

Final Report: Enhancing MPA Effectiveness: Identification and assessment of reproductively active epinephelid movement and fishery vulnerability for management improvement

Grant number: NOAA Coral Reef Conservation Grant NA10NMF4630069

Grantee: Kevin Hopkins, University of Hawaii Systems

Reporting Period: 12/01/2010 - 03/31/2012

Award Period: 12/01/2010 - 03/31/2012

Amount of grant: \$49,890

Executive summary

The current study examined sex-specific patterns of reproductive movement, residency and seasonality at two camouflage grouper (*Epinephelus polyphekadion*) fish spawning aggregation (FSA) sites in Pohnpei, Micronesia—one open (Ant Channel) and one closed (Kehpara Marine Sanctuary) to fishing. Based on findings, FSA at the two sites appear to form at similar (February-April), although not identical times, but within the same lunar cycle (full moon). Although there appeared to be seasonal consistencies in spawning times between sites in 2012, variations were observed in 2011, with aggregations forming in Ant in February and March, but February-April at Kehpara. Similar to other co-aggregating groupers, males arrived earlier and resided longer at FSA than females, suggesting an enhanced vulnerability to selective fishing at unprotected spawning sites. In contrast to co-aggregating protogynous groupers, there was no clear sex-specific difference observed in aggregation frequency for the gonochoristic camouflage grouper, i.e. the number of months males and females participate in aggregations annually. Female camouflage grouper frequently returned to the spawning site in consecutive months, highlighting their ability to rapidly recover from spawning. No clear patterns of movement to and from FSA sites were evident for Ant, although some indications of the use of common reproductive migratory pathways were observed at Kehpara, illustrating the ability to design common area protection measures among all three co-aggregating

species. Although few individuals were recaptured to define catchment areas, one individual was detected approximately 25 km from the FSA in Pohnpei, while another was detected 10 km from the tagging site in Ant. These findings suggest that catchment areas for the populations are relatively large, but approximate to those from squaretail coral grouper (*Plectropomus areolatus*) and brown-marbled grouper (*Epinephelus fuscoguttatus*). Tagging mortality appeared to be significantly higher for camouflage grouper (~ 50%) than that for previously tagged epinephelids at the FSA site, possibly as a result of fishery-induced barotrauma, post-tagging mortality or predation. Future tagging studies will incorporate new methods to retain fish post-tagging, which may increase survival rates. In spite of the shortcomings, the data derived from this and earlier NOAA-funded research is sufficient to develop informed management policies for these three co-aggregating species. Two new regulations are currently out for 30-d public comment in Pohnpei and are predicted to pass: (1) the extension of the March-April sales ban to include February, and (2) a 14-inch (35 cm) size limit on all epinephelids¹. Based on findings, large-scale MPAs ($\geq 100 \text{ km}^2$) would ideally be needed to fully protect these spawning populations during non-reproductive periods. Although large-scale MPAs are not politically feasible in Pohnpei, both Ant and Kehpara populations of camouflage grouper could benefit from well-enforced small-scale MPAs that include proximate areas identified as migratory pathways. These measures, in combination with the temporal catch and size restrictions at sales should prove beneficial to populations of camouflage grouper in Pohnpei.

Background

The camouflage grouper is a widely distributed and commercially important medium-bodied grouper that aggregates to spawn throughout its distributional range (Rhodes 2012). The species is listed as Near Threatened on the IUCN Redlist (www.iucnredlist.org) as a result of population declines and spawning aggregation loss throughout its distributional range, primarily from indiscriminate aggregation fishing. Unlike many of its congeners, the species has recently been found to be a functional

¹ Brown-marbled grouper size limits are set at 24 in (~60 cm) to reflect its size at 50% sexual maturity.

gonochore with a maximum lifespan in Pohnpei of 22 years (Rhodes et al. 2011). In Pohnpei, camouflage grouper recruit into the fishery at Age 2, but are first present in the spawning aggregation at Age 4. The species is the primary grouper targeted by commercial fisheries in Pohnpei (Rhodes and Tupper 2007; Rhodes et al. 2008) and is a popular target of nearshore fisheries throughout the region. As a direct result of aggregation fishing, fisheries-induced size and age truncation have been detected, further highlighting the need to improve management for the species, particularly during spawning times.

The proposed project was undertaken to improve management and conservation of the camouflage grouper, *Epinephelus polyphekadion*, and increase understanding of its reproductive life history, particularly its reproductive movement. For the current study, acoustic and conventional tagging was conducted to examine sex-specific patterns of reproductive movement and residency. Using this information, the project sought to enable a comparative demographic assessment of the temporal and spatial dynamics of the species during reproductive and non-reproductive periods. These findings are being used to develop informed management recommendations to the Pohnpei State Government to improve temporal and spatial (MPA) management.

