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19D Managing fish spawning aggregations

Possible Spawning Aggregations of *Plectropomus leopardus* at Lankayan Island, Malaysia

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Abstract. Spawning aggregations of coral trout *Plectropomus leopardus* have never been reported in Malaysia. This paper is the first preliminary field observation of small aggregations of coral trout reached up to maximum of 44 fishes at Lankayan Island, Sugud Islands Marine Conservation Area (SIMCA), Malaysia. The aggregation abundance showed temporal variation related to moon phase and availability of food sources. Generally, peak aggregation formed in May/ June and August/November. We observed colour variations during aggregation with obvious dark and pale phases. Coral trout displayed contrast color variation believed to be an important mechanism for sex-specific communication strategy. Correlation indicated that color variations altered according to total length (TL) of coral trout. Observations showed that coral trout with TL of more than 36 cm were mostly in the dark phase during aggregation. Aggregation occurred at the reef slope at depths ranging from 12 to 22 m. Coral trout with a mixture of dark and pale phases patrolled along the slope exhibiting territorial defense behaviour. Open jaw and side-waving behaviour observed in dark-phase coral trouts suggested behaviours indicative of a spawning aggregation. This study suggests that a decade of protection of SIMCA that offers opportunities for recovery of an exploited fish stock which is important for long term sustainability and management of the species.

Key words: Coral trout, *Plectropomus leopardus*, aggregation, MPA, behaviour.

Introduction

Many spawning aggregations have been lost before any management actions were undertaken (Sala et. al., 2001). Coral reef fishes that form mass spawning aggregations are targets for fishers and, if overfishised, may no longer form or does so with much reduced numbers (Sadovy de Mitcheson et. al., 2008)

Nearly 67 species of coral reef species from nine families form aggregations to spawn (Sadovy de Mitcheson et. al., 2008). However, most of the reef fish spawning aggregations are not well understood or documented in the wild (Claydon, 2004). Most sources of spawning aggregation information for the Indo-Pacific countries come from fisher interviews (Sadovy de Mitcheson et. al., 2008). This is perhaps due to spawning being difficult to observe especially as it takes place at dusk or at night (Moyle & Cech, 2004; Colin et. al., 2003) or it may take place under difficult scuba diving conditions such as in deep water (Golbuu & Friedlander, 2011) or strong currents (Colin et. al., 2003). In most condition when spawning is difficult to observe in the field, proxies for spawning behaviour will be used such as presence of females with swollen bellies from hydrated eggs, or species-specific body colouration or behaviours that occur only during the reproductive season (Pet et. al., 2005). Sadovy de Mitcheson et. al., (2008) applied indirect indicators of spawning including courtship, coloration change, seasonal increase in Gonadosomatic Index (GSI) and seasonally high catches of gravid fish to suggest spawning with increased numbers suggesting aggregation. Both spawning and aggregation need to be confirmed to identify a spawning aggregation since aggregation can also occur for other reasons, such as feeding.

The reproduction of coral trout (*Plectropomus leopardus*) includes spawning aggregation, home range and migration have been extensively studied on the Great Barrier Reef (Samoilys & Squire, 1994; Samoilys, 1997; Zeller, 1998; Frisch et. al., 2007). However, until today there is no published report of coral trout spawning aggregation in the Asia Pacific region. Grouper spawning aggregations have often been reported to occur a few days before or after the new moon (Zeller, 1998; Johannes et. al., 1999; Golbuu & Friedlander, 2011) or full moon (Sala et. al., 2001; Sadovy de Mitcheson et. al., 2008). The number of fish in spawning aggregations varies with species. The Nassau grouper in the Caribbean was estimated to form aggregations of between 30,000 and

100,000 individuals (Smith, 1972 in Sala et. al., 2001). At the other extreme, coral trout appear to form relatively small aggregations (Sadovy et. al., 2005). Samoilys & Squire (1994) recorded peak number of between 63 to 90 coral trout on the Great Barrier Reef in October. Several smaller aggregations may form in one reef or reefs that are close to one another (Sadovy et. al., 2005).

No take reserves or strict Marine Protected Areas (MPAs) where fisheries exploitation is spatially limited have been used to protect critical habitats such as spawning sites, nursery grounds (Palumbi, 2004) and to maintain spawn stock biomass of many commercial species (Robert, 1997). The use of MPAs for fisheries management is becoming popular (Forcada et. al., 2008). However, the establishment of MPAs has not always typically incorporated spawning aggregation criteria in their design (Sadovy et. al., 2005). In the absence of exploitation on overexploited populations, spawning biomass is likely to increase, improving reproductive potential and eventually rebuilding fish stocks (Sumaila et. al., 1999). Thus, no-take reserves are crucial in the role of maintaining sufficient biomass of reproductively active fish in order to be able to replenish stocks (Robert, 1997) both inside and outside the reserves.

