

Spawning-related biting behavior of *Arothron meleagris* (Tetraodontiformes, Tetraodontidae)

Hiroyuki Doi¹, Kaori Maei², Takafumi Yoshitake³,
Kazuyuki Momota¹, Harumi Sakai^{4†}

Abstract : An unusual instance of biting behavior by the pufferfish *Arothron meleagris*, possibly related to spawning behavior was observed during low tide of new moon spring tide while scuba-diving off the Maldives Islands. Multiple males were following, biting and clinging persistently to a female. Subsequent internet searches revealed that similar biting behavior was common among several congeners, possibly being a characteristic spawning-related behavior of the genus.

Key words : Pufferfish, *Arothron meleagris*, biting behavior, spawning

Pufferfishes (Tetraodontidae) have four beak-like powerful teeth, two on each jaw, which can be used to eat even hard shellfish. Pufferfish's biting behavior has also been observed in other behavioral situations, including aggression and breeding¹. Breeding male *Takifugu alboplumbeus*, for example, bites the female's body, thereby stimulating the latter to release eggs². Pair-spawning *Canthigaster rostrata*³ and *Torquigener albomaculosus*^{4, 5} are also known to stimulate female spawning by biting. In the unique case of the African freshwater puffer *Tetraodon schoutedeni*, a tandem pair or trio (a female bitten and clung to by a single or two males) results in the female spawning adhesive demersal eggs, scattered into the water after a period of tandem swimming⁶.

Two of the authors (KM and TY) observed an unusual instance of biting behavior by the pufferfish *Arothron meleagris* (Japanese name "Mizorefugu"), possibly related to spawning behavior similar to tandem swimming in *T. schoutedeni*, while scuba-diving off the Maldives Islands. Some periods of their observations have been released as video clips by Dive PAPAPPA Ishigaki Island⁷⁻¹⁰. Subsequent internet searches revealed that similar biting behavior was common among several congeners, such

being documented with photos or video clips. Such behavior involving spawning is an important consideration when investigating the diversity and evolution of pufferfish reproductive behavior.

Materials and Methods

Arothron meleagris

One of 14 species of the genus *Arothron* worldwide, *A. meleagris* is known from tropical Indo - Pacific coral reefs^{11, 12}. Body coloring of *A. meleagris* is basically black with many small white dots, but yellow variants are also known¹³. The ecology of the species, including reproduction, is unknown apart from some scattered information on feeding habits¹⁴⁻¹⁷.

Observation

The present observations were conducted at Rasdhoo Madivaru, a scuba diving site located about 800 m east (04°15'52"N, 73°00'01"E) of Rasdhoo Island (5 minutes by boat), on the outer reef of the atoll facing the open ocean. Water depth was about 10 m, the area including reef-building corals in colonies, and coral sand substrate.

On January 26, 2020 (moon age 1.4, new moon spring

Received date: 30 June 2022, Accepted date: 31 August 2022

¹ Osaka Aquarium NIFREL, 2-1 Senri-banpaku-koen, Suita, Osaka 565-0826, Japan

² Maldivian Stars, Lot No.11043 2nd Flr, Nirohlu Magu, Hulhumale, Republic of Maldives

³ Dive PAPAPPA Ishigaki Island, 210-10 Tonoshiro, Ishigaki, Okinawa 907-0004, Japan

⁴ Department of Applied Aquabiology, National Fisheries University, Shimonoseki, Yamaguchi 759-6595, Japan

† Corresponding author: sakaih@fish-u.ac.jp

tide), a tour-guiding dive was conducted for about 60 minutes from 13:05, with pufferfish observations occurring for about 10 minutes from about 13:48 (shortly after maximum low tide)

. The water temperature was 28-29°C, with visibility of ca. 30 m. An OLYMPUS Tough TG-5 digital camera was used for both videos and photographs. Pufferfish sizes were estimated with an iron indicator stick (46 cm long).

Results and Discussion

Biting behavior of *Arothron meleagris*

Initially, several *A. meleagris*, including one lighter-colored individual (probably female) bitten and clung on to by two others, and surrounded by four additional dark-colored individuals (probably all males), the size of each being about 25 cm in total length, were found on the bottom near the reef-building coral (Fig. 1a). One male was biting and clinging tightly to the back of the female, the other clinging similarly to the ventral surface of the caudal peduncle. Several white bite marks were observed on the female's back, including on the left side, behind the eyes, and above the left pectoral fin. Similar obvious bite marks were also observed on the bodies of some of the males (Fig. 1a, 1c). During the observation, the female sometimes tried to shake off the clinging males but failed⁷.

