



PRE-SPAWNING SNOUT-GRIPPING BEHAVIORS OF GYMNOTHORAX PICTUS AND GYMNOTHORAX THYRSOIDEUS (MURAENIDAE) IN CAPTIVITY

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PRE-SPAWNING SNOOT-GRIPPING BEHAVIORS OF *GYMNOTHORAX PICTUS* AND *GYMNOTHORAX THYRSOIDEUS* (MURAENIDAE) IN CAPTIVITY

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Key words: Anguilliformes, moray eel, snout gripping, pre-spawning behavior, courtship.

ABSTRACT

The main focus of this study has been on the distinctive pre-spawning snout-gripping behaviors and mate choice of two moray species (*Gymnothorax pictus* and *G. thyrsoideus*). The behavior of snout-gripping means that the male grips the female's snout with its jaws. It is the most distinctive behavior to confirm the success of mating pair formation naturally and was rarely described on moray eels or other coral reef fishes. The reproductive behaviors of the two moray species were also first observed and photographed in the laboratory aquaria. Over 22 reproductive events including 9 spawning events by 28 adult individuals of *G. pictus* were recorded. Eight sequential behaviors were recorded in the successful spawning events of *G. pictus* searching, courting, inviting, snout-gripping, rushing toward the water surface, turning around, spawning, separating and settling to the bottom. *G. thyrsoideus* also exhibited similar pre-spawning behaviors as *G. pictus*, but showed more aggressive behaviors between the males than *G. pictus*. Courtships and mating affairs occurred about 23 times by 32 adult individuals of *G. thyrsoideus*, but without spawning. Both species mated mainly between a female and a male at night (8:00PM-2:00AM). It only took a shorter time for *G. pictus* to go from snout-gripping to spawning (3-7 seconds), but a longer time for *G. thyrsoideus* to go from snout-gripping to separating (35-43 seconds).

I. INTRODUCTION

Any behavior is distinctive if it is performed without being based upon prior experience and therefore is an expression of innate biological factors, it was different from the imprinting (Wiens and Lorenz, 1952; Eckhard, 1958). The behaviors of Anguilliformes fishes are wonderful; they have a special extension body and raptorial jaws (Mehta and Wainwright, 2007; Tomohiro et al., 2015). Some special behaviors that were observed during feeding sequences of muraenid eels include: knot, rotate, shake and strike (Miller, 1987; 1989).

Moray eels are extremely secretive, wary of divers, and may spawn infrequently (Kris 2003). The reproductive behavior and spawning behavior of moray eels were less documented and confirmed visually (Adler, 1975; Thresher, 1984). Apparent reproductive behaviors were observed in the field only in four occasions (Brock, 1972, Moyer and Zaiser, 1982; Ferraris, 1985) (Table 1). These observations in the order presented, represent a probable spawning sequence. That is, the eels approach each other, rise up face to face, entwine their bodies, return to the substrate with bodies still entwined and after some time, spawn with abdomens pressed together.

The reproductive behavior of moray eels can be as a pair in some species such as in *Gymnothorax javanicus*. It was observed that this species would be lying on the bottom and entwined around one another, but no visible gamete released was apparent (Brock, 1972). Moyer and Zaiser (1982) reported that a pair of *Gymnothorax kidako* was similarly entwined, and one turned to wrap itself around the other. On the contrary, *Uropterygius necturus* just prior to spawning was seen with three males grasping the female just behind the head and within a few minutes the group dispersed (Moyer and Zaiser, 1982). Ferraris (1985) reported that a group of spawning *G. herrei* in the Philippines showed seven males holding onto a single female. The mass of bodies then began to rise above the substrate. This activity was apparently initiated by the female, whose head extended slightly above those of the males.

In the present study, due to the paucity of information on the reproductive behavior of moray eels, we reared peppered morays

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Table 1. Comparison of the reproductive behaviors of six moray species.