The current study was also designed to allow reproductive life history comparisons among camouflage grouper and other co-aggregating species (brown-marbled grouper, *Epinephelus fuscoguttatus*, and squaretail coral grouper, *Plectropomus areolatus*) for which information on catchment area and reproductive movement is now known (Rhodes and Tupper 2007; Rhodes et al. 2012). From combined catchment area estimates, the study sought to provide information to recommend area requirements for protecting adult camouflage grouper away from (catchment area, home range) and at spawning sites (sex-specific habitat use, spawning site fidelity, residency, pattern and distance of reproductive migration). Study findings are being used to examine inter-annual variations in spawning times within and between spawning sites (Ant Atoll and Kehpara Marine Sanctuary, Pohnpei Island) for the design of appropriate temporal management protocols. The project has provided opportunities for capacity building to state and local NGO staff,

awareness raising among stakeholders, and participation by local college interns. This study has built on ongoing coral reef fish and fisheries research in Pohnpei by the University of Hawaii at Hilo, the University of Guam and the University of the US Virgin Islands.

Results

Acoustic and Conventional Tagging and Recapture

Between and 15 February and 15 April 2011, a total of 20 *E. polyphkadion* (5 females, 13 males, 2 unknown sex) were conventionally (Floy T-bar) tagged inside the Kehpara Marine Sanctuary. Of these, acoustic tags were implanted in 12 fish that included 5 females and 7 males. In addition to those fish tagged at Kehpara, 27 additional *E. polyphkadion* were acoustically tagged at nearby Ant Atoll in 2011 (12-16 March 2011) that included 13 males, 13 females and one of unknown sex. An additional 8 individuals (7 males, 1 female) were acoustically and conventionally tagged at Ant 4-5 March 2012. Sizes for *E. polyphkadion* at Kehpara ranged from 360-485 mm TL (average \pm SD = 433.3 \pm 36.2 mm TL), while those from Ant were significantly smaller (range = 325-435, mean \pm SD = 381.6 \pm 28.3 mm TL). Individuals at Kehpara were tagged at the aggregation site that forms on the outer reef, while those at Ant were tagged at the aggregation site in the main channel. All fish were injected with oxytetracycline and released immediately after tagging. Of all the fish tagged for this project, only one individual has been recaptured—an acoustically tagged female (400 mm TL, 1.2 kg) tagged at Ant Channel (3/14/11) and recaptured at an undisclosed location on the atoll after 208 days at liberty (10/8/11). Using these two sites, the project was provided an opportunity to examine and compare catchment areas and reproductive movement and seasonality, and compare findings.

Receiver placement, download and maintenance

On Pohnpei, a total of 47 acoustic receivers were distributed at and away from the Kehpara Marine Sanctuary (Figure 1) from early January 2011 until February 2012. Of

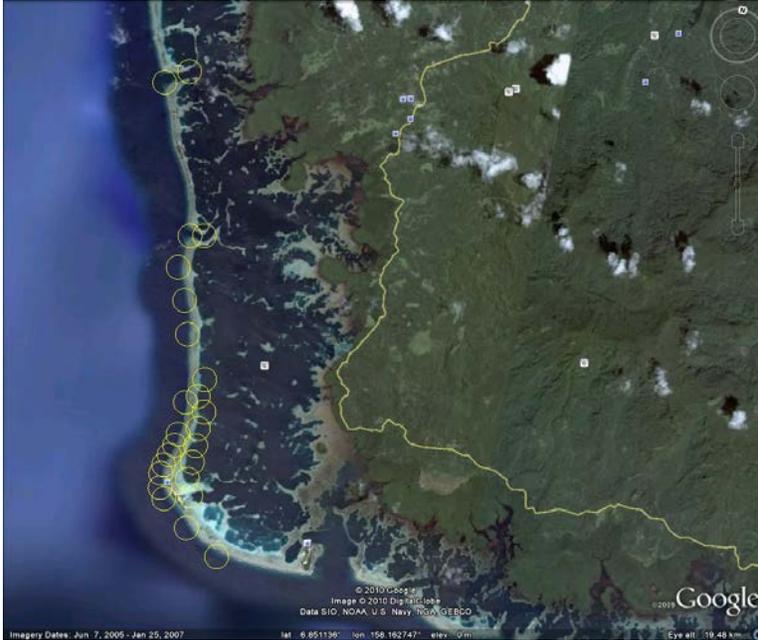
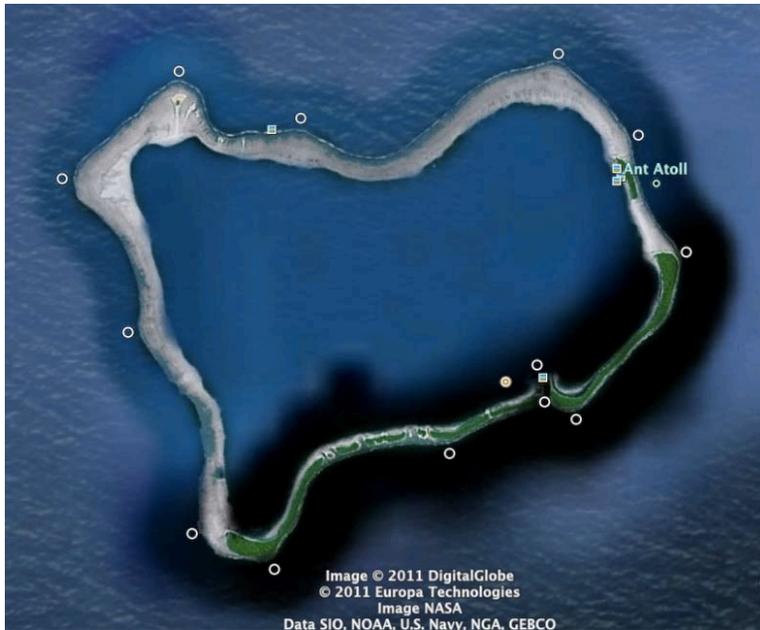