The main objective of this study is to determine the temporal variation of aggregation abundance in relation to the moon phase. The second objective is to observe and document colour variation of coral trout and behaviors that may indicate spawning to determine whether the aggregations are spawning aggregations.

Materials and Methods

Study site. – The field survey was done at Bimbo Rock (N6^{0}31.24 E117^{0}55.78) and Reef 38 (N6^{0}30.66 E117^{0}55.25), two submerged patch reefs at Lankayan Island, Sabah Malaysia. The reefs measured 1.2 ha for Bimbo Rock and 2.8 ha for Reef 38. The aggregation at Bimbo Rock occurred on a reef slope ranging from 16 to 22 m depth, orientated from southwest to east. Aggregation at Reef 38 occurred on a reef slope ranging from 13 to 22 m depth from the north to east. The survey sites both have steep walls that face eastward. The reefs are affected by strong currents from the northeast during the North East Monsoon from November to March each year.

Censuses – The underwater visual censuses were conducted randomly from April to November 2011. The aggregation slopes for both reefs were mapped. The Bimbo Reef aggregation slope measured 2000 m^2 in area and Reef 38 measured 1000 m^2 in area. Following the methodology of Samoilys (1997), the aggregation site maps were drawn on underwater slates. For each census, the position of individual fish was recorded on the slate. Fish size (total length, TL) was estimated to the nearest centimeter (cm). Each census was conducted by one observer and a buddy diver.

Colour variation: The colour variations of coral trout are categorized into four phases: 1) Dark; 2) Pale; 3) Olive-green; and 4) Patterned/marking. Colour was recorded when fish was first sighted. Change of initial colouration to a different colour phase after the first sighting was not recorded in this study. Our preliminary observations showed that coral trout mostly appeared olive-green. In comparison, the patterned and obvious body marking appeared during hunting and while resting near coral and rubble bottom. We assumed that the patterned body marking allowed fish to be camouflaged from their prey during hunting. We made an assumption that the dark phase is male fish and pale is female. This assumption was made based on following criteria: 1) territorial defensive behavior e.g. open jaws and gills when two or more dark phase fishes were near to each other; 2) scars on dark phase fishes.

Food availability – Presence or absence of juvenile fusilier (e.g.: *Pletrocaesio tessellate*, *Caesio caerulaurea*) were noted in all censuses.

All censuses were conducted during daylight hours from 08:30 to 17:00 during good visibility of >8m. Each census took an average of 50 minutes to complete. Thirty-two (32) censuses were randomly conducted from April to November 2011 (N=16 for Reef 38; N=16 for Bimbo Rock).

Results

Population – Figure 1 shows the frequency distribution of coral trout total length (TL) at Bimbo Rock and Reef 38. Coral trout at Bimbo Rock are larger mainly ranging between 36 to 55 cm TL. Conversely, the population at Reef 38 comprised smaller coral trout mainly ranging between 26 to 45 cm TL. The smallest coral trout recorded at both sites was 20 cm in total length and the largest recorded reached 65 cm. Bimbo Rock consists of larger fishes compared to Reef 38 (ANOVA: $F=29.09$; $P<0.05$).

The average abundance count per survey was 18.5 fishes (SD= 12.2 with range 1-44, N=16) at Bimbo Rock. Coral trout number peaked at 44 fishes at Bimbo Rock two days before the full moon in November. The same site recorded lowest count of only one (1) fish three days before full moon in June (Table 1). However, the abundance increased to 25 fishes five days later (two days after full moon in June). The recorded abundance varies with day. For example in July, four days before full moon, only eight fishes were counted. A day later (three days before full moon), the abundance increased to 21 fishes. Generally, the number of fish recorded increased in May/June and in August to November at Bimbo Rock (Table 1).

