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Palau Spawning Aggregation Monitoring Training Workshop Report

Koror, Republic of Palau, 18-30 June, 2003

Prepared by:
Kevin L. Rhodes, Ph.D.
Workshop Facilitator & Trainer

For the Pacific Island Countries Coastal Marine Program
The Nature Conservancy

Author Contact Details:
Kevin L. Rhodes: Pacific Marine Science and Conservation, 160 Conaway Ave., Grass Valley, California 95945, USA.
Email: klrhodes_grouper@yahoo.com

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Indo-Pacific Resource Centre
The Nature Conservancy
51 Edmondstone Street
South Brisbane, QLD 4101
Australia

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Cover photo: A group of camouflage grouper, *Epinephelus polyphekadion*, at Ngerumekaol (Ulong Channel) spawning aggregation site. (A Smith). End photos: Andrew Smith

TABLE OF CONTENTS

Table of Contents ii
List of Figures ii
List of Tables ii
Background 1
Target Fish Species 2
Training Sessions and Materials 3
Workshop Participants 3
Monitoring Training and Observations 3
Training Skills: Mapping and Transect Placement 4
Training Skills: Abundance Counts and Length Estimation 4
Training Skills: Spawning Signs and Behavior Associated with Aggregations 7
Observations: Distribution, Density and Abundance 9
Recommendations Based on Findings 11
Monitoring 11
Diver Disturbance 12
Area Closure 13
Sales and Catch Ban 13
Concluding Remarks 13
References 14
Appendices 15
Appendix 1: Participants in the Spawning Aggregation Training Workshop, Koror, Palau 15

LIST OF FIGURES

Figure 1: Target species for the Ngerumekaol monitoring training workshop 2
Figure 2: Trainee counting fish within a transect at Ngerumekaol spawning aggregation 5
Figure 3: Sample abundance data sheet (truncated) taken from actual counts of camouflage grouper at Ngerumekaol on lunar day 27 5
Figure 4: Abundance data trends for camouflage grouper taken from counts by participants at Ngerumekaol Channel. 6
Figure 5: Abundance data trends for brown-marbled grouper taken from counts by participants at Ngerumekaol Channel.. 7
Figure 6: Gravid female camouflage grouper 8
Figure 7: Territorial disputes and color change in camouflage grouper 8
Figure 8: Color change in a male brown-marbled grouper 9
Figure 9: Mean and standard deviation abundance for camouflage grouper 10
Figure 10: Mean and standard deviation abundance for brown-marbled grouper 11

LIST OF TABLES

Table 1: Abundance counts (per 1000 m^2) for camouflage grouper from Ngerumekaol during the training exercise. 6
Table 2: Abundance counts for brown-marbled grouper from Ngerumekaol during the training exercise. 7

BACKGROUND

Among coral reef fishes, those most susceptible to over-fishing are some of the commercially important members of groupers (Serranidae) and wrasse (Labridae) that form spawning aggregations. These fishes, and many others, aggregate to spawn at predicable sites and times and are often heavily targeted by fishers. As a result of heavy fishing on spawning aggregations, aggregation loss, declines in genetic diversity and altered reproductive output have been recorded, with the potential for alterations in trophic food webs and coral reef ecosystems.

The vulnerability of spawning aggregations to over-fishing is now widely recognized, as is the need to conserve and manage some fish populations at the aggregation level. To design meaningful management and conservation protocols and examine the effects of conservation actions on populations forming spawning aggregations, some form of monitoring is usually required. Toward this end, The Nature Conservancy is conducting spawning aggregation monitoring training workshops among areas of the western Pacific that are being affected by local or commercial overfishing. Workshops focus on areas affected primarily by the live reef food fish trade (LRFFT). The workshops are designed to promote an awareness of the importance of spawning aggregations and their vulnerability, and to introduce local resource managers and conservationists to basic monitoring techniques for identifying, recording and responding to changes within spawning populations.[1]

The following report highlights monitoring skills training exercises and findings from the 18-30 June 2003 monitoring training workshop conducted at Palau International Coral Reef Center and Ngerumekaol (Ulong Channel) grouper spawning aggregation site, Koror State, Palau. The monitoring training program introduced basic data-gathering techniques to practitioners for managing spawning aggregations, including the determination of reproductive season, identification of spawning aggregation sites, site mapping and area determination, species identification and aggregation behavior, species abundance and fish length estimation and data collection, processing and analysis. The workshop focused primarily on the use of underwater visual census techniques and was designed to accommodate local resource managers interested in establishing long-term monitoring programs for management and conservation purposes.