Figure 1. Map of southwest Pohnpei providing the details of the acoustic array (circles) (project start date 2011-February 2012). The yellow circles represent likely 'detection halos' for each of the receivers placed in the array. One receiver, placed at Palikir Pass (23 km north of the sanctuary) is not shown.

those, 10 receivers were removed following the expenditure of their battery life in October 2011. Receivers were re-oriented in February 2012 to focus on long-distance movement by this and other acoustically tagged co-aggregating groupers (squaretail coralgrouper and brown-marbled grouper) and to examine temporal interactions with grey reef sharks (*Carcharhinus amblyrhinchos*). Most receivers were initially concentrated within the area of the spawning aggregation to identify small-scale movement patterns. Additional receivers were placed across from the aggregation site in the inner lagoon and at inside seaward and lagoonal channel entrances (Kehpara, Peleng, Palikir and Dawak Channels). In addition, in March 2011 a total of 13 receivers were distributed around the entire reef at Ant Atoll (Figure 2). Current receiver locations on Ant are the same as in 2011, while those on Pohnpei are distributed approximately every 4 km around the island, with concentration of 5 receivers within the aggregation site (Figure 3).

All Kehpara receivers were initially downloaded and/or maintained in April 2011, with a subsequent and final download of concentrated Kehpara receivers in late January 2012. Three receivers located in the FSA core at Kehpara were downloaded in June to determine reproductive seasonality for 2012. No information on movement for tagged camouflage grouper is yet available for the 2012 spawning season. None of the Ant receivers were downloaded in 2011 and only 6 of 13 receivers were retrieved and downloaded in March 2012 owing to unfavorable seas. Remaining receivers (i.e. those not downloaded in March 2012) were retrieved, downloaded and replaced in June 2012, along with receivers in the aggregation core at Ant.



*Figure 2: Ant Atoll receiver distribution (2011-present). The *E. polyphekadion* point of capture and spawning aggregation is located at the channel mouth (bottom right).*

Acoustic results: Movement, catchment areas and home range

Of the acoustically tagged camouflage grouper tagged at Kehpara, all but one demonstrated initial movement away from the tagging site. Some directional patterns of movement were evident to demonstrate the use of common migratory pathways (*see below*). Recent evidence of grouper movement to and away from spawning sites (e.g.

Rhodes and Tupper 2008; Rhodes et al. 2012) suggests variable and possibly predictable sex-specific movement of fish during reproductive periods. In past surveys, male grouper tended to frequent spawning sites during most and often all months of the spawning season, whereas females visit sites only during a single month.

Information for catchment area assessments was dependent on both the acoustic results and tag recaptures. Only one of the conventionally tagged fish was recaptured during the survey period, a female at Ant Atoll. The actual catch location of that individual was undisclosed, making estimates of catchment area problematic. Nonetheless, some information was derived from acoustic results that enable comparisons to other co-aggregating grouper species. It is not clear why tag returns were so low relative to other groupers tagged in Pohnpei, which had an approximately 10% return rate. We suspect that this reflects tag-induced mortality, tag loss/shedding or underreporting by fishers. Similar to estimations of catchment area, home range areas were not established owing to equipment malfunction in the VR100. The unit was not operational during either 2011 or 2012. The unit was been returned to Vemco for repair, but was returned in time for the 2012 reproductive season.

Patterns, directions and distances of movement

Kehpara

Directional patterns of movement for camouflage grouper were primarily available from data collected prior to February 2012, after which receivers were widely spaced to identify long-distance patterns and distances of movement (Figure 3). In June 2012, only those in the FSA core were downloaded for analysis.

At Kehpara, all of the acoustically tagged males was detected by core FSA receivers in 2011. In contrast, only one of four females was detected at or near the spawning site. One female appears to have been preyed upon, with rapid and erratic movements displayed by the fish following tagging. Such movement has in the past been indicative of shark predation (*See Female 41240 below*). Two other females were detected initial by the

receivers following release but provided no directional information, i.e. were only detected in the aggregation core. Of the fish displaying directional movement, all but two



Figure 3: Current receiver distribution around Pohnpei (February 2012-present). Receivers were relocated to examine long-distance movement of groupers and coastal reef sharks away from the aggregation (tagging) site.

of the fish moved to the south. Of the fish moving southward, most moved past the southernmost receiver, moored at 3.1 km south of the aggregation, while two fish moved into the lagoon through Kehpara Channel, the closest channel to the aggregation site. Of the two fish moving northward, one was last detected only 2 km north of the site, while the other continued northward for 38 km along the outer reef to Palikir Pass, the northernmost receiver post. The maximum distance of fish moving past the southernmost or northernmost receivers is unknown. Thus, these can be considered minimum distances of movement. Details of individual movement and fates of 10 of 12 tagged fish at Kehpara are as follows:

1. Male 41229, 485 mm TL, 2.1 kg, tagged 2/15/11: This male remained at the aggregation site for 33 days after tagging, demonstrating no movement among receivers during that period. Following full moon in March (19 March), this male left the aggregation site, swam south along the reef, and through the adjacent Kehpara Channel into the lagoon. The individual was again detected on 26

January 2012 within the aggregation, but demonstrated no additional movement (Table 1).

