Spatial Distribution and Characterization of the Triggerfish *Balistoides viridescens* (Balistidae) on a Spawning Aggregation Site at Guam, Mariana Islands

Distribución y Caracterización Espacial del Peje Puerco *Balistoides viridescens* (Balistidae) en Una Agregación de Desove en Guam, en las Islas Marianas

Distribution Spatial et Caractérusation de la Baliste *Balistoides viridescens* (Balistidae) sur un Site D'Agregation à Guam, Iles de Marianas

TERRY J. DONALDSON and ARIELLE G. DIMALANTA
*University of Guam Marine Laboratory, UOG Station, Mangilao, Guam 96923 USA. *donaldsn@uguam.uog.edu.*

ABSTRACT

Transient spawning aggregations are formed by species that migrate periodically from relatively distant home ranges to specific sites where they persist for days or weeks during a spawning cycle before returning home. Many of these spawning aggregations form on a seasonal basis, with formation occurring just prior to the new moon, full moon, or both. Most species spawn in pairs or groups and have pelagic gametes. The Indo-West Pacific triggerfish species *Balistoides viridescens* (Balistidae), however, forms spawning aggregations just prior to both new and full moons, and spawns demersally with males arriving at the spawning aggregation site first to defend nesting sites and then attracting females to spawn in them. GPS-transect surveys of a principle site at Guam revealed patterns of spatial distribution of both male, female, and older juvenile triggerfishes on this site during daylight hours. Most individuals were concentrated on a shallow bench (4 - 8 m) adjacent to a cut in the fore reef with regular fidelity. Triggerfishes moved out from nocturnal shelter sites in the lower spur and groove zone to this area and were often observed patrolling this portion of the site while swimming in loose aggregations in the water column. During patrols, males and females displayed to one another, often rising to within 1m of the surface over the edge of the reef slope. These interactions appear to reinforce familiarization among individuals prior to courtship and spawning on the site.

KEY WORDS: Behavior, habitat, mating system, reef fish, spawning aggregation

INTRODUCTION

Reef fish spawning aggregations form at specific times and places and are, at least in their unfished state, relatively large in size and may consist of hundreds or even thousands of individuals. Fishes forming these aggregations may leave their home ranges or reefs and travel distances ranging from tens of meters (usually resident spawning aggregation species) to over hundreds of kilometers (transient spawning aggregation species) in order to reach a specific spawning aggregation site (Domeier and Colin 1997, Colin et al. 2003, Claydon, 2004). In most cases, spawning aggregations assemble for relatively brief periods of time (a few hours to a few days or more) in order to complete reproduction before returning home (Colin 199, Domeier and Colin 1997, Luckhurst 1998, Rhodes and Sadovy 2002). The frequency of spawning aggregation formation can vary both for species and for individuals. Fishes may form spawning aggregations daily (e.g., resident species), seasonally (resident or transient species), or annually (transient species). Spawning for most reef fish species is pelagic and may include pair spawning (male/female pair within the aggregation), streak spawning (male/female pair joined by an additional male who does not participate in courtship), and group spawning (male/female pair joined by two or more males, often without elaborate courtship), or mass spawning, e.g., when a large number of individuals spawns together simultaneously. Less commonly seen is demersal spawning in nests or holes in the substratum. For example, the triggerfish *Pseudobalistes flavomarginatus* (Balistidae) forms spawning aggregations in which males prepare and defend nest sites on sand and rubble bottoms while attempting to attract females for mating during the new and full moon phases (Johannes 1981, Gladstone 1994, Colin 2011, Donaldson, Unpublished data). The mating system is lek-like (Gladstone 1994, Donaldson, Unpublished data). Successful males court and spawn with at least one female during each spawning period on the aggregation. Males then defend these nests but they are usually abandoned the day after the new or full moon (Donaldson, Unpublished data, but see Johannes 1981, Gladstone 1994, Myers, 1999). There is some initial evidence that males demonstrate site fidelity for both aggregation sites and nest sites, and may return to them during each spawning cycle (Colin 2011, Donaldson, Unpublished data).