[1] The workshops are a part of a larger project that The Nature Conservancy has received funding from the East Asia and Pacific Environmental Initiative (EAPEI) through the Office of Strategic Planning, Operations and Technical Support, Bureau for Asia and the Near East, U. S. Agency for International Development, the Packard Foundation, and the Oak Foundation to conserve coral reef biodiversity by reducing the depletion of aggregating reef fish in Pacific Island countries. This project aims to improve resource management and spawning aggregation site protection, increase awareness of these resources' vulnerability to over-exploitation, and enhance capacity to manage reef fish spawning aggregations and MPAs that incorporate these sites. It has three objectives: (1) to develop and facilitate the application of cost-effective management controls on the exploitation of aggregating reef fish resources; (2) to strengthen the capacity to assess, monitor, and manage aggregating reef fish resources; and (3) to raise the awareness and appreciation among stakeholders of the vulnerability of aggregating reef fish populations and associated ecosystems, the nature and significance of spawning aggregations, and options for improving management.

TARGET FISH SPECIES

The monitoring training program focused on three species of grouper (Family Serranidae). Those species observed aggregating during training exercises include the brown-marbled grouper, *Epinephelus fuscoguttatus* (Figure 1.1), squaretail coralgrouper, *Plectropomus areolatus* (Figure 1.2) and camouflage grouper, *E. polyphekadion* (Figure 1.3).

Figure 1.1
Latin: *Epinephelus fuscoguttatus*
FAO: Brown-marbled grouper
Palau: Remochel, hludel or meteungerel
(temekai = general name for large *Epinephelus* spp.)

Figure 1.2
Latin: *Plectropomus areolatus*
FAO: Squaretail coralgrouper
Palau: Tiau (general name for *Plectropomus* spp.)

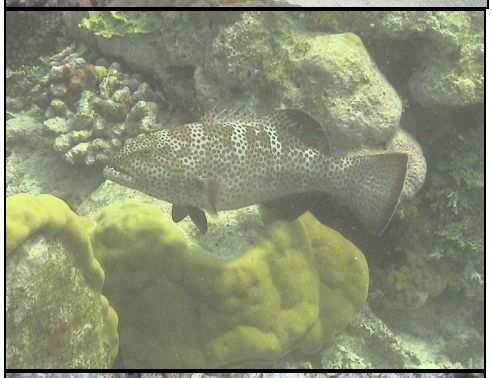

Figure 1.3
Latin: *Epinephelus polyphekadion*
FAO: camouflage grouper
Palau: Ksau
(temekai = general name for large *Epinephelus* spp.)

Figure 1: Target species for the Ngerumekaol monitoring training workshop (A Smith)

TRAINING SESSIONS AND MATERIALS

Workshop training sessions focused on the skills necessary to conduct basic monitoring of spawning aggregations. The skill sessions included:

1. Fish species identification
   - Still photographs
   - Plastic identification cards (SPC/TNC/IMA)
   - PowerPoint® presentations
   - Underwater video (Pohnpei and Dyaul, Ngerumekaol)
   - Printed references (e.g. Micronesian Reef Fishes, Robert Myers; LRFFT Awareness package poster, SPC/TNC/IMA)

2. Fish length estimation
   - Wooden fish models

3. Spawning signs
   - Underwater video (Pohnpei and Ngerumekaol)
   - PowerPoint® presentations
   - On-site training and recognition

4. Abundance counts
   - Underwater monitoring on aggregation sites
   - Classroom presentation using video

5. Site mapping: tools and techniques
   - Classroom presentations
   - Site-based mapping

WORKSHOP PARTICIPANTS

Participants from national and state government agencies and local non-government organizations (NGOs) participated in the workshop. Participants and their affiliations are as follows (contact details given in Appendix 1):

1. Palau Conservation Society—Jason Kuartei, Valentino Kloulechad
2. Bureau of Marine Resources—Harvey Renguul, Roman Mongami
3. Palau International Coral Reef Center—Jim Kloulechad, Dave Idip, Asap Bukkurou, Masao Udui
4. Koror State Rangers—Rengechel Dlutaoch, Mista Moros, Dr. Kathy Chaston
5. Helen Reef Resource Management Program—Dominic Emilio, Ken Tarkong, William Andrew

MONITORING TRAINING AND OBSERVATIONS

At Ngerumekaol, spawning aggregations of the three target species vary in duration within the year. Squaretail coralgrouper aggregations form monthly in relatively small numbers in comparison to some other sites investigated in Palau and elsewhere (Johannes *et al*. 1999). By contrast, spawning aggregations of brown-marbled grouper form from May to August and camouflage grouper from June to July. Annual variations in the seasons and months occur. June and July are common spawning months to all species at Ngerumekaol and June was chosen as the month for conducting training.

TRAINING SKILLS: MAPPING AND TRANSECT PLACEMENT

At Ngerumekaol, monitoring training began with site mapping. Site mapping skills training involved (1) recognizing aggregation boundaries, (2) marking boundaries with floats and lines visible both underwater and at the surface, and (3) measuring and calculating aggregation areas based on the markers.

Optimally, site mapping should be initiated and completed during the days of maximum abundance for each individual species. During the training workshop, site mapping was conducted prior to the days of peak abundance owing to time constraints to complete all skills training. Therefore, total areas for each species' aggregation was calculated as approximate for the purpose of estimating total abundance. Rough estimates for camouflage grouper based on the mapping exercises placed the aggregation at approximately 20,000 m^2 (177 m x 112 m). Approximations for aggregation area of brown-marbled grouper were 10,000 m^2 (100 m x 100 m). No estimates were made for squaretail coralgrouper.