The female threatened another male approaching from the front by opening her mouth and showing her teeth. However, the biting males held the female down on the bottom, the latter then shaking her body thereby disturbing the coral sand and moving forward about 10 cm⁸. Subsequently, three of the four surrounding males also bit the female, resulting in five males clinging to and holding down the female on the coral sand bottom (Fig. 1b, 1c). However, the female swelled her body, shook off all the clinging males, and fled from them for about 10 m, her body remaining swollen⁹. The males quickly followed, two biting the female's caudal peduncle, whereupon the female swam into a reef crevice. The other males followed, with an eventual total of seven individuals (one female and six males) in the crevice¹⁰. Although biting by

multiple males continued, observations were discontinued at 13:58 because of insufficient air remaining in the SCUBA tanks.

Arothron meleagris commonly lives solitarily on coral reefs¹⁸, such having also been observed in the Maldives¹⁹. In fact, solitary individuals of *A. meleagris* on a southwestern reef off Colombia each occupied an area of

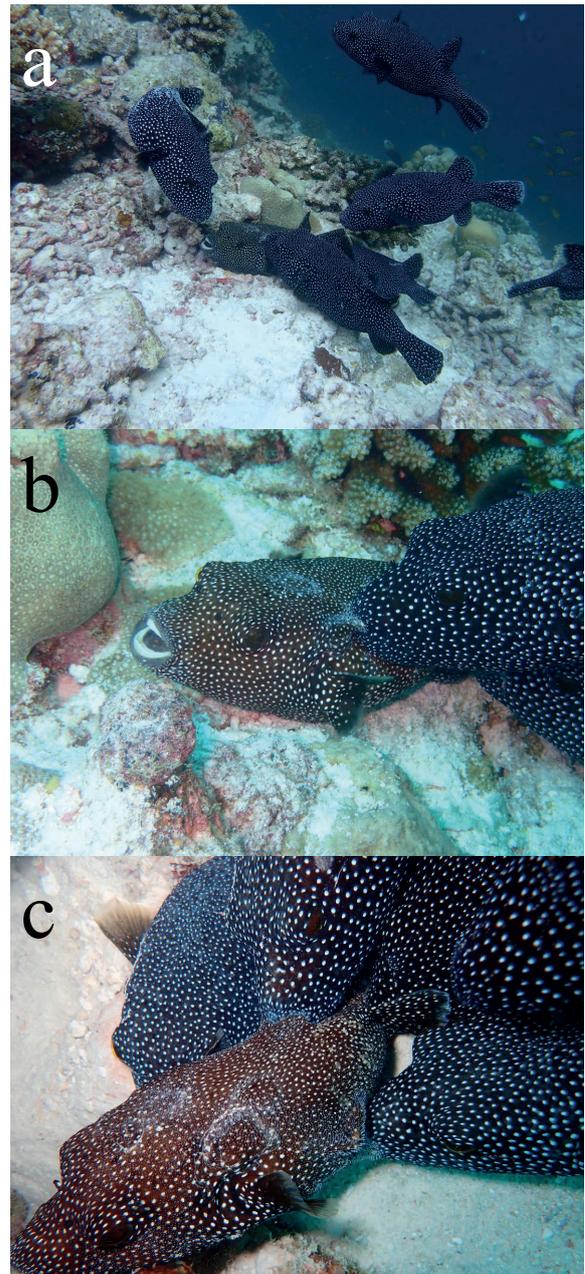


Fig.1 Biting behavior probably related to spawning in *Arothron meleagris* (photos by KM); a, a female bitten by two males, surrounded by four males; b, two males biting a female; c, five males biting a female, male and female with bite marks.

ca. 388 to 457 m² 15). Clearly, the aggregation of *A. meleagris* observed during low tide of new moon spring tide here, a single presumed female surrounded and bitten by six presumed males, contradicts the usual solitary lifestyle of the species. Although actual spawning was not observed, it was highly probable that the school was engaged in spawning behavior, similar to that of *Tetraodon schoutedeni* as documented⁶⁾.