Another species of triggerfish, the Titan triggerfish, *Balistoides viridescens*, forms spawning aggregations, as well. This species is largest in the family Balistidae, reaching a body size greater than 60 cm SL (Myers 1999), and is distributed in the Indo-West Pacific from the Red Sea east to the Tuamotu Archipelago in French Polynesia, north to southern Japan, and south to New Caledonia and the Great Barrier Reef (Myers 1999). Adult titan triggerfish feed usually upon various macroinvertebrates and corals, and are found mainly on seaward and lagoon reefs to a depth of 40 m (Myers 1999). This species is observed usually singly or rarely in pairs, and like many other relatively large predatory species, tends to be uncommon at any locality (Donaldson, Unpublished data). The titan triggerfish, like *P. flavimarginatus*, is extremely wary and aggressive, and reportedly is especially so on nest sites (Myers 1999, Colin, 2011).

The discovery of a titan triggerfish spawning aggregation site at Guam, Mariana Islands afforded the opportunity to examine the aggregation's characteristics. This paper provides a preliminary examination of the spatial distribution, lunar periodicity and behavior of this species at this spawning aggregation site.

METHODS

Study Site

Visual surveys of the triggerfish spawning aggregation site were conducted at Orote Point, Guam, Mariana Islands (ca. N13.2695, E144.3751) between January 2009 and October 2011 (Figure 1). The site is an exposed fringing reef at the mouth of Apra Harbor that consists of a shallow bench (4 - 8 m) below the spur and groove zonethat grades first gently and then steeply down the reef slope to the bottom (ca 30 - 45 m). The spur and groove zone (1 - 3 m) has numerous holes in the pavement, occasional large boulders, and overhanging ledges along the grooves. The bench is made up mainly of coral pavement with numerous individual *Pocillopora* spp. corals, some large boulders, and holes. At the interface between the bench and the reef slope, the coral composition shifts to relatively dense patches of *Porites rus* corals, coral boulders, and various other coral species; the corals are distributed down slope where the bottom shifts to rubble, sand, and patches of coral.

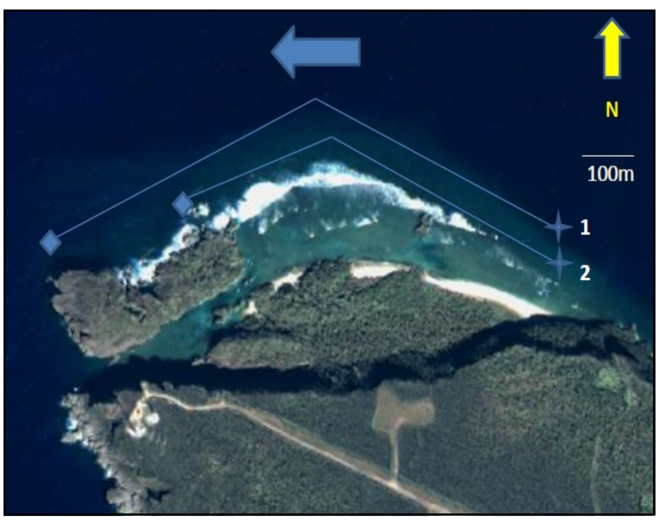

Figure 1. Orote Point and entrance to Apra Harbor, Guam, Mariana Islands. The arrows indicate paths swum during GPS-linked transect surveys of triggerfish at the spawning aggregation site in the reef bench (1) and spur and groove (2) zones.