The placement of transects was the second major skills training exercise performed at Ngerumekaol. Trainees learned (1) how to determine where to place transects within aggregations, (2) how to measure transects within aggregations, (2) simple methods for marking and identifying transects underwater and at the surface. For the workshop, transects were placed in areas that appeared to be the core area, or area of highest density.

TRAINING SKILLS: ABUNDANCE COUNTS AND LENGTH ESTIMATION

Upon completion of transect placement and site mapping, trainees learned to perform abundance counts on each of the three species, based on two 1000 m^2 (100 m x 10 m) transects placed within the aggregation core (Figure 2). Trainees were familiarized with simple methods for coding data and counting fish in large aggregations. A sample data collection sheet from the Ngerumekaol aggregation site is shown in Figure 3. Following data collection, trainees learned methods for data input, analysis and presentation.

Abundance counts at Ngerumekaol varied widely by individual (Table 1), but provided a similar profile to that found by previous investigations (Johannes *et al.* 1999). Figure 4 shows abundance trends for camouflage grouper that suggest peak abundance on Lunar Day 26 and spawning possibly occurring over two, or possibly three nights (Lunar Days 26 to 28). For brown-marbled grouper, spawning likely occurred on Lunar Days 26 and 27, indicated by the sudden drops in abundance on those days, although spawning could have also occurred on the day of initial monitoring or before (Figure 5).

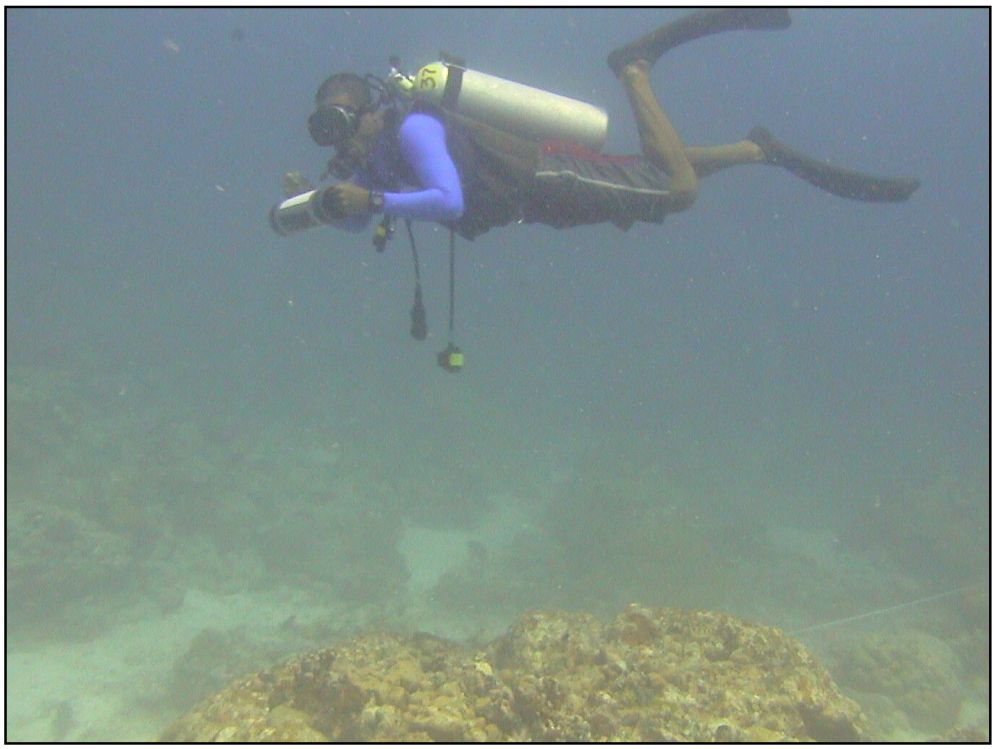

Figure 2: Trainee counting fish within a transect at Ngerumekaol spawning aggregation (A Smith)

Site #: 1, Ngerumekaol Time: 1330		Date: 26/06/03
Species #: 2, *Epinephelus polyphekadion*		Transect #: 1
Observer: Asap Bukkurou Visibility: 20 m		Lunar date: 27
Group	Frequency	Total
1	IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII II	52
5	IIIII IIIII IIIII IIIII II	110
10	IIIII IIIII IIIII	150
20	II	40
50		0
Total		352

Figure 3: Sample abundance data sheet (truncated) taken from actual counts of camouflage grouper at Ngerumekaol on lunar day 27

Table 1: Abundance counts (per 1000 m^2) for camouflage grouper from Ngerumekaol during the training exercise.