2. Male 41230, 380 mm TL, 1.0 kg, tagged 2/16/11: This male left the aggregation site immediately after tagging and moved north. The fish was detected 1 km north of the spawning site until its return to the aggregation site on 6 March 2011. The individual remained in close proximity to the aggregation core for 13 days, or 2 days after full moon. During this period, it was detected by 3 receivers, all which were located in the core area of the aggregation. The fish was again detected within the aggregation core at a single receiver on 16 April and from 16-20 May. Subsequently, the fish was again detected at a receiver located 1 km north of the aggregation on three separate occasions: 8 and 18 September and 7 November 2011.

Table 1: Summary table of tagged camouflage grouper at Kehpara Marine Sanctuary (Pohnpei) and Ant Channel (Ant Atoll). Fish ID corresponds to text in Section XX. Tagging months are labeled with an 'X', while '√' marks represent months of return to the site(s). Calendar months are January 2011- June 2012. Shaded areas represent aggregation months and show conformity in aggregation periods between these two sites.

	Fish ID	F/M	IA	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Kehpara 2011	41229	M	!		X	!										!					
	41230	M	!		X	!	!	!	!	!	!			!		!	!	!	!	!	!
	41231	M			X		!					!									
	41232	M	!			X												!			
	41233	M				X															
	41238	F				X															
	41239	F	!			X												!			
	41240	F				X															
	41241	F	!			X												!			
	41282	M	!				X											!	!		
41283	M					X															
Ant 2011	41244	M	!			X												!	!		
	41245	M				X															
	41278	M				X															
	41279	M	!			X													!		
	41285	M	!			X												!			
	41292	M				X															
	41295	M				X															
	41296	M				X															
	41237	F	!			X												!	!		
	41242	F	!			X															
	41243	F				X															
	41244	F	!			X												!	!		
	41277	F				X															
	41288	F	!			X														!	
41289	F				X																
41291	F	!			X												!				
41293	F	!			X													!			
Ant 2012	3616	M																X	!		
	3617	M																X	!		
	3618	M																X	!		
	3619	M																X	!		
	3620	M																X	!		
	3621	M																X	!		
	3623	F																X	!		
	3624	M																X	!	!	!

In 2012, this male returned to the FSA site and was detected on numerous occasions between 26 January and 9 June, with the greatest period of detection between first quarter and full moon periods. The male showed movement away from the core FSA area for camouflage grouper 1 day prior (March) and on the day of full moon (April).

3. Male 41231, 470 mm TL, 2.4 kg, tagged 2/16/11: This male was detected by six receivers: two within the aggregation core and four to the south (two reef flat and two seaward reef wall). The fish moved among these receivers for 5 days prior to leaving the aggregation area and migrating southward. The fish was last detected by a receiver located 1-km south of the camouflage grouper aggregation core. It was detected again by the same southern receiver on 24 April 2011 and 30 September 2011. The fish was not detected in 2012 at the FSA site.
4. Male 41232, 400 mm TL, 1.0 kg tagged 3/13/11: This male was detected by 5 receivers, including one in the aggregation core and 4 receivers located to the south up to 3.12 km from the aggregation. Following tagging, the individual remained at the aggregation site until 20 March (1 day after full moon). It then moved to the south, swimming approximately 0.5 km hr⁻¹ until its last detection. In 2012, the male returned to the FSA site in March and was detected by the FSA core receiver between 2 and 8 March (full moon). No other detections were made in 2012.
5. Male 41233, 480 mm TL, 2.0 kg, tagged 3/13/11: This male was detected by only two receivers, one in the aggregation core and a second 3.12 km south of the aggregation site. Following tagging, the male maintained a presence at the aggregation site for 7 days until 20 March, when it departed to the south. Curiously, the fish was not detected by any of the other receivers between the aggregation core and the southernmost receiver.
6. Female 41239, 410 mm TL, 1.1 kg, tagged 3/17/11: This individual was detected by 4 receivers, including two within the aggregation core and two to the south of the aggregation. Similar to the males described above, this female remained at the site until 20 March, when it departed and moved southward along the outer reef and was last detected 2 km south of the site.

The female returned from the south to the FSA in March 2012, arriving at the site and remaining from 1 March until full moon on 8 March. It went undetected by any receiver thereafter. Its southward entry into the FSA suggests consistent movement direction to the site, however, it was not detected by the receiver south of the FSA when it left.