Species	Male vs female	Behavior	Gamete observed	Reference
<i>Gymnothorax herrei</i> (in the field)	a group 7♂ : 1♀	Seven males were holding onto a single female. The mass of bodies then began to rise above the substrate	No	Ferraris (1985)
<i>G. javanicus</i> (in the field)	a pair 1♂ : 1♀	A pair was observed lying on the bottom and entwined around one another	No visible gamete release was apparent	Brock (1972)
<i>G. kidako</i> (in the field)	a pair 1♂ : 1♀	Similarly entwined, and one turned to wrap around the other	No	Moyer & Zaiser (1982)
<i>G. pictus</i> (in captivity)	a pair 1♂ : 1♀	Searching, courting, inviting, snout-gripping, rushing toward the water surface, Turning around, spawning, separating	Yes	This study
<i>G. thyrsoideus</i> (in captivity)	a pair 1♂ : 1♀	Searching, courting, inviting, snout-gripping, rushing toward the water surface, separating	No	This study
<i>Uropterygius necturus</i> (in the field)	a group 3♂ : 1♀	Within a few minutes the group dispersed, the pair pressed their abdomens together and then turned sharply apart and separated	Yes, leaving behind a cloud of gametes	Moyer & Zaiser (1982)

Table 2. The events of mating behaviors of the female mature individuals of *Gymnothorax pictus* and *G. thyrsoideus*, observed in our aquaria.

Name of female individual	TL (mm)	WT (g)	Number of mating	Time and date of mating	Duration of snout-gripping (sec) ^C	Position of female snout which male grip on	
						Left	Right
Gp ^A .1	563.0	268.8	2	10:30 pm Jul. 5, 2002; 0:30 am Apr. 4, 2003	5.8 ± 0.8	2	0
Gp. 2	579.0	289.5	1	8:30 pm Apr. 22, 2003	5.4	0	1
Gp. 3	592.0	401.0	5	1:30 am Apr. 25, 10:00 pm Aug. 25, 2003; 10:30 pm Mar. 18, 10:40 pm May 24, 02:00 am Jun. 21, 2004	4.7 ± 0.7	2	3
Gp. 4	629.0	368.3	5	0:30 am Apr. 4, 10:30 pm May 27, 2003; 11:30 pm Mar. 17, 1:30 am Apr. 25, 10:40 pm May 24, 2004 10:30 pm Aug. 22, 2003;	5.3 ± 0.9	3	2
Gp. 5	636.0	390.1	4	11:30 pm Mar. 19, 0:30 am May 25, 0:30 am Jun. 20, 2004	6.2 ± 0.6	2	2
Gp. 6	522.0	257.3	1	12:00 am Jun. 23, 2004	4.7	0	1
Gp. 7	623.0	414.2	3	8:30 pm May 15, 2003; 0:30 pm May 25, 0:40 pm Jun. 24, 2004	3.8 ± 0.4	1	2
Gp. 8	416.0	154.4	1	12:00 am Oct. 31, 2004	4.3	0	1
Gt ^B .1	590.0	340.9	8	10:00 pm Aug. 28, 10:30 pm Nov. 22, 2001; 10:30 pm Jan. 3, 5:30 pm Mar. 29, 5:30 pm Apr. 25, 10:30 pm Jun. 18, 0:30 am Jul. 27, 10:00 pm Oct. 2, 2002	40.1 ± 4.4	5	3
Gt. 2	667.0	593.2	5	01:00 am Sept. 30, 2001; 5:00 pm May 6, 4:30 pm Jun. 30, 10:30 pm Aug. 19, 2002; 12:00 pm Feb. 18, 2003	36.8 ± 3.0	2	3
Gt. 3	557.0	432.4	3	0:30 am Feb. 15, 4:00 pm Mar. 29, 10:30 pm Nov. 13, 2002	42.1 ± 2.8	3	0
Gt. 4	623.0	449.7	2	10:00 pm Jul. 16, 4:30 pm Nov. 7, 2002	39.8 ± 3.1	1	1
Gt. 5	585.0	528.3	3	0:30 am Feb. 18, 01:00 am Apr. 26, 2:30 pm Jul. 26, 2003	38.0 ± 7.2	2	1
Gt. 6	602.0	262.6	1	9:00 pm Apr. 15, 2003	35.2	1	0
Gt. 7	597.0	508.7	1	10:30 pm Aug. 7, 2003	36.7	1	0

^A: *Gymnothorax pictus*, Gp; ^B: *Gymnothorax thyrsoideus*, Gt; ^C: Time lag from snout-gripping to separating

(*Gymnothorax pictus*) and greyface morays (*G. thyrsoideus*) in the aquaria for natural spawning and described the pre-spawning

behaviors. Reproductive behavior by the two species has not yet been observed in either the field or the aquarium.