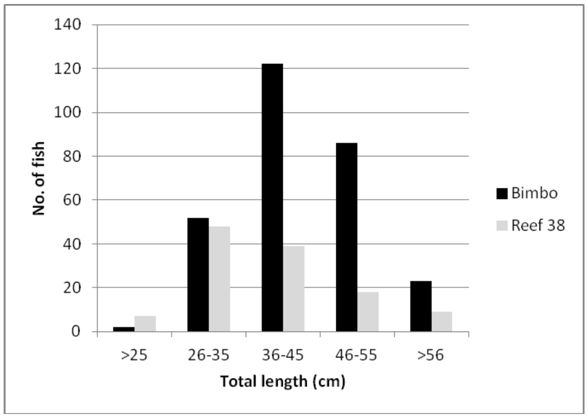

Figure 1: Frequency distribution of coral trout total length at Bimbo Rock (N=296) and Reef 38 (N=117) . Note: graph showed 32 censuses.

At Reef 38, an average 7.6 fishes were counted per census (SD= 5.5, range 0-16, N=16). Peak count was 16 fishes three days after new moon in May and two days before full moon in November (Table 1). Zero coral trout were counted three days after the new moon in April and full moon in May. The coral trout number at Reef 38 increased after new moon in May and during new moon in August. As with Bimbo Rock, the fish number tended to increase in May prior to the new moon and November prior to the full moon.

Table 1: The number of coral trout during different moon phase, and presence or absence of juvenile fusilier (food availability) from April to November 2011. (Figures in bold indicates highest abundance of fishes recorded.)

Month	Moon phase	No. of fish	Food availability
Bimbo			
April	2 days after new moon	10	-
April	2 days before full moon	11	-
April	1 days before full moon	2	-
April	1 day after full moon	3	-
May	3 days before new moon	20	Yes
May	2 days before new moon	**30**	Yes
June	6 days after new moon	**29**	Yes
June	3 days before full moon	1	-
June	2 days after full moon	**25**	Yes
July	4 days before full moon	8	-
July	3 days before full moon	21	-
Aug	3 days before new moon	19	-
Aug	New moon	20	Yes
Sept	5 days after new moon	23	-
Nov	2 days before full moon	**44**	Yes
Nov	Full moon	21	Yes
Reef 38			
April	3 days after new moon	0	-
April	2 days before full moon	7	-
April	3 days before new moon	6	-
May	3 days after new moon	**16**	-
May	6 days before full moon	**14**	-
May	1 day before full moon	4	-
May	Full moon	0	-
May	4 days after full moon	2	-
May	3 days before new moon	5	yes
June	5 days after new moon	2	-
July	4 days before full moon	3	-
July	2 days before full moon	6	-
July	7 days before new moon	8	-
Aug	1 day after new moon	**15**	-
Aug	2 days before new moon	13	-
Nov	2 days before full moon	**16**	-

Moon phase & colour – The dark phase fish occurred in highest percentages at 95% three days before new moon in May; 76% six days after new moon in June; 88% two days after full moon in June and 50% two days before new moon in November (Figure 2a). The numbers of dark and pale phases were almost equal two days before new moon in May, three days before new moon and new moon in August. Fish with patterned markings were not found in large numbers except two days before the full moon in November. Increased coral trout numbers on this particular day suggest possibility of mass hunting with 23% of fish in camouflage marking body coloration.

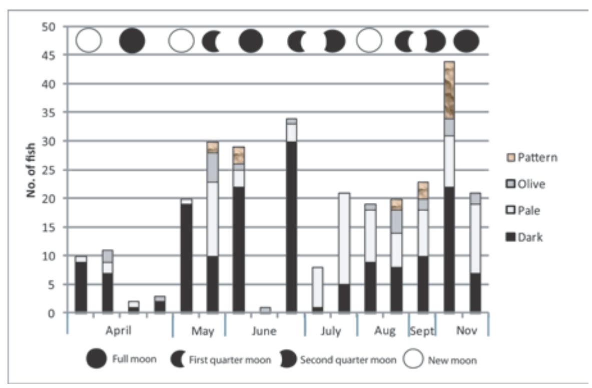

Figure 2a: The coral trout color variation at different moon phase in Bimbo Rock. Note: the moon phase is illustrated to the best fit.

In contrast to Bimbo Rock, the numbers of dark phase fish recorded were higher one day after new moon and two days before new moon in August at Reef 38. The dark phase coral trout appeared more abundant before the new moon. The number of dark phase was almost the same percentage with the pale phase in six days before the full moon in May and two days before full moon in July, seven days before new moon in July and two days before full moon in November. The olive coloration and pattern marking were not obvious in Reef 38. Briefly, fewer coral trouts were counted during full moon except November.