	Participant							
Lunar Day	Asap	Masao	Kevin	Ren	Harvey	Jim	Mean	St. dev.
26	279	226	367	480	270	138	286	59.1
27	352	372	288	375	293	150	326	42.1
28	233	270	200	335	290	174	248	39.9
2	7	8	8	13	9	---	8	0.8

Length frequencies training for the workshop used wooden fish models. Training involved both dry (land-based) training and underwater training. However, for training, length frequency estimations at the Ngerumekaol site were not performed and dry training was covered during a two dive training periods.

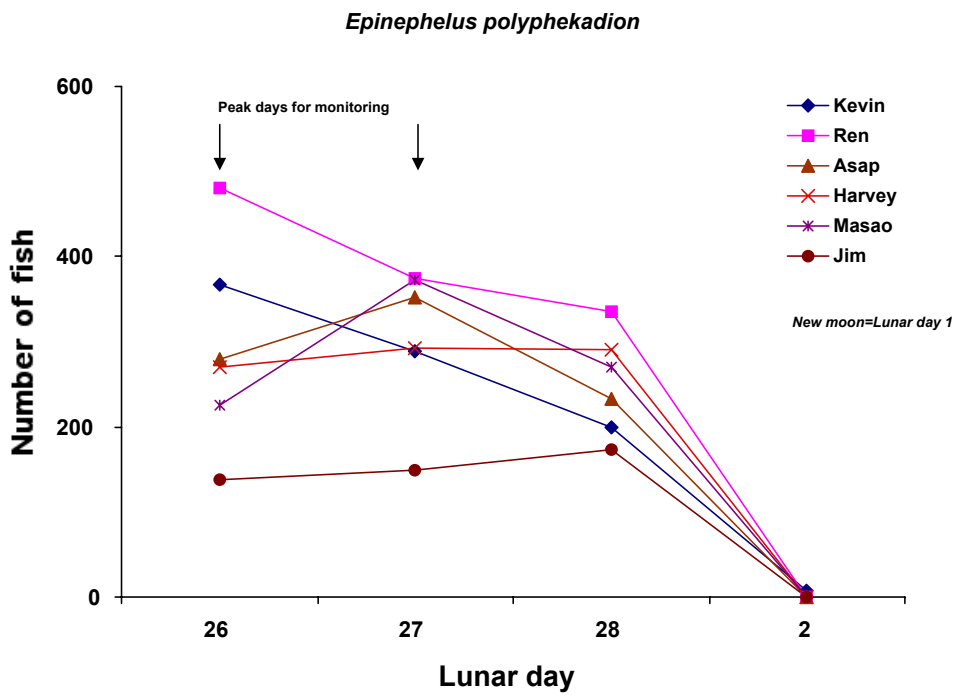

Figure 4: Abundance data trends for camouflage grouper taken from counts by participants at Ngerumekaol Channel. Transect area = 1000 m^2. Trends are consistent with findings from previous monitoring at the site (Johannes *et al.* 1999)

Table 2: Abundance counts for brown-marbled grouper from Ngerumekaol during the training exercise.

	Participants						
Lunar Day	Asap	Masao	Kevin	Ren	Mista	Mean	St. dev.
26	9	13	8		19	12.3	4.99
27	11	9	6	14	9	9.8	2.95
28	2	3		2	---	2.3	0.58
2	0	2	3	0	2	2.3	0.58

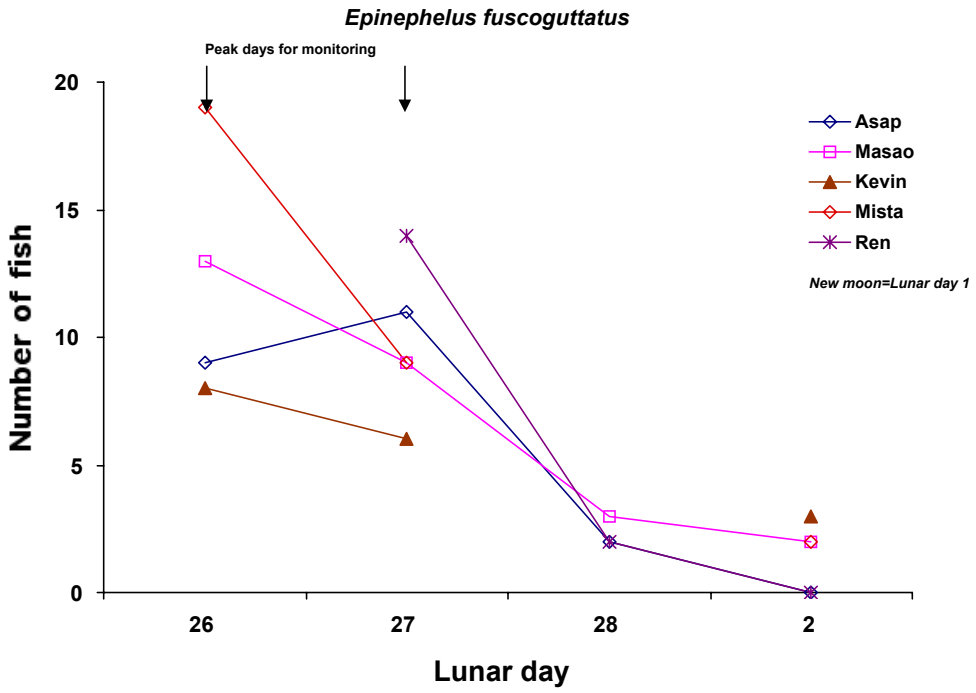

Figure 5: Abundance data trends for brown-marbled grouper taken from counts by participants at Ngerumekaol Channel. Transect area = 1000 m^2. Trends are consistent with findings from previous monitoring at the site (Johannes *et al.* 1999).

