predators (e.g., sharks, snappers, jacks, groupers) and other megafauna (e.g., rays, whale sharks) (Johannes *et al*., 1999) that are becoming increasingly scarce around the world (Myers and Worm, 2003, 2005). Protection of spawning aggregation sites therefore provides greater ecosystem protection and a more holistic ecosystem-based approach to management of marine resources than non-protection. Researchers and local fishers should work together to identify the location and timing of additional spawning aggregations to better inform future management actions. Incorporating spawning aggregations into an MPA network plan is fundamental to the successful function of the network since maintenance of healthy spawning aggregations is critical to population protection as well as ecosystem function as a whole. Protection of spawning aggregations cannot only help conserve fish stocks but also provide non-consumptive economic benefits such as ecotourism, if properly managed.

While a monitoring plan for the Ebiil Conservation Area has yet to be finalized, certain indicators can provide examples of types of information that can be collected to measure the effectiveness of management efforts. In the Ebiil Management Plan, under Objective 1,

Indicators to "Maintain important fish and invertebrate populations: the grouper aggregations are to be monitored to assess and evaluate population density, size of specific species and the overall population structure". Aggregations are key indicators of fishery stock condition and important but vulnerable species and healthy aggregations address Ecosystem Based Management & Conservation objectives. The actual methods by which the aggregation is to be surveyed at Ebiil, or for larger initiatives, such as the Protected Area Network (PAN) or the Micronesia Challenge (MC) have yet to be determined and recommendations are provided below **Enhanced Protection and Enforcement**

The findings of this survey reinforce the work of other organizations and institutions throughout Palau, clearly indicating that grouper populations around Palau would substantially benefit from an expanded closed season (addition of August), identification and protection of additional spawning sites, and enhanced community-based management and enforcement to control illegal and improper fishing practices. Long-term monitoring of the site is essential for assessment of effectiveness of management and to address any changes or concerns over time.

Unprecedented Extraction of Tiau

In addition to the market surveys done by PCS, the Bureau of Marine Resources collects data of total fish weight sold at all fish markets in Palau annually, although data on trends in landings in recent years are not available.In 2008 the total weight of Tiau sold at the fish markets in Palau was 18,908 kg. The Bureau of Marine Resources indicates that this is the highest recorded weight sold of Tiau in the ten years that they have been collecting data. By estimating the mean weight of the 776 Tiau sampled in the 2009 market survey, the estimated average weight of each Tiau sold is 2.34 kg. By dividing this average weight into the total weight sold in 2008 (18,908 kg), we estimate that about 8080 individuals of Tiau were sold at the fish markets of Palau in 2008. It is important to stress that this number is reflective only of the number of fish sold at the market and does not reflect the number of Tiau caught or consumed for private gatherings, local customs, public functions or independent sales. To put this number into context, this compares with a maximum of about 460 Tiau counted at the Ebiil site in 2009 and similar numbers recorded from other aggregations (Johannes et al, 1999). This suggests that a significant proportion of fish that aggregate to spawn in Palau might be removed from aggregations in August, many of them still reproductively active. Note that there are only about 14 or so aggregations of groupers known or suspected in Palau in total.

There have also been reports in previous years of the extraction of groupers for export from Palau as part of the live reef food fish trade. Some of the aggregations fished for groupers for this trade, reported in 2008, was by illegal means; i.e. poaching.

Designing Surveys and Monitoring Aggregations in Palau

Knowing the total aggregation area is fundamental in being able to effectively monitor grouper population dynamics. The PCS/SCRFA study shows that not only is *E.polyphekadion* present at the Ebiil aggregation site, but their numbers exceed that of *P. areolatus* and *E. fuscoguttatus*. Neither the PCS methods, nor the methods designed by Golbuu, Y.et al. (2008) represent the full area or populations of groupers. When surveys are designed that do not take

into consideration the entire aggregation area, or the spatial dynamics in the densities of fish as they move within the aggregation temporally, they do not representatively the fish gathering at the site and therefore their meaning is unknown.

1.6 Recommendations

Despite significant advances in the general understanding and awareness of the problems faced by reef-associated fisheries and the need to manage them, significant challenges remain to achieving sustainable management of aggregating species. Like many places the community that manages Ebiil needs to make decisions about the use of this valuable resource.

General comments on utilization of the Ebiil MPA for best community benefit in the long term

1. Ebiil channel is a spawning aggregation site for three locally important species of grouper, at least one of which appears to have undergone a substantial reduction over the last 5 years. This suggests either that poaching at the site is occurring or that overfishing in general on the species outside of the spawning season, and probably outside of the Ebiil is excessive. Certainly, the fact that so many small tiau, below sexual maturation, are being found in the market is a strong indication that the stock as a whole is being overfished. Hence, the exploitation of this, and probably other grouper species which share a similar biology, should not be allowed at all from aggregations. Ebiil should be maintained as an important aggregation site for the species; through the spawning behavior young fish for fishing outside of the Ebiil area for local communities are provided. Ebiil channel is also almost certainly a spawning site for the threatened and protected Maml.