Survey Transects

Visual census transects were made at the site using the GPS transect method (Colin and Donaldson, Unpublished manuscript), in which a snorkeling observer towed a GPS unit contained within a waterproof housing fitted to a floating drogue and attached to a line held on a reel attached to the snorkeler. Typically, 2.0 m of line was released from the reel so that the drogue could be towed directly behind the observer as he swam the transect. The GPS unit was set on the "Track" function and recorded the position of the observer/unit every 15 seconds (four per minute with the second measurement serving as the "mean" position value for a given minute). The observer's electronic watch was synchronized with the GPS unit's clock. Observations were recorded once per minute on underwater paper so that counts of triggerfish observed at the site could be related to a position at a given time. Underwater photographs and video recordings were made occasionally to supplement the visual observations. Transects began at the eastern end of the site (Figure 1) and each was swum in an approximately westward direction along the outer portion of the bench. The observer was able to count triggerfish both on the bench zone and the upper reef slope (visibility downslope was usually greater than 25 m). If surf conditions permitted, a second transect would be swum along the mid-outer spur and groove zone to the westward-most edge of this zone ("The Cut") before it gave way to deeper water along the cliff line (Figure 1). Transect length on the bench was approximately 860m; on ten occasions, transect lengths were cut short because of strong currents that prevented swimming past The Cut (ca. 600 m). Distances swum in the spur and groove zone was approximately 600 m and depended both upon current and surf conditions. The width of all transects regardless of zone was ca. 20 m. Because of logistical limitations, most transects were swum variously between 0700-1300H during all phases of the moon over a 30-month period (January 2009 - June 2011). The lack of daily surveys compromises the data to some extent with respect to temporal patterns in the formation and maintenance of the spawning aggregation(see Colin et al. 2011) but at Orote Point did not affect data on the spatial distribution of the triggerfish within the site. In this paper, we report data from 96 bench transects and 24 spur and groove zone transects, and provide a general description of the pattern of spatial distribution of triggerfish on the spawning aggregation site. More detailed analysis will appear elsewhere (Donaldson, In preparation).

RESULTS

Body Size and Gender Assignment

Body sizes of individuals were not measured directly but rather were divided into three classes: large (> 45 cm TL), medium (25 - 45 cm) and small (ca. 20 - 25 cm). Gender was inferred from observations of behavior and is provisional: large individuals were considered male, medium-sized individuals were considered presumptive females, and small individuals were considered to be juveniles of either sex.

Temporal Periodicity of Spawning Aggregation Formation

Spawning aggregations of titan triggerfish formed during every month throughout the year. The mean numbers (pooled data by month) of males (Figure 2a), presumptive females (Figure 2b), and juveniles (Figures 2c) varied on a monthly basis but this variation may be an artifact of unequal sampling because of heavy seas at the site during certain months.

Spawning aggregations formed prior to both new and full moon periods. Typically, the mean number of individuals observed would increase from a first or third quarter periods as the full or new moon approached (Figure 3a). Males tended to arrive before females and remained on site after the new or full moon for a variable number of days before departing as the quarter moon phase approached. Females arrived soon after but tended to be more abundant prior to and at the new moon compared with other phases (Figure 3b). Females tended to depart soon after the new moon but would begin to arrive again as the first quarter approached. Juveniles tended to arrive in a pattern similar to that of males but would also tend to linger at the site after the new or full moon (Figures 3c and 3d, with data from separate years with irregular sampling).

Spatial Pattern and Behavior of the Spawning Aggregation

Males patrolled the bench spawning aggregation site during morning hours and swam also in the water column above both the bench and the upper reef slope, sometimes up to the surface. Details of geographical coordinates of individuals and the spawning aggregation core will appear elsewhere (Donaldson, In preparation). Most individuals were observed just east of The Cut while a second smaller group was observed occasionally near the transect starting-point (Figure 4). Presumptive females and juveniles also swam about the site and joined the males in the water column. Individuals of the latter group were observed to move along the bench-reef slope interface, or just down the reef slope, and intermingle with those of the larger group. For example, during bench surveys, as the observer moved from the eastern border of the site to the western border, triggerfish in the water column and down near the bottom would gather successively in a loose but growing group and swim above the edge of the reef slope and parallel to the observer as far as the western edge of The Cut ("Parading" behavior) before drifting off and swimming back to the bench. Male-male and male-presumptive female interactions were observed also. These interactions consisted usually of mutual lateral and frontal displays; males often tilted to a ca. 45 degree angle during these displays. During spur and groove surveys during morning, triggerfish were observed moving singly, in pairs, or in small groups of 3 - 4 individuals away from the spur and