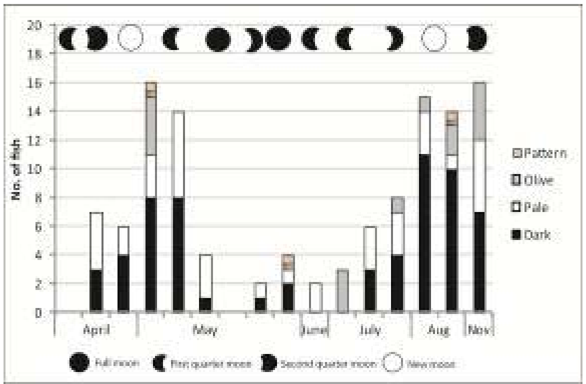

Figure 2b: The coral trout color variation at different moon phase in Reef 38. Note: the moon phase is illustrated to the best fit.

Size & colour – At Bimbo Rock, more than 54% coral trout larger than 36 cm TL appeared in the dark phase (Figure 3a). For example, 64% of coral trout within the 36-55 cm were in dark phase. Larger fish appeared more often in the dark than the pale phase. At Reef 38 smaller coral trout ranging from 26 to 35 cm TL tended to have pale colouration (Figure 3b). Similarly to Bimbo Rock, larger fishes more than 36 cm TL mostly appeared in dark colouration in Reef 38.

Food availability –Seven censuses at Bimbo Rock recorded presence of juvenile fusilier (Table 1). The result showed the number of coral trouts increased whenever there were presence food sources. At Reef 38, only one census recorded with presence of juvenile fusilier. However, the number of coral trout number not increased.

Aggregation behaviour - Coral trouts aggregated at the reef slope ranging from 13 to 22 m depth. Coral trout patrolled along the reef slope, about 1.5 to 2m from the coral substrate. No spawning rush was sighted during any census. However, territorial defensive behaviours were observed between 2 to 4 larger (36-55 cm TL) dark phase fishes with open jaws when near to each other. Also side-waving behaviour by dark phase fish was observed strongly suggestive of courtship behaviour.

At Bimbo Rock, coral trout aggregate in larger numbers and mostly appeared in dark phase. In three censuses in May, June and November, groups of 10 to 20 individual dark phase coral trout were observed with 5 to 10 bluefin trevally (*Caranx melampygus*) jointly hunting a school of juvenile fusilier (*Pterocaesio tessellate*). Hunting occurred along the reef slope ranging from 14 to 20 m depth. Coral trout staying near to corals or rubble substrate were often noted to be in the patterned body colouration. This patterned colouration occurred when coral trout were hunting preys hiding among the coral. The camouflage mode of body colouration changed quickly to either dark, olive-green or pale phases whenever the coral trout ceased their hunting attempts.