7. Female 41240, 430 mm TL, 1.5 kg, tagged 3/17/12: This female appeared to have been consumed by a shark of unknown species. The tag demonstrated shark-like patterns of movement almost immediately after the release of the tagged camouflage grouper female and was detected by 17 receivers over a 7-d period.

The tag was not detected again after 24 March, suggesting it was discarded on the reef away from any moored receiver.

8. Male 41282, 440 mm TL, 1.5 kg, tagged 4/15/11: This tagged male displayed northward movement following presumed spawning and was detected by 9 receivers. Following tagging, the male remained at the spawning site for 4 days (until 20 April, 2 days after full moon). The fish immediately moved northward apparently along the outer reef, as it was not detected by any reef flat receivers placed to the north of the aggregation site. The fish was then sequentially detected at 33 m, 2 km, 3 km, 3.5 km, 5 km, 6 km and 7 km north of the aggregation over a period of 13 hours, representing an approximate 0.5 km hr^{-1} rate of movement. Its last detection was at Palikir Pass 22 km to the north of where it was tagged. The fish moved this distance in 38 hrs, or at approximately 0.6 km hr^{-1} overall. This represents the longest recorded distance of movement for this fish in Pohnpei.

In 2012, this male returned to the FSA site in both March and April, apparently moving in from the south. Although there were receivers along the outer reef from Palikir to the FSA, none detected this fish moving back from its last known location in 2011. It entered the FSA on 26 February and departed on 8 March (full moon). It returned on 29 March and departed 6 April (full moon), moving to the south as it left.

9. Male 41283, 430 mm TL, 1.2 kg, tagged 4/15/11: This tagged male was detected by 5 receivers, including the central receiver at the aggregation site and 4 other receivers to the south of the aggregation. The fish remained at the aggregation for only a single day prior to moving southward. The fish moved off the reef wall and onto the reef flat prior to moving into the lagoon through the Kehpara Channel 5 days after tagging. The fish was again detected at the FSA on 20 April, but did not register any detections thereafter.
10. Female 41241, 390 mm TL, 1.5 kg, tagged 3/17/11: This tagged female displayed similar behavior to other fish, remaining in the aggregation core until 20 March, at which time it departed and moved southward along the outer reef wall and past the southernmost receiver moored at 3.12 km from the aggregation. The fish was detected by a total of 6 receivers, but spent all of its detected time at the aggregation, except for the 5.5 hr period of southward migration.

In 2012, this female returned to the site from the south 4-d prior to full moon. It stayed in the FSA core until the afternoon of 7 March, the day prior to full moon in that month.

Ant Atoll

For Ant, 8 receivers were downloaded around the FSA site in February 2012, with the remaining receivers downloaded in June 2012. Following tagging in 2011, none of the

individuals were observed to remain at the tagging site for more than 4 days. Alternatively, individuals are concentrated in inner lagoon areas where receivers are absent. The paucity of data from Ant receivers suggests improvements to the receiver array are needed, with greater concentration in and near the aggregation site.

1. Male 41244, 420 mm TL, tagged 3/14/11: This male was not detected by receivers in 2011 following tagging, but returned to the FSA in 2012, where it was detected by one channel receiver in February and March 2012. Although the resolution was poor, detections suggest the fish arrived at the FSA 3 d before 1st quarter moon (FQM=1 March) and departed the day of full moon (8 March). Similarly, the male arrived in the following month 1 d before 1st quarter moon and departed on full moon, equivalent to an 11 residency period in both months.
2. Male 41245, 395 mm TL, tagged 3/12/11: Male 41245 was only present at the FSA for two days after tagging and did not return thereafter, or was not detected by receivers.
3. Male 41278, 420 mm TL, tagged 3/16/11: This male was detected by FSA receivers for only 3 days prior to departing the site. The male did not return to the site in 2012 or was not picked up by the receivers.
4. Male 41279, 350 mm TL, tagged 3/16/11: This male was not detected by receivers after its release in 2011, but re-appeared at the FSA in one month in 2012. The fish was detected by a single receiver inside Ant Channel on 31 March and appeared to depart on 3 April. It is not clear whether this represents its entire period of residency.
5. Male 41285, 410 mm TL, tagged 3/16/11: Male 41285 was detected by two outer reef receivers in March 2012 before being detected at an inner channel receiver on 7 March, the day prior to the full moon. This latter receiver detection appears to have been made during its departure, based on movement patterns by other detected fish during that month. The distance of movement represents a minimum of 10 km.
6. Male 41292, 405 mm TL, 3/14/11: This male was not detected after tagging and did not return in 2012.
7. Male 41295, 405 mm TL, tagged 3/14/11: This male was not detected after tagging and did not return in 2012.
8. Male 41296, 405 mm TL, tagged 3/14/11: This male was not detected after tagging and did not return in 2012.