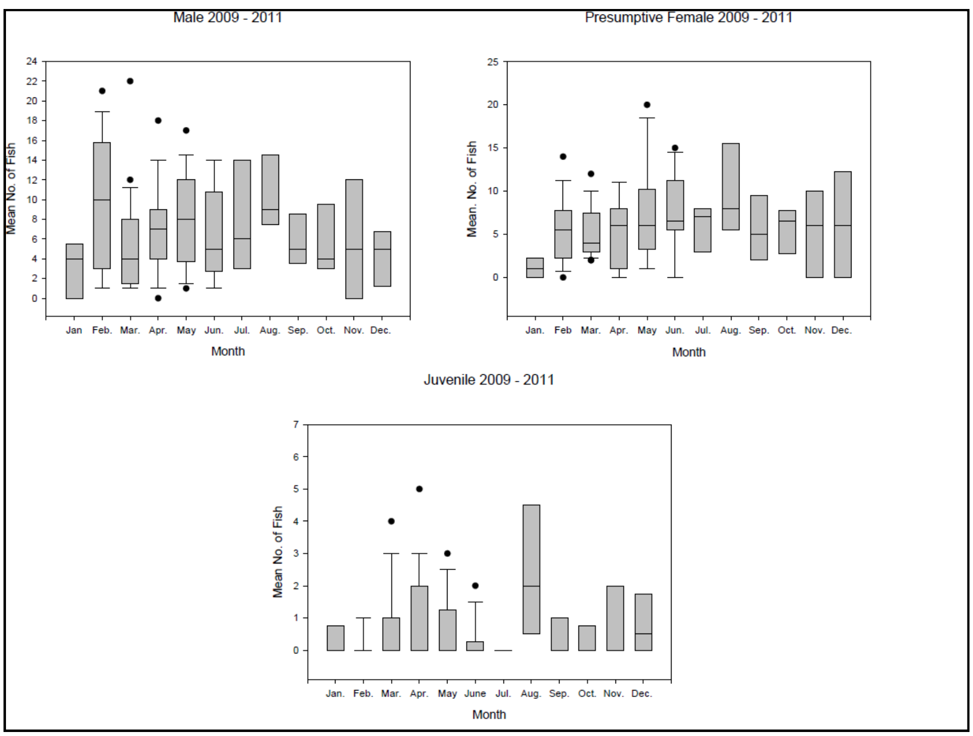

Figure 2. Mean number of male, presumptive female and juvenile triggerfish per month on the spawning aggregation site at Orote Point, Guam. Error bars indicate standard errors around the mean. Dots indicate outlier values. Data are pooled for each month.