Similar behavior observed and reported in other *Arothron* species

In addition to the above observations, one of the authors (KM) had also observed a tandem pair of *Arothron caeruleopunctatus*, a female of about 25 cm length bitten and clung to by a male of similar size, at the Five Rock diving site at Ari Atoll (Maldive Islands) (03° 34' 08"N, 72° 56' 28"E), on February 20, 2013. Both individuals lay almost motionless on the bottom (about 20 m depth) throughout a five minute observation. Although it was unknown how long such behavior had continued before and after the observation period, it might also have been related to spawning behavior.

No instances of similar behavior have been observed or reported for the other *Arothron* species inhabiting the Maldives region (*A. hispidus*, *A. immaculatus*, *A. mappa*, *A. nigropunctatus*, and *A. stellatus*)¹⁹⁾.

On the other hand, internet searches have revealed similar biting behavior, probably associated with breeding, uploaded for many *Arothron* species, as follows: *A. meleagris*²⁰⁾, Costa Rica (09°55' N, 04°05' W), a female bitten by 1 male and surrounded by 9 others (5 normal and 4 yellow individuals); *A. hispidus*²¹⁾, Cocos Island, off the coast of Costa Rica (05°52' N, 87°07' W), a female bitten by a single male; *A. nigropunctatus*²²⁾, Palau (07°30' N, 34°37' E), a female bitten by 2 or 3 males and surrounded by a further 1 or 2 males; *A. nigropunctatus*²³⁾, Komodo National Park, Indonesia (08°58' S, 19°43' E), a female bitten by 2 males; *A. reticularis*²⁴⁾, Indonesia, Sulawesi Sea, Manado (01°58' N, 24°82' E), a female bitten by a single male.

The above information indicates that spawning within the genus *Arothron* typically includes male biting

behavior directed toward a single female, the only other recorded example of such spawning behavior, one or two males biting and clinging to a female until or subsequent to spawning, has been in the African freshwater puffer *Tetraodon schoutedeni*⁶⁾, as mentioned above.

According to the mitochondrial genome analysis²⁵⁾, the genus *Arothron* forms a cluster with *Tetraodon*, *Chelonodon*, and *Omegophora*. Although spawning behavior in *Chelonodon* and *Omegophora* is unknown, presence of similar biting and clinging spawning behavior in genera closely related to *Arothron* would be very important when considering the evolution of their spawning habits. Further studies of tetraodontid spawning ecology based on diving and aquarium observations must be important.

Acknowledgements

We thank Mr. Hiroyuki Murai, Dr. Kiyonori Nishida (Osaka Aquarium Kaiyukan) and Mr. Hiroshi Obata (Osaka Aquarium NIFREL) for their kind support. Thanks also go to Dr. Graham S. Hardy (Ngunguru, New Zealand) for English corrections.

References

- 1) Su JX, Hardy GS, Tyler JC: A new generic name for *Anchisomus multistriatus* Richardson 1854 (Tetraodontidae), with notes on its toxicity and pufferfish biting behavior. *Rec West Aust Mus*, **13**, 101-120 (1986)
- 2) Ando H: Molecular and ecophysiological aspects of semilunar-synchronized spawning migration in the grass puffer. *Comp Physiol Biochem*, **35**, 45-53 (In Japanese) (2018)
- 3) Sikkel PC: Social organization and spawning in the Atlantic sharpnose puffer, *Canthgaster rostrata* (Tetraodontidae). *Env Bio Fish*, **27**, 243-254 (1990)
- 4) Kawase H, Okata Y, Ito K: Role of huge geometric circular structures in the reproduction of a marine pufferfish. *Sci Rep*, **3**, 2106 (2013)
- 5) Kawase H, Okata Y, Ito K and Ida A: Spawning behavior and paternal egg care in a circular