TRAINING SKILLS: SPAWNING SIGNS AND BEHAVIOR ASSOCIATED WITH AGGREGATIONS

Trainees also learned to observe and record spawning signs and behaviors associated with aggregations. Within aggregations at Ngerumekaol, courtship, gravid females (Figure 6) aggression during the establishment of territories for males (Figure 7), color change (Figures 7 and 8), and bite marks were commonly observed.

Figure 6: Gravid female camouflage grouper (A. Smith)

Figure 7: Territorial disputes and color change in camouflage grouper (A Smith)

Figure 8: Color change in a male brown-marbled grouper (A Smith)

OBSERVATIONS: DISTRIBUTION, DENSITY AND ABUNDANCE

At Ngerumekaol, distribution, density and abundance of target species varied. For camouflage grouper, aggregating fish were widely distributed over approximately 20,000 m^2. The general shape of the aggregation area for camouflage grouper was triangular that began as a single point at the end of the channel toward Ulong Island and fanned out to the channel mouth on the seaward edge of the reef. The fish ranged approximately 50 m north and south of the channel along the wall down to an average depth of approximately 20 m. Although no accurate estimates of total fish numbers were taken, highest concentrations appeared to be associated with the main channel, from the mouth to approximately 100 m in to the east, and in the areas bordering the channel to the north and south. Highest density approximated 10-12 fish m^2. Although not directly comparable, fish abundance appeared much greater than the maximum of 2,225 individuals estimated in 1996 (Figure 5). Maximum densities, based on workshop data, would put the abundance of camouflage grouper at Ngerumekaol during the June 2003 aggregation period at 6,520 ± 842 individuals (Figure 9).

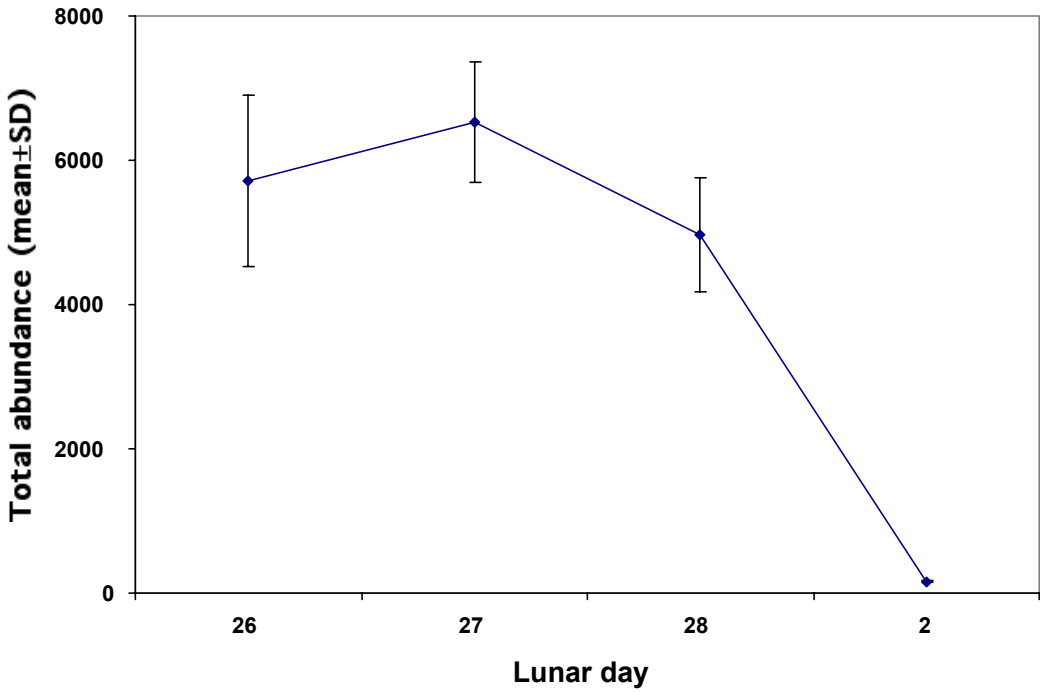

Figure 9: Mean and standard deviation abundance for camouflage grouper. Mean transect counts and standard deviations (Table 1) have been multiplied by 20 to produce the above graph. Since monitoring covered only 5 % of the total aggregation area (20,000 m^2/ 1,000 m^2) these results should not be used for comparison to other studies.