2. Ebiil channel is a highly attractive, biologically important and interesting site. In addition to maml and groupers, large groups of triggerfish spawn at the site and large *P. laevis* may be seen. The coral is in very good condition. A major benefit to the guardians of Ebiil could be in diving tourism. However, Ebiil (south entrance) is not a particularly large area and uncontrolled diving activity could significantly damage corals. Moreover, it is possible that large numbers of divers could negatively affect reproductive activity of important commercial fish. Therefore, it is suggested that any diving activity permitted be low-volume and carefully managed. Moreover, it would be important to closely monitor the area where diving is occurring to register any changes due to diving activity and manage accordingly. In reality diving activity is very difficult to control and sufficient funds and adequate training for the necessary training in capacity enforcement would need to be identified.

3. Ebiil should be considered an important source of productivity for surrounding fisheries. However, the channel mouths are a small area and, therefore, any planned future use should <u>not be extractive</u>. Fishing pressure is already too high in Palau to sustain the more vulnerable reef fish species like groupers, and certainly increased use should not be encouraged, at least not until the reef resources as a whole have been properly managed and poaching has stopped. It should be noted that sport/recreational catches, even if fish are released will almost certainly cause significant fish mortalities.

Catch and release, without close supervision and adequate training, while appealing, in practice is likely to be counter productive; it is likely to diminish resources, result in enforcement challenges in relation to non recreational uses and be expensive to manage properly.

4. Decisions need to be made about the priorities of the community in respect of marine resources. It is not possible to have 'it all'. If fish are needed for local food and livelihoods then fisheries, and special biological areas such as spawning aggregations, need to be protected, as 'bank deposits' or 'larders' to generate fish for non-spawning times and into the future. Moreover, given that Palau has relatively few known or suspected spawning sites for groupers, with only about 6 in total for the Northern Reefs, then each one should be highly valued for its fishery supply importance, and managed accordingly.

General recommendations on use and monitoring of spawning aggregations of commercially significant reef fish species.

1. All grouper spawning aggregations should fall within the boundaries of an effectively managed MPA.

2. The national ban on the harvest, sale, purchase, or possession of vulnerable grouper species should be extended to cover the entire year for at least the next 5 years. This would employ a measure known as 'precautionary principle', where there is evidence of potential harm in the absence of complete scientific proof, in this case, the extinction of grouper species in Palau. The principle implies that there is a social responsibility to protect against potential harm or destruction, when scientific investigation has found a plausible risk.

3. MPAs need to be effectively managed and enforced. MPAs that incorporate ALL the spawning aggregations in Palau would help to curb the spectacular decline of some of these species in Palau. Of the known 14 spawning aggregations sites for groupers in Palau, 6 fall within the boundaries of legislated protected areas. The level at which these areas are 'effectively' managed is up to debate. However, with the data showing that there is a dramatic increase in grouper species sold at the fish market correlated with the known grouper aggregation time in August it is evident that the groupers are being targeted during the spawning time.

4. A national and potential regional protocol that captures the special and temporal characteristics of grouper aggregations needs to be developed as soon as possible utilizing the lessons learned from the work at Ebiil over the past twenty years. Monitoring should be conducted as frequently as possible at all sites. Of the known 14 spawning aggregations sites, currently zero receive consistent monitoring.

5. There needs to more research conducted on the grouper spawning aggregations in Palau. In addition, increased monitoring of the existing aggregations needs to be done to effectively gauge not only the health of the species, but also the health of the marine ecosystems.

6. Multiple management measures, including non-aggregation management for targeted aggregating species, are often needed. MPAs are not enough because they do not manage fishing effort and it is too high fishing effort that leads to overfishing. Particular attention should be paid to those species that aggregate for very short periods and occupy few known spawning sites or are also taken at non-aggregation times.

7. A lack of understanding of adult and larval connectivity among aggregating species makes it difficult to effectively apply spatial protection measures, and additional measures should be considered.

8. Every effort should be made to validate reports of spawning aggregations when only indirect evidence is available by directly sampling catches for gonad inspection or by observing spawning.

9. Specific recommendations in relation to aggregation monitoring at Ebiil.

- Put in regular permanent stakes, ideally numbered, for consistent surveying of extended old survey and for easy transfer among different surveyors (divers).
- An extension of the old transect both shallow and deep and lengthwise will cover the transect which can be readily surveyed in two sweeps by 3 divers not exceeding a depth of 25 m (in deepest point) – total of 5 surveys will cover the entire site and is easily completed in two dives. It is important that the full extent of the aggregation is surveyed.
- The northern side of Ebiil channel mouth should be checked for possible aggregation.
- Swath width should be periodically measured with a tape as a reminder to divers of the distances being surveyed.
- Suggest that all swaths be the same at 20 m unless visibility is too low.
- At a minimum, detailed surveys should be continued for all aggregating months (April-August inclusive based on previous work at Ebiil and also on fisher interviews) to capture variability in numbers. During each of these 5 months, surveys should ideally start prior to buildup and end as numbers decline i.e. starting on day 5 before New moon and continuing to one day after new moon. This would be a total of 6 days for 1 month in 2008 and 5 months in 2009 for a total of 36 dive days. There should be at least three competent divers for each survey day during this period. At an absolute minimum 3 sampling days per month is recommended (see above).
- The information resulting from detailed surveys would be an excellent baseline for this important conservation area and provide guidance for other areas in northern reefs. The information gained here on timing and locations would make it easier to more efficiently survey other sites for aggregation validation.
- Ideally all surveys should be with GPS and three divers swimming 5 transects but a timed swim with trained divers could be substituted according to the (timed/distance area) method. The 5 transects should be swum irrespective of

method chosen. Some spatial detail would be lost without GPS and the divers would have to work very closely together, but if there are concerns about consistent use of GPS then this is one option to consider.

