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note

Lunar periodicity in spawning of white grunt, *Haemulon plumierii*

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ABSTRACT.—Understanding lunar periodicity in spawning is necessary for guiding studies on reproduction in fishes, but is unknown for the abundant and economically important white grunt, *Haemulon plumierii* (Lacépède, 1801). We sampled mature white grunts in the eastern Gulf of Mexico during each of the four lunar periods of April 2016, coinciding with the seasonal peak of their spawning activity. Spawning-capable white grunts were macroscopically distinguishable from actively spawning fish, which we further confirmed microscopically. There was a clear lunar pattern with peak oocyte hydration and presence of flowing milt (i.e., actively spawning fish) during the full moon. A full moon spawn may be advantageous to juveniles settling during the following new moon after a short pelagic larval duration previously determined to be approximately 14 d. These findings can guide future research seeking to quantify either batch fecundity or production of white grunts by identifying the lunar period during which sampling should occur.

White grunts, *Haemulon plumierii* (Lacépède, 1801), are a haemulid fish found on low-to-medium relief reefs in the western Atlantic Ocean from Maryland, USA, to Brazil, including the Caribbean Sea and Gulf of Mexico (McEachran and Fechhelm 1998). In the eastern Gulf of Mexico (eGOM), white grunts are one of the most ubiquitous and abundant fishes (both numerically and as biomass) on both natural and artificial reefs (Stallings and Simard 2015). The species is targeted by both recreational and commercial fishers, particularly in the eGOM where an estimated 2.9–4.1 million fish were landed annually from 1989 to 1995 (Murphy et al. 1999). Given their assumed importance ecologically (due to their abundance) and clear importance as a fishery species, understanding basic aspects of their biology is fundamental to guiding future research, stock assessments, and management.

In the eGOM, we know that the spawning season for white grunts extends from April through September, with a peak in spawning activity during April and May (Murie and Parkyn 1999). However, we do not know whether spawning activity is linked to the lunar cycle and, if so, which period(s). Understanding lunar periodicity in spawning is a prerequisite for estimating batch fecundity or calculating tissue production (e.g., DeMartini et al. 1994, Granneman and Steele 2014). Here, we describe the lunar periodicity of mature gonads in white grunts captured in the eGOM during the peak of their spawning season (April 2016).

Materials and Methods

During April 2016, we collected 124 white grunts from natural reefs located offshore of Tampa Bay, Florida, at depths of 10–25 m. Collections occurred from 09:45 to 15:00 hrs during each of the four lunar periods (April 8, new moon + 1 d; April 14, first quarter; April 22, full moon; April 29, third quarter). Times of collection were based on prior observations and discussions with fishers regarding the timing of the presence of hydrated oocytes. All specimens were captured via hook and line. Because our focus was entirely on mature fish, we retained only specimens >18 cm total length, which has been reported as the smallest size at which both female and male white grunt first reach sexual maturity in the region (Murie and Parkyn 1999) and elsewhere in their range [e.g., Shinozaki-Mendes et al. 2013a; but note that mature white grunts have been observed at 13 cm TL off Cuba (García-Cagide 1987) and 16 cm TL off Jamaica (Gaut and Munro 1983)]. Retained fish were individually tagged, placed on ice, and brought back to the lab for processing at the University of South Florida, College of Marine Science.

In the laboratory, we measured the pinched-tail total lengths of all fish. White grunts were dissected using surgical scissors by cutting from the vent to the pelvic girdle. The fish were carefully opened and the gonads were removed for macroscopic assessment of reproductive phase. Following the standardized terminology suggested by Brown-Peterson et al. (2011), we assigned the mature fish to one of two phases: (1) spawning capable and (2) actively spawning. Spawning capable fish included those with gamete development that allowed for spawning during the current reproductive cycle. Actively spawning is a subphase of spawning capable corresponding to hydration and ovulation in females and spermiation in males (Brown-Peterson et al. 2011). We used descriptions of white grunt gonads and gametes by Palazón-Feréndez (2007) and Shinozaki-Mendes et al. (2013b) to guide our assessment of reproductive phases. Specifically, spawning capable fish had large gonads occupying most of the body cavity (especially in females), ovaries that were yellowish to orange in color, highly vascularized, with oocytes visible to the naked eye, and testes that were opaque, milky white in color, and laterally flattened (Fig. 1). The gonads of actively spawning fish have most of the same characteristics as spawning capable fish, but can be distinguished by the presence of hydrated oocytes in females (oocytes become increasing large, translucent, and spherical; West 1990) and flowing milt in males (Fig. 1). We preserved subsamples of mature ovaries in 2% neutrally buffered formalin following Lowerre-Barbieri and Barbieri (1993). Preserved samples were inspected under a dissecting microscope at a magnification of 24× to confirm the reproductive phase based on the presence of hydrated oocytes. Confirmation of reproductive phase in males was based on whether milt was produced when light pressure was applied to the testes. All processing was led by a single observer (CDS) with assistance by EBP.