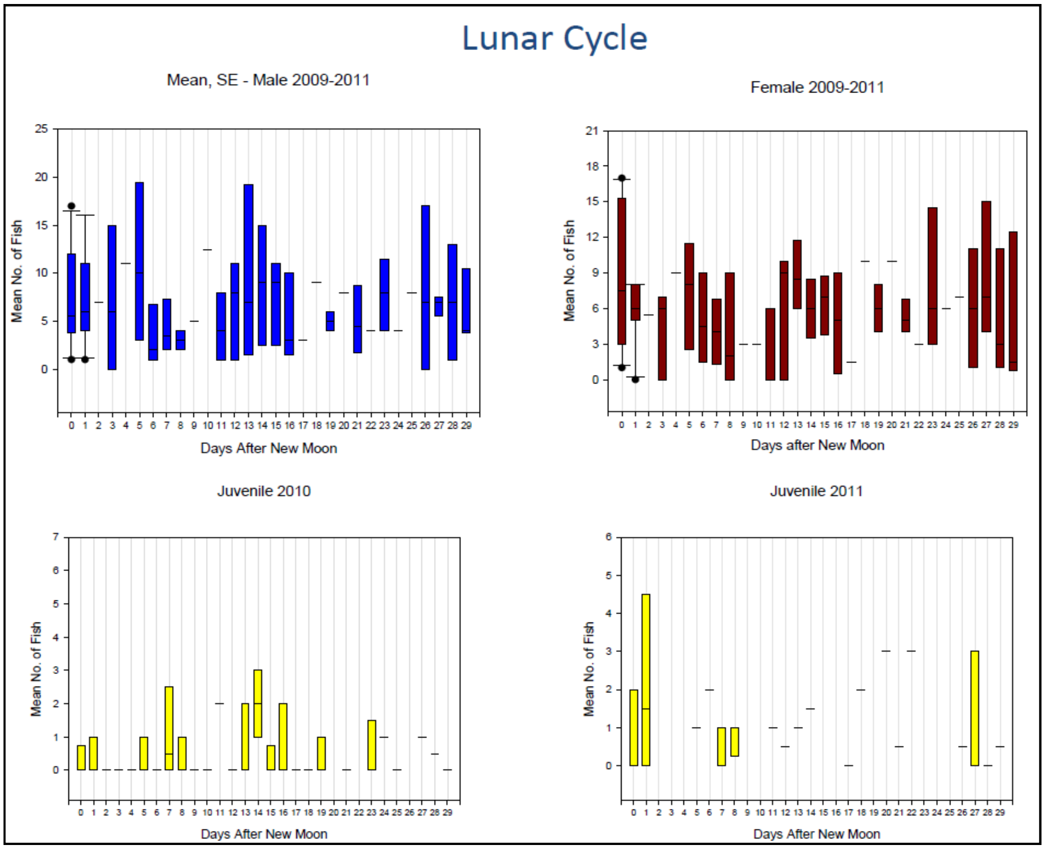

Figure 3. Mean number of male, presumptive female and juvenile triggerfish per day over the lunar month. New moon is considered day 0 and full moon falls on day 14. Data are pooled for each day surveyed, and a number of days were not surveyed because of logistical constraints.

Figure 4. Spatial distribution of triggerfish in the bench zone of the spawning aggregation site at Orote Point, Guam. A smaller subset of individuals was encountered frequently on the eastern side of the site (smaller ellipse) but these individuals often swam westward (direction denoted by red arrow) toward to join most individuals at the point (larger ellipse) where the bench extended furthest out away from shore before turning inwards again.

groove zone and out onto the bench. Occasionally, one or more triggerfish would pause and display to one another near an eroded coral pillar at the edge of the spur and groove zone. Triggerfish in the spur and groove zone were also observed sleeping in holes in the pavement at night.

Limited observations of males during late afternoon indicated that males appeared to form temporary territories that included potential nest sites; nests at Orote Point were found in fissures and shallow holes in the reef. Males defended against rival males and attempted to attract females to court as sunset approached. Spawning was not observed, however, but males were observed guarding what appeared to be nests on the following morning.

DISCUSSION

Temporal Patterns

Monthly variation in the mean abundance of triggerfish on the spawning aggregation may be a consequence of sampling artifacts because of inclement conditions, but may also reflect a pattern of one or more peaks of activity (Johannes 1981, Sale 1978, 1980, see also Thresher 1984). Such peaks might result from selection for periods of favorable minimal currents that might limit the dispersal of larvae produced during the course of spawning away from favorable substrata (Johannes 1978, Lobel 1978). Further, at higher latitudes spawning aggregation formation, and hence abundance of individuals at a given site, may be seasonal because of the influence of lower water temperatures during colder months of the year (e.g. Fricke 1980, Thresher 1984). Regardless, triggerfish spawning demersally throughout a season (a full year being the greatest extent of a season) follows the same general pattern observed of many other tropical demersal and pelagic spawning species (Thresher 1984).

Spawning aggregation formation by this species is bilunar with peaks around the new and full moons. This is consistent with observations of spawning aggregation formation by *Pseudobalistes flavimarginatus* in Australia (Gladstone 1994), Palau (Johannes 1981, Colin 2011, Donaldson, Unpublished data), and elsewhere (Myers 1999). In both species and prior to courtship and spawning, the size of the spawning aggregation increases daily as the new or full moon approaches, with males arriving at the site ahead of females. Nest site selection, maintenance, and defense by male, *P. flavimarginatus* is seen easily during this time period (Johannes 1981, Gladstone 1994, Donaldson, Unpublished data), with females reportedly contributing to nest defense as well (Gladstone 1994). These behaviors remain to be seen in greater detail for *B. viridescens* at Orote Point. Additional observations are needed to elucidate male behavior at nest sites during spawning aggregation formation and female behavior after spawning has occurred.