9. Female 41237, 375 mm TL, tagged 3/15/11: This female was tagged on 15 March 2011. After tagging, she was detected by the outer channel receiver and stayed at the site until the day of the full moon. She returned to spawn in both March and April FSA in 2012. She was present 7 and 6 days, respectively during those months.
10. Female 41242, 375 mm TL, tagged 3/15/12: This female was tagged in March 2011 and was not detected after tagging, however, she returned to the site on 27 March and remained until the day of the full moon on 6 April 2012.
11. Female 41243, 400 mm TL, tagged 3/14/11: No detections were made for this female.
12. Female 41277, 325 mm TL, tagged 3/16/11: This female was only detected in 2011 and only for 3 days after tagging.
13. Female 41288, 435 mm TL, 3/14/11: Female 41288 was not detected after tagging in 2011, but returned to the site in April 2012 where she was detected from 1 April until around midnight on 5 April.
14. Female 41289, 400 mm TL, tagged 3/14/11: No detections were made for this female.
15. Female 41291, 350 mm TL, tagged 3/14/11: No detections were made for this female, however, she was detected again at the inner channel receiver between 3 and 7 March.
16. Female 41293, 375 mm TL, 3/14/11: This female was not detected by any receiver following tagging in 2011, but returned to the site in March 2012. She was only detected on two days: 31 March and 5 April.
17. Male 3616, 400 mm TL, tagged 3/4/12: This male was tagged on 4 March 2012 and went undetected again until 31 March when it re-entered the FSA. It remained at the FSA until 5 April, the day prior to full moon.
18. Male 3617, 400 mm TL, tagged 3/14/12: This male was tagged on 4 March 2012 and appeared to remain at the site until 8 March, the day of full moon. He returned on 30 March and remained until the full moon in April.
19. Male 3618, 400 mm TL, tagged 3/4/12: This male only remained at the site, or was detected by receivers on two days, suggesting he was at the site a total of 4 days post-tagging. The male did not return in April.
20. Male 3619, 460 mm TL, tagged 3/4/12: This tag was never detected.

21. Male 3620, 360 mm TL, tagged 3/4/12: This male was only detected on 8 March 2012, 4 days after tagged and did not return in April 2012.
22. Male 3621, 460 mm TL, tagged 3/4/12: This male was only detected on 8 March 2012, 4 days after tagged and did not return in April 2012.
23. Female 3623, 370 mm TL, tagged 3/5/12: This female went undetected in March following tagging and was later detected only for a single day on 4 April 2012 indicating that she participated in the FSA that month.
24. Male 3624, 560 mm TL, tagged 3/5/12: This male demonstrated a residency pattern unlike all the other tagged camouflage grouper, frequenting the site from the time it was tagged in March until June. All detection patterns indicated residency to be aggregation-related. The fish stayed (or was detected over) 9 d in March, 12 days on April (25 March-5 April), 14 d in May (20 April-4 May) and 14 d in June (19 May-2 June). These detections represent arrivals on or around new moon and departures 1 or 2 d prior to full moon in each month. These patterns suggest that the spawning season for this species may be protracted, with smaller aggregations following the main spawning period. The data suggests additional underwater observations are needed to confirm reproductive seasonality.

Abundance counts and individual distribution

Although not part of the stated objectives for the current study, we were able obtain reliable baseline abundance counts and distribution of the three grouper species co-aggregating at the Kehpara spawning site (camouflage and brown-marbled grouper, squaretail coral grouper). Using a long transect that traversed the three aggregation sites and divided into 50-m sections, a 2-person dive team using closed circuit rebreathers (CCR) or Nitrox conducted technical dives during all but two days between 8 and 19 March 2011. Results demonstrated that camouflage grouper arrive at the aggregation site approximately 5 days prior to the full moon and depart shortly after spawning (Figure 4). Previous investigations show the species spawning 1-2 d prior to full moon (Rhodes and Sadovy 2002), followed by immediate departure, which conforms to the current data. Arrival times, however, conflicted with previous reports, which showed camouflage grouper arriving 10-12 days prior to full moon (Rhodes and Sadovy 2002). This information may suggest behavioral changes in aggregation formation following the

intense fishing that occurred in 1999 (Rhodes and Sadovy 2002), which resulted in age and size truncation (Rhodes et al. 2011).