For brown-marbled grouper, site mapping and subsequent investigation showed fish to be concentrated along a coral ridge that splits the main channel beginning approximately 100 m east of the channel mouth. Fish were also observed along the walls bordering the channel on either side of the coral ridge. Mean maximum abundance was 12.3 fish/1,000 m^2 transect. If the aggregation area was 10,000 m^2, as approximated, 123±50 individuals were present during the spawning period (Figure 10). These numbers are substantially lower than those from previous monitoring (Johannes *et al.* 1999) but are difficult to compare. Additional monitoring of the species is needed to determine if populations have been negatively affected since the last monitoring period (1994-1996).

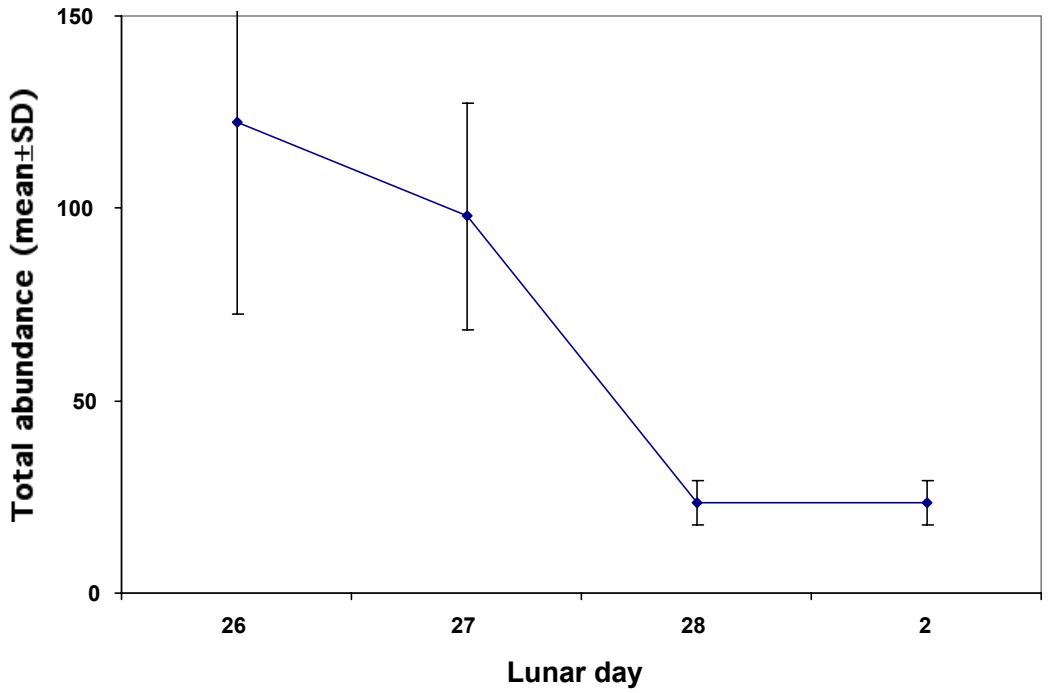

Figure 10: Mean and standard deviation abundance for brown-marbled grouper. Mean transect counts and standard deviations (Table 2) have been multiplied by 10 to produce the above graph. Monitoring covered 10 % of the total aggregation area (10,000 m^2/ 1,000 m^2).

Formal counts on *Plectropomus areolatus* were not taken systematically or regularly. Data on numbers within transects or total abundance counts are not available.

RECOMMENDATIONS BASED ON FINDINGS

The monitoring of spawning aggregation sites is an important component of effective marine resource management, particularly for documenting the effects of aggregation fishing and management effectiveness. Aggregations are site-specific and are typically comprised of a substantial portion of the total number of fish spawning within the local population. Formation of these aggregations is typically brief, e.g., 1-2 weeks over only a few months and around particular lunar cycles (full or new moon). Aggregations likely represent the period during which total reproductive output for the species occurs and it is during these times that the fish are highly vulnerable to over-fishing due to their brief and predictable nature.

MONITORING

Investigations of abundance and distribution of spawning aggregations of grouper at Ngerumekaol suggest the aggregations of *Epinephelus polyphekadion* may have increased substantially since previous monitoring was conducted in 1994-1996, however *E. fuscoguttatus* abundances were much lower than numbers seen in 1994-1996. For management and conservation, increases in abundance of *E. polyphekadion* following the area and seasonal closure could be used as a positive sign that conservation efforts are working. Whereas the apparent decreases in the abundances of *E. fuscoguttatus* are perhaps reason for concern, although it is difficult to speculate based on only a single month of monitoring data.

- Routine monitoring is recommended for Ngerumekaol to determine the effects of conservation and management on fish abundance.

Contour and species mapping at Ngerumekaol is currently being conducted by the Coral Reef Research Foundation (CRRF) under contract to The Nature Conservancy (TNC). These maps will provide an accurate determination of aggregation boundaries and densities that can be easily used to determine the number and location of transects to be used for effective monitoring at the site. Once completed, monitoring should be conducted routinely by the key conservation and resource management agencies in Palau under Koror State's coordination. Monitoring could focus on the months of the year when the three target species co-occur at the site (e.g. May-August).