- Based on the 2008/9 data to be collected, it should be possible to determine a more refined and simpler survey method for surveying from 2010 onwards.
- It would be valuable to consider tagging studies in the future to determine how far the fish that assemble at Ebiil travel from home reefs to determine adult fish connectivity and assist in MPA boundary design. Such information might also illustrate that States share the same fish stocks.

Benefits of conducting detailed surveys to establish a solid baseline for future work in relation to conservation efforts.

1. A proper baseline allows for the assessment of effectiveness of management and decisions and for adaptive management by reliably assessing aggregation numbers. Our surveys, for example, indicate that there is well over a magnitude of difference between previous and current estimates of fish numbers and, importantly, that a single survey line would not reflect changes in two species at the site and is unlikely to be sensitive to changes in the third until aggregation size has changed markedly.
2. The information collected can be used to make assessments (through modeling) of the possible contribution of the aggregation site to the overall fishery (i.e. 'interest' generated or 'spillover'); this is very important for demonstrating why such sites need to be protected and what benefit they confer to the State and beyond.
3. Understanding what is happening in August is important for supporting the need to include protection of August as an aggregation month (this is according to indications from other studies and from fisher interviews, and which continued monitoring at Ebiil could confirm). This would also help in managing other aggregation sites in the northern reefs.
4. A well-studied site will provide information that will assist in other surveys in the area (will help with picking times and places likely for aggregation) and provides an opportunity for regular surveying of the site for other key and vulnerable species (in addition to grouper, we were also able to survey Maml and Kemedukl (*Bolbometopon muricatum*) for which there is little field information in Palau and in which there is interest. The site is very likely an aggregation area for Maml.
5. There is enormous value in having demonstration sites that become well-known and understood both within and outside of a country. These can be a source of pride and generate national international interest and exposure. Very few aggregation sites anywhere in the Pacific have been studied with any intensity and so sites in Palau (Ulong and Ebiil) could become leaders in this sense. It is very important to have confidence in the scientific basis of marine studies to support management. It is strongly suggested that comprehensive expert surveys of Ebiil are conducted at least once every three years. SCRFA is available to assist if invited.

References

Colin, P. L., Sadovy, Y. J. & Domeier, M. L. 2003. Manual for the Study and Conservation of Reef Fish Spawning Aggregations. Society for the Conservation of Reef Fish Aggregations. Special Publication No. 1 (Version 1.0), pp. 1-98 (www.scrfa.org).

Colin, P.L.. T.J. Donaldson and L.E. Martin. 2005. GPS Density Surveys: A New Method for Quantitatively Assessing Reef Fish Spawning Aggregations (and other populations of reef fishes).
(Abs.) Seventh Indo-Pacific Fish Conference. Taipei.

Ebiil Management Plan. 2009.

Golbuu, Y. Mereb, G., Merep, A. Friedlander, A. 2009. Spatial and temporal characteristics of multi-species grouper spawning aggregation sites in Palau: differences in age of closure, species composition and abundance.

Johannes, R. E. 1994. Unpublished Results of Ebiil Channel Spawning Aggregation Study. Palau Marine Resources Division Technical Report in collaboration with Ngarchelong State.

Johannes, R. E., L. Squire, T. Graham, Y. Sadovy and H. Renguul. 1999. Spawning aggregations of groupers (Serranidae) in Palau. The Nature Conservancy Marine Research Series Publication No. 1: 144 pp.

Marine Protection Act. 1994. RPPL No. 4-18. Fourth Olbiil Era Kelulau.

Mersai, C., Severance, C.J., 2008. Introductory Handbook for Biological and Social Monitoring of MPAs in Palau.

Sadovy, Y (Ed). 2005. Napoleon Fish (humphead wrasse), *Cheilinus undulatus*, trade in southern China and underwater visual census survey in southern Indonesia. *IUCN Groupers & Wrasses Specialist Group*. 26 pp. Reported submitted by Patrick L. Colin, Coral Reef Research Foundation.

Sadovy, Y. 2007. Report on current status and exploitation history of reef fish spawning aggregations inPalau. Western Pacific Fishery Survey Series: Society for the Conservation of Reef Fish Aggregations, Volume 3. SCRFA and the Palau Conservation Society.

Sadovy de Mitcheson, Y, Cornish, A., Domeier, M, Colin, P., Russell, M. & Lindeman, K. 2008. A Global Baseline for Spawning Aggregations of Reef Fishes *Conservation Biology*. 22(4, 5):1233-1244.