We used a chi-squared test of independence to examine whether spawning phase (spawning capable vs actively spawning) was dependent on lunar period. We used *t*-tests to examine whether the total lengths differed between spawning capable and

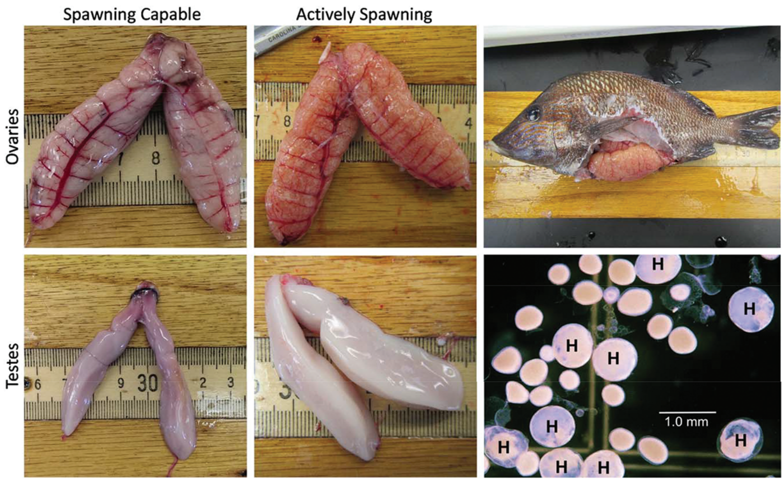

Figure 1. Macroscopic phases of mature white grunts (*Haemulon plumierii,* left and center columns) showing ovaries in top row, testes in bottom row, spawning capable gonads in the left column, and actively spawning in the center column. The right column shows a female white grunt with large ovaries occupying most of its body cavity (top) and hydrated white grunt eggs (each marked with "H") observed through a dissecting microscope (bottom; microscope photo credit: EBP; all others: CDS).

actively spawning fish. We also qualitatively compared the lunar patterns in reproductive phases with tide predictions from the tide station closest to our collections sites (Egmont Channel, FL Station ID: 8726347, located approximately 12–20 km from collection sites).

Results and Discussion

Of the 124 white grunts collected, 119 were mature, comprising 68 females and 51 males (Table 1). The appearance of hydrated oocytes was readily identified macroscopically, allowing for rapid distinction between the spawning capable and actively spawning phases in females (Fig. 1). Compared to ovaries, the two phases of testes were less distinguishable macroscopically (Fig. 1). However, the actively spawning testes tended to have a fuller appearance, were lighter in color compared to spawning capable testes, and the two phases were easy to distinguish based on the presence of flowing milt when light pressure was applied. Thus, distinguishing between spawning capable and actively spawning white grunts was both straightforward and efficient.

We found a clear relationship between the lunar period and reproductive phases ($\chi^2 = 30.21$, df = 3, $P < 0.001$). Among the females, none were assigned to the actively spawning phase during the new moon, 23% were in it during the first quarter, 91% during the full moon, and 17% during the third quarter (Table 1, Fig. 2). Thus, reproduction in white grunts appeared to peak during the full moon. This suggestion was further supported by our observations that actively spawning males were observed only during full moon (Fig. 2). Moreover, the sizes of spawning capable fish [female mean TL = 27.2 (SE 0.55) cm; male mean TL = 28.8 (SE 0.53) cm] did not differ (females $t_{66} = 0.54$, $P = 0.59$; males $t_{49} = 0.51$, $P = 0.61$) from those actively spawning [female mean TL = 27.6 (SE 0.47) cm; male mean TL = 27.8 (SE 0.72) cm]. Thus, the

Table 1. Number of spawning capable and actively spawning white grunts (*Haemulon plumierii*) collected during the four lunar periods of April 2016 in the eastern Gulf of Mexico.