- Routine monitoring should be conducted monthly between May and August at Ngerumekaol.

Abundance varies daily within spawning aggregations of target species at Ngerumekaol and elsewhere (Johannes *et al.* 1999; Rhodes and Sadovy 2002). Monitoring findings during training mimicked, to a certain degree, findings from previous work that found peak abundance for the species between 5 and 1 day prior to new moon. Therefore, monitoring at Ngerumekaol should be conducted during these periods.

- Routine monitoring at Ngerumekaol should be conducted between 5 days and 1 day prior to the new moon in monitoring months.

The number of transects necessary to accurately estimate fish abundance at Ngerumekaol will vary by species. A minimum of two transects is recommended for each species. The number and distribution of camouflage grouper may require more than two transects. The wide distribution of squaretail coralgrouper suggests careful evaluation of density for transect placement in areas representative of potentially varying aggregation densities. The actual placement of transects for all species will depend on findings from the CRRF/TNC study. Monitoring for each species is likely to require one day.

- For monitoring at Ngerumekaol, a minimum of one day and two transects per species is necessary to accurately evaluate fish abundance.

For routine monitoring at Ngerumekaol, based on two transects per species, three days would be required. A cost analysis is needed to evaluate the total costs of monitoring over the proposed period.

- A cost analysis based on three day per month over a four-month monitoring period is needed prior to initiating a monitoring program at Ngerumekaol.

DIVER DISTURBANCE

Diver disturbance on the aggregation is substantial and was noted on several occasions. Disturbance resulted in fish movement away from their established territories, causing disputes between these and other fish in adjacent territories. During courtship, these types of disturbances could result in negative impacts in pairing between mates. The impacts to reproductive output are unknown. Spawning in these species occurs nocturnally and diver disturbance impact to spawning is likely negligible.

At Ngerumekaol, fish aggregate over a period from 10 days prior to new moon until 1 day after new moon (e.g. 11 days) (Johannes *et al.* 1999). Males arrive at the site to establish territories from 10 days before new moon and females arrive beginning 6 days prior to new moon to begin courting males. Spawning, as mentioned, likely occurs beginning 2-3 days before new moon, depending on species. Diver disturbance to any of these spawning behaviors could occur during this period. Periods of peak abundance (and possibly interactions between sexes) occur during period of peak abundance (5 days to 1 day prior to new moon).

- Diver disturbance could be eliminated by banning recreational diving at Ngerumekaol from May through August, although this may be unacceptable to the dive industry.
- Recreational diving should be banned a maximum of 10 days prior to new moon or a minimum of 5 days prior to new moon.
- Recreational dive bans for other sites depend on the temporal nature of spawning that may vary from Ngerumekaol.
- The relatively small number of dive shops in Palau should enable variability in the timing of dive bans at different spawning aggregation sites.
- At a minimum, dive bans at the three major spawning sites in Palau—Ebiil, Western Entrance and Ngerumekaol—should be instituted as soon as possible.

AREA CLOSURE

At Ngerumekaol, in general, fish allowed a close approach by divers. This condition occurs when spearfishing within an area is minimal or nil. Fishing line and anchor damage was also minimal, with only one fishing line of recent origin observed. Moreover, both the area of the *E. polyphekadion* aggregations and the number of fish counted (although preliminary) suggest positive effects from the area closure at Ngerumekaol. Additional monitoring is necessary to detect whether there are actual effects on the aggregation site.

- Several positive signs within the spawning aggregation were observed that are likely tied directly to the area closure.

SALES AND CATCH BAN

The 1 May -31 July sales and catch ban for grouper appears to be having a positive effect, if indeed abundance of fish at Ngerumekaol has increased and if other sites are found to show similar increases in abundance. Routine monitoring is necessary to establish trends. However, the sales and catch ban period may not fully coincide with actual spawning months. Routine monitoring and investigation of spawning periods should be conducted to verify spawning times. If spawning times are found to differ from sales and catch ban periods, these management tools should be adjusted to maximize management and conservation effectiveness. Past monitoring findings show June through September as the peak periods of spawning aggregation formation at the sites investigated. Therefore, the effectiveness of the current ban period in reducing impacts to spawning fishes is reduced.

- Spawning season for the three species should be investigated further in relation to the sales and catch ban.
- Maximum effectiveness to reduce impacts to spawning grouper could be achieved by adjusting the sales and catch ban period.
- Based on past findings, the sales and catch ban should be extended through 31 August.

CONCLUDING REMARKS

Palau has established itself as a global leader in spawning aggregation conservation and management. Although preliminary, the measures that Palau has implemented to manage and conserve spawning fish appears to be producing substantial benefits. Increased abundance of spawning fish at Ngerumekaol and other local aggregation sites should increase reproductive output to boost local populations. Ultimately, this depends on the fate of the larvae produced at these sites and further work is needed to demonstrate this potential effect (e.g. where they recruit). However, to verify the effects of conservation and management, continued monitoring is needed.