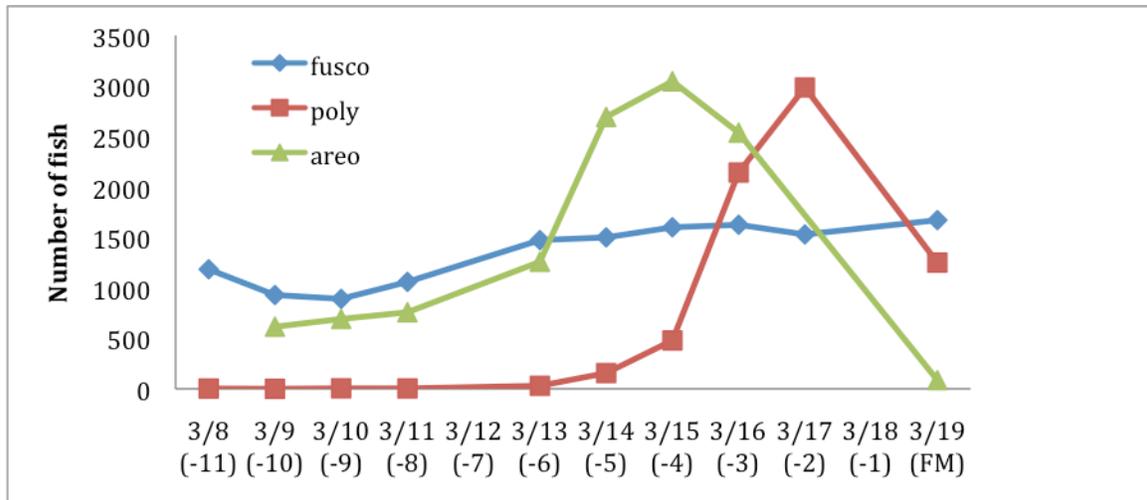


Figure 4: Abundance counts of camouflage grouper (*poly*), brown-marbled grouper (*fusco*) and squaretail coral grouper (*areo*) at the Kehpara spawning site 8-19 March 2011. FM=full moon. Results show peak abundances 2 days before full moon, with declines following presumed spawning.

Maximum abundances for camouflage grouper reached nearly 3000 individuals (2985 fish) 2 days prior to full moon, substantially lower than that reported in 2002 (Rhodes and Sadovy 2002). Logistic constraints prevented dives 1 day before full moon, so we are uncertain if those counts 2 days before full moon are maxima. Fish were concentrated along 200 m of the reef at 30 to greater than 50 m depth (Figure 5).

Local stakeholder engagement in field activities

During tagging in 2011 and 2012, four patriarch fishers were involved in tagging activities, while three state marine conservation unit officers assisted with tagging. Two state, one national conservation officer and one Conservation Society of Pohnpei staff also contributed to dive activities during receiver mooring and maintenance. The director of the Office of Fisheries and Aquaculture and two of his assistants participated in tagging operations in March 2011. All local marine resource agencies were informed of all field-based activities at the two sites. Co-PI Rhodes has provided updates to the governor of

Pohnpei on a regular basis. One college intern assisted during tagging operations (*see Photo 1*).

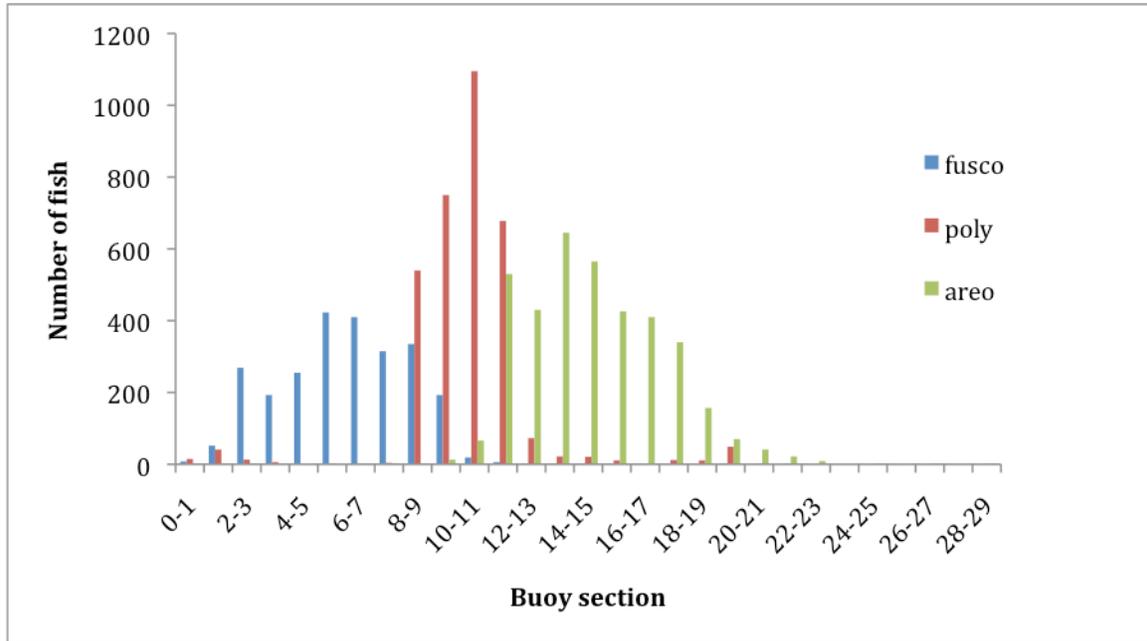


Figure 5: The maximum number of individual counted in 50-m sections along the long transect. Camouflage grouper (*poly*) is shown in red, while those of brown-marbled grouper (*fusco*) and squaretail coral grouper (*areo*) are represented by blue and green bars, respectively.

Dissemination of results and management

It is anticipated that final results will be available to Pohnpei State and the community at large by August 2012. We will provide a detailed report to the state of our findings, along with recommendations to improve management. We are currently in the process of improving management of this species through an extended sales ban period and size limits. The ban would add February to the current March-April sales ban, thereby covering the known spawning season for camouflage grouper at Kehpara. Additional recommendations will follow for Ant once the full dataset is available.