Spatial Patterns and Behavior

Spawning was not observed at Orote Point but observations of *P flavimarginatus* (Fricke 1980) suggest that spawning occurs very early in the morning, perhaps just prior to or after sunrise. Nest defense for *P. flavimarginatus* is biparental with the female confined to the nest site by the male (Gladstone 1994, Colin 2011). Observations of *P. flavimarginatus* in Palau, however, indicate that the nest and the spawning aggregation site are abandoned by both females and males by the following morning after the day of the new moon, when spawning presumably took place (Donaldson, Unpublished data). Further, male and not female *B. viridescens* at Orote Point were observed guarding nest sites both before and directly after the days of the new and full moons. This contrasts with reports that large females guard nests of both *P. flavimarginatus* and *B. viridescens*, with the former being less aggressive than the latter species (e.g., Randall et al. 1996) but, in part, supports observations that larger individuals of *P. flavimarginatus* acted as males, and tended and very aggressively guarded nests prior to spawning, while smaller females arrived only just before courtship and spawning occurred (Gladstone 1994, Donaldson, Unpublished data). Clearly, the relationships between body size, gender, and nest defense of large species of triggerfishes need to the resolved.

ACKNOWLEDGMENTS

We thank Zachary Foltz, Kathryn Chop, David Benavente, Jason Miller, and especially Joe Cummings for their assistance in the field. Alejandro Acosta kindly translated the abstract into Spanish and Mecki Kronen translated it into French. Support for this study was provided by the U.S. Fish and Wildlife Service Sportfish Restoration Program administered through the Guam Division of Aquatic and Wildlife Resources. This is a contribution of the University of Guam Marine Laboratory.

LITERATURE CITED

Claydon, J. 2004. Spawning aggregations of coral reef fishes: characteristics, hypotheses, threats and management. *Oceanography and Marine Biology: An Annual Review* **42**:265-302.

Colin, P.L. 1992. Reproduction of the Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae) and its relationship to environmental condition. *Environmental Biology of Fishes* **34**:357-377.

Colin, P.L. 2011. Yellowmargin triggerfish- *Pseudobalistes flavimarginatus*, with notes on other triggerfishes. Pages 542-547 in: Y. Sadovy de Mitheson and P.L. Colin (eds.) *Reef Fish Spawning Aggregations: Biology, Research and Management*. Springer, New York, New York USA.

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

Colin, P.L., Y.J. Sadovy de Mitcheson, and T.J. Donaldson. [In press]. Grouper spawning aggregations: Be careful what you measure and how you measure it: A rebuttal of Golbuu and Friedlander (2011). *Estuarine, Coastal and Shelf Science*.

Domeier, M.L. and P.L. Colin. 1997. Tropical reef fish spawning aggregations: defined and reviewed. *Bulletin of Marine Sci*ence **60**: 698-726.

Fricke, H.W. 1980. Mating systems, maternal and biparental care in triggerfish (Balistidae). *Zietschrift fur Tierpsychologie* **53**:105-122.

Gladstone, W. 1994. Lek-like spawning, parental care and mating periodicity of the triggerfish *Pseudobalistes flavimarginatus* (Balistidae). *Environmental Biology of Fishes* **39**:249-257.

Johannes, R.E. 1978. Reproductive strategies of coastal marine fishes in the tropics. *Environmental Biology of Fishes* **3**:65-84.

Johannes, R.E. 1981. *Words of the Lagoon*. University of California Press, Berkeley, California USA. 245 pp.

Luckhurst, B.E. 1998. Site fidelity and return migration of tagged red hind (*Epinephelus guttatus*) to a spawning aggregation site in Bermuda. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:750-763.

Myers, R.F. 1999. *Micronesian Reef Fishes, 3rd Edition*. Coral Graphics, Barrigada, Guam. 330 pp, 192 pls..

Randall, J.E., G.R. Allen, and R.C. Steene. 1996. *Fishes of the Great Barrier Reef and Coral Sea - Revised and Expanded Edition*. University of Hawaii Press, Honolulu, Hawaii USA. 557 pp.

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

Thresher, R.E. 1984. *Reproduction in Reef Fishes*. TFH Publications, Neptune City, New Jersey USA. 399 pp.