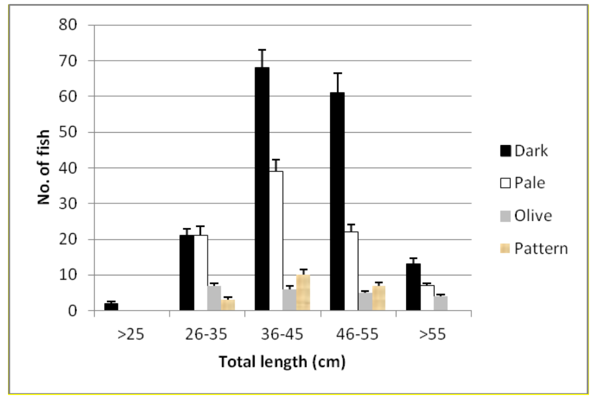

Figure 3a: The color variation at different total length (N=296) at Bimbo Rock

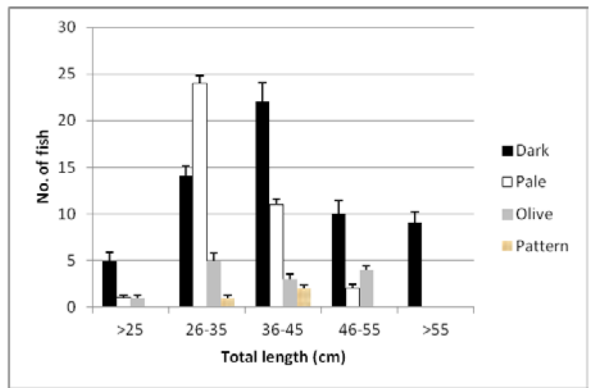

Figure 3b: The colour variation at different total length (N=117) at Reef 38

Discussion

Peak aggregation numbers were recorded two days before the new moon in November at Bimbo Rock. The results show a wide variation in fish abundance during different months and moon phases. However, the results indicated aggregation possibly occurred in May/June and August/November for both sites. Coral trouts are often reported to be solitary or not forming big groups outside of the reproductive season. The high abundance counts in this study indicated the coral trouts aggregated for spawning or feeding. No spawning activities were observed during this field survey however colouration and behaviours observed strongly suggest that the aggregation is associated with reproduction. At Bimbo Rock, juvenile fusiliers at the reef probably encourage coral trouts to aggregate and participate in joint-hunting with bluefin trevally. This suggest that the occurrence of aggregations may also be dependent on the food sources. Particularly at Bimbo Rock, the aggregations of coral trout seem to be related to the presence of juvenile fusilier.

The aggregation abundance varies from day to day (Sadovy et. al., 2005) and even within a day. The big variation within a day may suggest coral trout is resident spawners that move regularly to spawning sites within their regular home ranges (Ormond & Gore, 2003). Samoilys & Squire (1994) showed different coral trout abundance at daytime and at dusk within a day. They found that abundance was higher during dusk, but that maximum numbers of fish were also observed during daytime so they then suggested that aggregations are not just a diel phenomenon. Most reef fish species that aggregate spawn over three months or less each year (Sadovy de Mitcheson et. al., 2008). The timing of aggregation formation is also related to the moon phase (Sadovy et. al., 2005) and tidal conditions. Samoilys & Squire (1994) recorded spawning rushes at dusk. However, the similar species *Plectropomus areolatus* was reported to spawn one hour before high tide in the morning during new moon (Pet et. al., 2005). The present study is constrained as the first and preliminary observation of the coral trout aggregation limited to daytime observations excluding dawn and dusks. Thus, no comparison between day and dusk abundance could be made. More surveys at the different times, moon phases and tide conditions are needed to confirm spawning in the apparent spawning aggregations of coral trouts around Lankayan Island.

Colour variation and courtship behaviour or courting males has been described by Samoilys & Squire (1994) where the males show typical courtship markings of darkened fin edges. In the present study, obvious dark and pale phases were recorded. The dark phase was more abundant (higher percentage) in most censuses and larger fish tended to be in dark phase compared to smaller fish. Side-waving (courtship) was seen only in dark phase fish. However, it could not be confirmed whether only males exhibit the dark phase. The earlier assumption on dark phase is male fish were based on territorial defensive behaviours and scars on dark fishes as well as side-waving. In this study, the darkened fin edges as described by Samoilys & Squire (1994) were observed twice on two pale phase larger fishes (~55-65 cm TL).

Groupers are usually protogynous hermaphrodites where juveniles mature and function first as females and change to males when they grow older (Shapiro, 1987 in Levin & Grimes, 2002; Johannes et. al. 1999). Ferreira (1995) indicated that coral trout that of 32-36 cm fork length tend to be reproductively female. Further, Samoilys & Squire (1994) reported that larger coral trout tend to be male. In this study, smaller coral trout less than 36 cm TL at Reef 38 tended to be in pale phase suggesting that the pale phase represents female fish. However, without gonad examination of the coral trout in different colour phases in relation to size, the hypothesis that dark phase represents male and pale phase represents female cannot be tested. Colour variation of a species during the reproductive period may play an important role for fish to communicate, for example on differential sex or maturity status. Claydon (2004) and others suggested that aggregations give individuals an opportunity to assess the sex ratio of a population. During sex-ratio assessment, larger females may change sex when its perceives a lower relative number of males within the social group (Levin & Grimes, 2002). Thus, if the dark and pale colouration phases are mechanisms to differentiate between male and female fishes, the reproductive capacity of the spawn population can be easily assessed.

Management implications – Aggregations of coral trout or other groupers have never been recorded around Lankayan Island or in Sabah, Malaysia. Multiple dives have been conducted around Lankayan Island since 2005 and no record of aggregations was observed until 2010. The increased number of coral trout observed recently may indicate a recovery of the species that was depleted in the past. After a decade of protection from the establishment of Sugud Islands Marine Conservation area (since 2001), reef fish abundance and biomass increased within the reserve (Chung et. al. 2012). Groupers and other commercially important species are able to grow to larger sizes, which may increase the number of spawners within the reserve. In this study, the first finding of aggregations of adult coral trouts, likely to be spawning aggregations but possibly also associated with feeding, at well protected reefs show that the marine reserve serves an important role for fisheries management in maintaining a reproductively fish.

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