- structure constructed by pufferfish, *Torquigener albomaculosus* (Pisces: Tetraodontidae). *Bull Mar Sci*, **91**, 33-43 (2015)
- 6) Feigs F: Fresh-water puffers spawn. *Aqua Philadelphia*, **24**, 373-375 (1955)
 - 7) Dive PARAPPA Ishigaki Island: Biting behavior of *Arothron meleagris* 1. <https://youtube/3EB90fqRdW4> (2022a) (accessed 27 June 2022)
 - 8) Dive PARAPPA Ishigaki Island: Biting behavior of *Arothron meleagris* 2. <https://youtube/05BvbOu2kY0> (2022b) (accessed 27 June 2022)
 - 9) Dive PARAPPA Ishigaki Island: Biting behavior of *Arothron meleagris* 3. <https://youtube/cEyndLI-ljs> (2022c) (accessed 27 June 2022)
 - 10) Dive PARAPPA Ishigaki Island: Biting behavior of *Arothron meleagris* 4. <https://youtube/wv2HfaESubQ> (2022d) (accessed 27 June 2022)
 - 11) Matsuura K: Taxonomy and systematics of tetraodontiform fishes: a review focusing primarily on progress in the period from 1980 to 2014. *Ichthyol Res*, **62**, 2-113 (2015)
 - 12) Matsuura K: A new pufferfish, *Arothron multilineatus* (Actinopterygii: Tetraodontiformes: Tetraodontidae), from the Indo-West Pacific. *Ichthyol Res*, **63**, 480-486 (2016)
 - 13) Su JX, Tyler JC: Diagnoses of *Arothron nigropunctatus* and *A. meleagris*, two extremely polychromatic Indo-Pacific pufferfishes. *Proc Acad Nat Sci Philad*, **138**, 14-32 (1986)
 - 14) Guzmán HM, Robertson DR: Population and feeding responses of the corallivorous pufferfish *Arothron meleagris* to coral mortality in the eastern Pacific. *Mar Ecol Prog Ser*, **55**, 121-131 (1989)
 - 15) Guzmán HM, López JD: Diet of the corallivorous pufferfish *Arothron meleagris* (Pisces: Tetraodontidae) at Gorgona Island, Colombia. *Rev de Biol Trop*, **39**, 203-206 (1991)
 - 16) Jayewardene D, Donahue MJ, Birkeland C: Effects of frequent fish predation on corals in Hawaii. *Coral Reefs*, **28**, 499-506 (2009)
 - 17) Palacios MM, Muñoz CG, Zapata FA: Fish corallivory on a pocilloporid reef and experimental coral responses to predation. *Coral Reefs*, **33**, 625-636 (2014)
 - 18) Matsuura K: Pufferfishes and their allies in Japan. Tokai University Press, Hadano (2017)
 - 19) Kuitert RH: Fishes of the Maldives Indian Ocean. Atoll Editions, Cairns (2014)
 - 20) Herreno E: Rough love. <https://www.nhm.ac.uk/wpy/gallery/2017-rough-love?tags=ed.6> (2017) (accessed 12 February 2022)
 - 21) Davis R: Star Ship Millennium Voyage. Isla del Cocos. <http://www.ms-starship.com/journal/dec98/24.htm> (1998) (accessed 12 February 2022)
 - 22) Chou A: Puffer fish mating aggregation in Palau. https://www.youtube.com/watch?v=qBOUm3_Cfbk (2019) (accessed 12 February 2022)
 - 23) Abourjeily S: Being a Puffer Fish can be a pain in the Ass at times. <https://www.facebook.com/photo.php?fbid=10155486734753126&set=pb.638958125.-2207520000.&type=3> (2017) (accessed 12 February 2022)
 - 24) Kobeh P: Pair of Reticulated pufferfish (*Arothron reticularis*) one covered with parasites and a large crab One is biting another either as courtship or for removing parasites, Manado Indonesia Sulawesi Sea. <https://www.mindenpictures.com/stock-photo-pair-of-reticulated-pufferfish-arothron-reticularis-one-covered-with-naturephotography-image90671874.html> (published year unknown) (accessed 12 February 2022)
 - 25) Yamanoue Y, Miya M, Doi H, Mabuchi K, Sakai H, Nishida M: Multiple invasions into freshwater by pufferfishes (Teleostei: Tetraodontidae): a mitogenomic perspective. *PLoS ONE* **6**, e17410 (2011) doi 10.1371/journal.pone.0017410

ミゾレフグ *Arothron meleagris* の 産卵に関係する可能性のある噛みつき行動

土井啓行, 前井 馨, 吉武孝文, 百田和幸, 酒井治己

和文要旨：モルジブ島Maldives Islands 沖でのスキューバダイビングにおいて、新月大潮の日中の干潮時に、産卵に関係すると考えられるミゾレフグ *Arothron meleagris* の特異な噛みつき行動が観察された。複数の雄が執拗に一尾の雌を追いかけ、噛みつき、ぶら下がっていた。インターネット検索を行ったところ、複数の同属他種における同様の噛みつき行動に関する画像や動画が掲載されていた。この行動は本属の産卵行動における特徴である可能性がある