Difficulties encountered

We were unable to retrieve and download 5 acoustic receivers at Ant during the February 2012 field season owing to unfavorable sea conditions. Those receivers were retrieved in June 2012, however one receiver was lost and another was not located. Moreover, one of the primary receivers inside the Ant FSA did not communicate with the computer following retrieval in June 2012. It will need repair before we can ascertain its content. It is likely to hold additional data for camouflage grouper FSA visitation frequency, residency and movement. We also did not anticipate either the equipment failure of the VR100 or the lengthy timeframe for repair. This equipment failure resulted in our inability to examine home range habitats. Catchment area could not be estimated because only a single tag was returned and camouflage grouper were rarely detected by receivers outside the FSA. Improvements to this ongoing project are to add additional receivers in and around the FSA areas in both study sites to more accurately verify residency times and, at a minimum, direction of movement into and away from the FSA immediately before and after spawning, respectively.

Summary findings

Acoustic tagging of camouflage grouper has provided information on direction and distance of movement following tagging. From our findings, camouflage grouper appear to primarily utilize outer reef migratory corridors to move toward home range areas. There are indications from this and past studies that fish cross into lagoon areas through reef channels that are closest to their home range habitats. It is still unclear what percentage of individuals maintains a home range on outer reef versus inner lagoon habitats. We are hopeful that the current receiver array will provide additional data on distance and direction of movement for this species.

Based on the data from Kehpara and Ant, the catchment area for camouflage grouper is substantial. Since most fish moved past the southernmost receiver, it is uncertain how much area to the south of the aggregation is catchment. However, the long distance movement of two individuals—at Kehpara (22 km) and one at Ant (10 km)—suggests

that catchments can be a minimum of 100 km². As stated earlier, the current receiver array may allow greater insight into how large the catchment area actually is.

Management improvement

The data suggests additional area protection could be afforded to the species by including migratory corridors into marine protected areas. The patterns and distances observed suggest that large MPAs are needed if this reproductive population is to be totally protected. In lieu of large scale area protection, small MPAs, such as the one at Kehpara, provide a useful tool that, when combined with temporal management around spawning times, can be effective. The information provided by the final receiver downloads enabled us to recommend and draft for public comment an extension to the current March-April grouper sales ban to include February. Given the brief seasonal timeframe of reproductive activity for this species (i.e. 2-months) and the inter-annual variation therein of the onset of aggregation formation, this extension holds the potential to effectively conserve one-half of the annual reproductive output.

Collaborations

During the course of the project, Co-PI Rhodes has collaborated with Dr. Richard Nemeth (CMES, University of the US Virgin Islands) on a comparative acoustic tagging project funded through a Saltenstall-Kenndy grant. That collaboration has allowed us to expand the acoustic array to Ant Atoll and combine tags for both projects. Dr. Nemeth and his field technician, Elizabeth Kadison, performed the dives that resulted in the abundance counts and distribution shown above. The acoustic array is also collecting information on a collaborative acoustic tagging project examining grey reef shark (*Carcharhinus amblyrhynchos*) movement in relation to grouper spawning aggregations. The latter project is being conducted along with Dr. Rachel Graham of the Wildlife Conservation Society. Both projects are ongoing.

References

Rhodes KL. 2012. *Epinephelus polyphekadion*. p 422-428, In Sadovy de Mitcheson Y and PL Colin (eds.), *Reef Fish Spawning Aggregations: Biology, Research and*

Management, Fish & Fisheries Series 35, DOI 10.1007/978-94-007-1980-4_12

- Rhodes KL, McIlwain JL, Joseph E and RS Nemeth. 2012. Reproductive movement, residency and fisheries vulnerability of brown-marbled grouper, *Epinephelus fuscoguttatus* (Forsskål, 1775). *Coral Reefs* 31:443-453
- Rhodes KL, Taylor BM and J McIlwain. 2011. Demographic profile of a spawning aggregation of camouflage grouper, *Epinephelus polyphekadion*. *Marine Ecology Progress Series* 421:183-198
- Rhodes KL, Tupper MH and CB Wichilmel. 2008. Characterization and management of the commercial sector of the Pohnpei coral reef fishery, Micronesia. *Coral Reefs* 27:443-454.
- Rhodes KL and MH Tupper. 2008. The vulnerability of reproductively active squaretail coral grouper (*Plectropomus areolatus*) to fishing. *Fishery Bulletin* 106(2):195-203.
- Rhodes KL and MH Tupper. 2007. A preliminary market-based analysis of the Pohnpei, Micronesia, grouper (Serranidae: Epinephelinae) fishery reveals unsustainable fishing practices. *Coral Reefs* 26:335-344.
- Rhodes KL and Y Sadovy. 2002. Temporal and spatial trends in spawning aggregations of camouflage grouper, *Epinephelus polyphekadion* (Bleeker 1849) in Pohnpei, Micronesia. *Environmental Biology of Fishes* 63: 27-39.



Photo 1: An acoustically tagged camouflage grouper being released at the Kehpara Marine Sanctuary by local College of Micronesia student intern McKye Ioanis as co-PI Rhodes looks on (Photo credit: Steve Lindfield).