	Females		Males	
Lunar period	Capable	Actively	Capable	Actively
New (+1 d, April 8)	15	0	11	0
First (April 14)	10	3	14	0
Full (April 22)	1	10	6	9
Third (April 29)	24	5	11	0

lunar patterns were not confounded by differences in sizes. There also were no confounding relationships with tides as the timing of low and high tides, tidal heights, and amplitudes were nearly identical between the new and full moon periods, as well as between the first and third quarters.

Spawning during the full moon may benefit settling white grunt juveniles. Haemulids, including white grunts, have short larval durations, lasting approximately 14 d on average (Lindeman et al. 2001). Thus, settlement after a full moon spawn would occur around the new moon, possibly providing some protection from predators if white grunts settle at night.

Our efforts can inform future investigations that seek to either estimate batch fecundity or calculate production in white grunt by identifying the lunar period in which their spawning activity peaks in the eGOM. To our knowledge, this was the first study to examine spawning periodicity of white grunt at the temporal scale of lunar period. Previous descriptions of spawning in white grunt have focused on intra-annual and seasonal patterns, with some equivocal results. For example, spawning has been reported to occur year-round in several studies, but with one peak during March and April off Jamaica (Munro et al. 1973), and two peaks (February to April and August to October) off both Venezuela (Palazón-Ferández 2007) and Brazil (Shinozaki-Mendes et al. 2013a). Spawning in the eGOM appears to be restricted to April through September with a single peak during April and May (Murie and Parkyn 1999). Although intraspecific variation in reproductive timing occurs across a wide range of taxa (reviewed by Hendry and Day 2005) and may explain the geographic differences reported for white grunt, it is also possible that the temporal scale of sampling used in previous studies may have missed the lunar period when fish were actively spawning. Our work builds upon previous efforts conducted intra-annually, highlighting the need to examine spawning across temporal scales (e.g., Koenig et al. in press) to avoid sampling bias (Lowerre-Barbieri et al. 2011).

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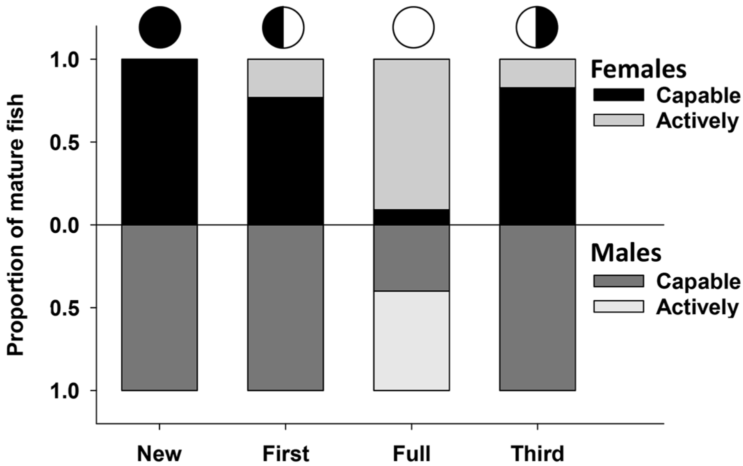

Figure 2. Proportion of mature white grunts (*Haemulon plumierii*) within four macroscopically assigned phases during each of the four lunar periods. In both sexes, the lighter colors indicate the fish were actively spawning (i.e., presence of hydrated eggs in females or flowing milt in males).

Literature Cited

Brown-Peterson NJ, Wyanski DM, Saborido-Rey F, Macewicz BJ, Lowerre-Barbieri SK. 2011. A standardized terminology for describing reproductive development in fishes. Mar Coast Fish. 3:52–71. http://dx.doi.org/10.1080/19425120.2011.555724

DeMartini EE, Barnett AM, Johnson TD, Ambrose RF. 1994. Growth and production estimates for biomass-dominant fishes on a southern California artificial reef. Bull Mar Sci. 55:484–500.