The recent monitoring workshop at Palau International Coral Reef Center provided the necessary basic training for monitoring at Ngerumekaol and other local spawning aggregation sites. Contour mapping

aggregating species distributions at those sites will soon be available to properly design monitoring regimes at Ngerumekaol (and elsewhere). These tools provide the basic framework for long-term monitoring that is necessary to prove management effectiveness and adjust or improve current management measures.

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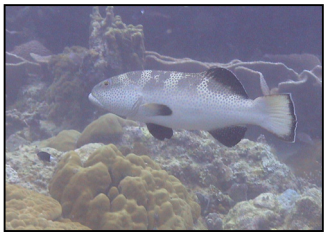
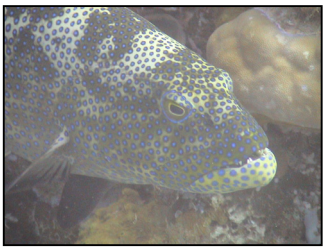
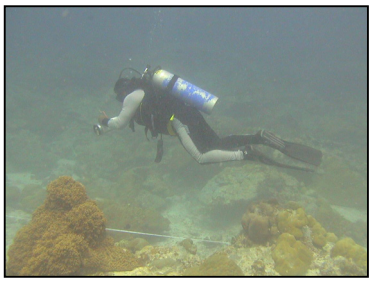
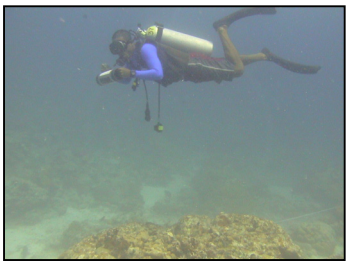
Rhodes K.L. and Y. Sadovy (2002) Temporal and spatial trends in spawning aggregations of camouflaged grouper, *Epinephelus polyphekadion* (Bleeker, 1849) in Pohnpei, Micronesia. *Environmental Biology of Fishes* 63: 27-39.

APPENDICES

APPENDIX 1: Participants in the Spawning Aggregation Training Workshop, Koror, Palau

Name	Agency	Contact Address
Asap Bukurrou	Palau Int'l Coral Reef Center	P.O. Box 7086 Koror, 96940, Palau Tel. 488-6950 Fax: 488-6951
David Idip	Palau Int'l Coral Reef Center	P.O. Box 7086 Koror, 96940, Palau Tel. 488-6950 Fax: 488-6951 Email: didip@picrc.org
Dominic Emilio	Helen Reef Resource Management Program	Tobi State, P.O. Box 1017 Koror, Palau 96940 Tel . 488-2218
Dr. Kathy Chaston	Koror State Rangers	P.O. Box 116 Koror, Palau 96940 Tel. 488-4001 Email: rica@palaunet.com
Harvey Renguul	Bureau of Marine Resource ROP National Government	P.O. Box 100 Koror, Palau 96940 Tel. 488-3125
Jason Kuartei	Palau Conservation Society	P.O. Box 1811, Koror, Palau 96940 Tel. 488-3993/4716 Email: pcs@palaunet.com
Jim Kloulechad	Palau Int'l Coral Reef Center	P.O. Box 7086 Koror, 96940, Palau Tel. 488-6950 Fax: 488-6951 Email: jkloulechad@picrc.org
Ken Tarkong	Helen Reef Resource Management Program	Tobi State, P.O. Box 1017 Koror, Palau 96940 Tel. 488-3238 (home) / 488-8044 (office)
Masao Udui	Palau Int'l Coral Reef Center	P.O. Box 7086 Koror, 96940, Palau Tel. 488-6950 Fax: 488-6951
Mista Moros	Koror State Rangers	P.O. Box 116 Koror, Palau 96940 Tel. 488-2150
Rengechel Dlutaoch	Koror State Rangers	P.O. Box 116 Koror, Palau 96940 Tel. 488-2150
Roman Mongami	Bureau of Marine Resource ROP National Government	P.O. Box 100 Koror, Palau 96940 Tel. 488-3125
Valentino Kloulechad	Ngarchelong Conservation Office	Palau Conservation Society P.O. Box 1811 Koror, Palau 96940 Tel. 488-3993/4716
William Andrew	Helen Reef Resource Management Program	Tobi State, P.O. Box 1017 Koror, Palau 96940 Tel . 488-2218

Name	Agency	Contact Address
Staff:		
Dr. Kevin L. Rhodes	Pacific Marine Science & Conservation	160 Conaway Ave., Grass Valley, CA 95945, USA Email: klrhodes_grouper@yahoo.com
Dr. Andrew J. Smith	The Nature Conservancy	P.O. Box 1738, Koror, PW 96940, Palau Tel. 488-2017 Fax: 488-4550 Email: andrew_smith@tnc.org