García-Cagide A. 1987. Características de la reproducción del ronco arará, Haemulon plumieri (Cuvier, 1829), en la region oriental del Golfo de Batabanó, Cuba. Rev Invest Mar. 8:39–55.

Gaut VC, Munro JL. 1983. The biology, ecology, and bionomics of the grunts, Pomadasyidae. *In:* Munro JL, editor. Caribbean coral reef fishery resources. International Center for Living Aquatic Resources Management, Manila, Philippines. p. 110–141.

Granneman JE, Steele MA. 2014. Fish growth, reproduction, and tissue production on artificial reefs relative to natural reefs. ICES J Mar Sci. 71:2494–2504. http://dx.doi.org/10.1093/icesjms/fsu082

Hendry AP, Day T. 2005. Population structure attributable to reproductive time: isolation by time and adaptation by time. Mol Ecol. 14:901–916. http://dx.doi.org/10.1111/j.1365-294X.2005.02480.x

Koenig CC, Bueno LS, Coleman FC, Cusick JA, Ellis RD, Kingon K, Locascio JV, Malinowski C, Murie DJ, Stallings CD. In press. The timing of spawning (diel, lunar, seasonal) in Atlantic goliath grouper, *Epinephelus itajara* (Lichtenstein, 1822). Bull Mar Sci. http://dx.doi.org/10.5343/bms.2016.1013

Lindeman KC, Lee TN, Wilson WD, Claro R, Ault JS. 2001. Transport of larvae originating in southwest Cuba and the Dry Tortugas: evidence for partial retention in grunts and snappers. Annu Proc Gulf Caribb Fish Inst. 52:732–747.

Lowerre-Barbieri SK, Barbieri LR. 1993. A new method of oocyte separation and preservation for fish reproduction studies. Fish Bull. 91:165–170.

Lowerre-Barbieri SK, Ganias K, Saborido-Rey F, Murua H, Hunter JR. 2011. Reproductive timing in marine fishes: variability, temporal scales, and methods. Mar Coast Fish. 3:71–91. http://dx.doi.org/10.1080/19425120.2011.556932

McEachran JD, Fechhelm JD. 1998. Fishes of the Gulf of Mexico. 1st edition. University of Texas Press, Austin.

Munro JL, Gaut VC, Thompson R, Reeson PH. 1973. The spawning season if Caribbean reef fishes. J Fish Biol. 5:69–84. http://dx.doi.org/10.1111/j.1095-8649.1973.tb04431.x

Murie DJ, Parkyn DC. 1999. Age, growth, and sexual maturity of white grunt in the eastern Gulf of Mexico: Part II. Final Report to the Florida Dept. of Environmental Protection under P.O.# S 3700 831415 to the Florida Marine Research Institute, St. Petersburg, FL. 57 p.

Murphy MD, Murie DJ, Muller RG. 1999. Stock assessment of White Grunt from the west coast of Florida. Report to the Florida Fish and Wildlife Conservation Commission. 56 p.

Palazón-Ferández JL. 2007. Reproduction of the white grunt, *Haemulon plumieri* (Lacépède, 1802) (Pisces: Haemulidae) from Margarita Island, Venezuela. Sci Mar. 71:429–440. http://dx.doi.org/10.3989/scimar.2007.71n3429

Shinozaki-Mendes R, Santander-Neto J, Silva J, Hazin F. 2013a. Reproductive biology of *Haemulon plumieri* (Teleostei: Haemulidae) in Ceará state, northeastern Brazil. Braz J Biol. 73:391–396. http://dx.doi.org/10.1590/S1519-69842013000200020

Shinozaki-Mendes R, Santander-Neto J, Silva J, Hazin F. 2013b. Gonad maturation of *Haemulon plumieri* (Teleostei: Haemulidae) in Ceará state, northeastern Brazil. Braz J Biol. 73:383–390. http://dx.doi.org/10.1590/S1519-69842013000200019

Stallings CD, Simard P. 2015. Quantifying participant use of artificial reefs in the eastern Gulf of Mexico using acoustic remote sensing techniques. Report to the Florida Fish & Wildlife Conservation Commission (FWC-12164). 157 p.

West G. 1990. Methods of assessing ovarian development in fishes: a review. Aust J Mar Freshwat Res. 41:199–222. http://dx.doi.org/10.1071/MF9900199