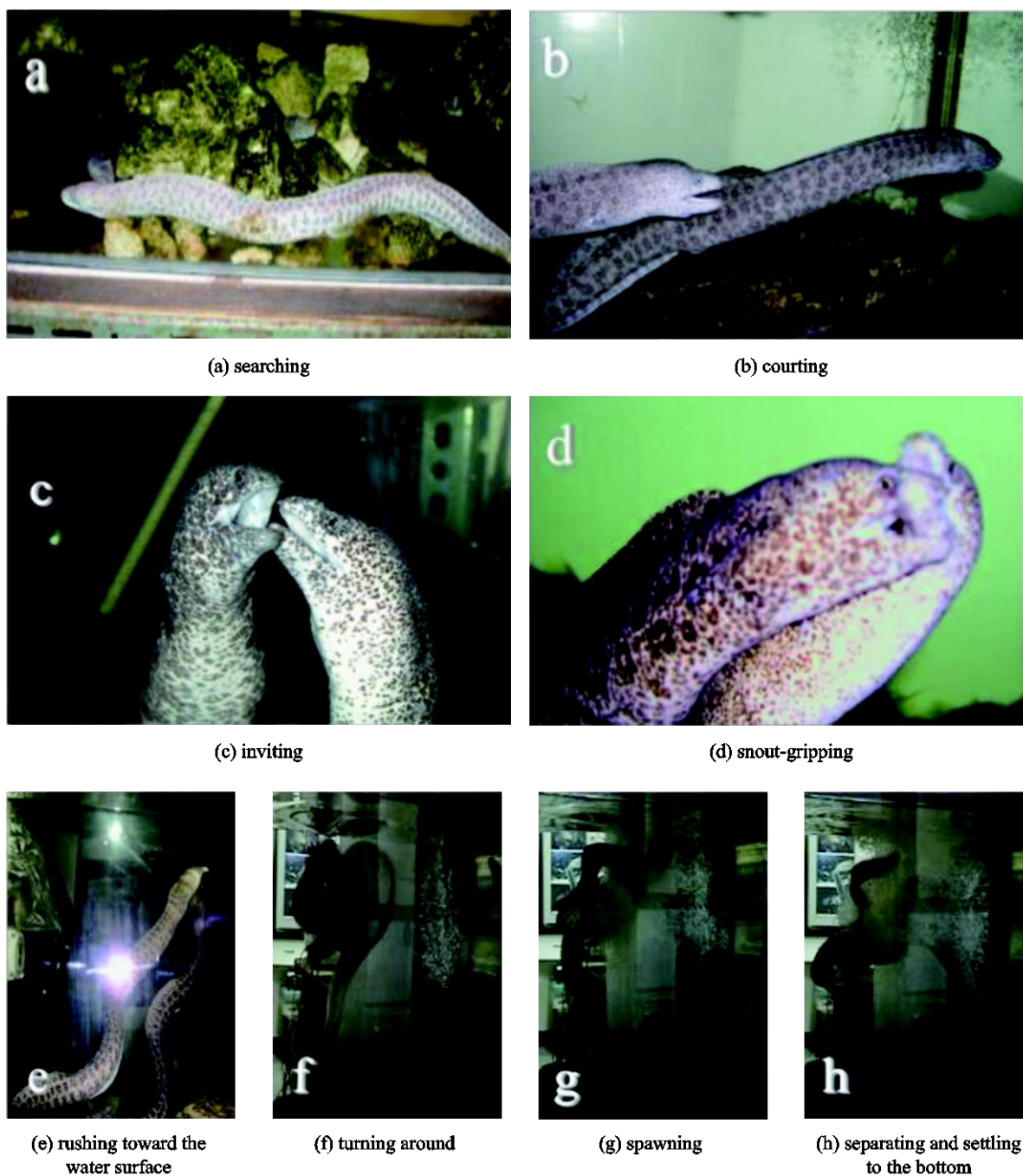


Fig. 1. Eight behavioral patterns involved in the spawning sequence of moray eel, *Gymnothorax pictus*.

II. MATERIALS AND METHODS

Two species of muraenid eels, *Gymnothorax pictus* and *G. thyrsoideus* were used in this study. A total of 28 individuals (eight females, ranging from 416 to 636 mm in TL) of *G. pictus* were collected by hook, line or hand net fishing along the intertidal zone in southeastern Taiwan (Lanyu and Chengkung). A total of 32 individuals (seven females, ranging from 557 to 667 mm in TL) of *G. thyrsoideus* were bought from Keelung and Nanfangang fish markets in northeastern Taiwan. All individuals

were transported to the laboratory aquaria in the Department of Aquaculture, National Taiwan Ocean University. The laboratory included eight 200 liter glass tanks (120*45*60 cm). The controlled temperature was between 24-28°C. Salinity was between 30-33 ppt., and with a photoperiod of 10-hour light and 14-hour darkness. Aquaclear power head aerators were attached to the filter plates for surface water agitation. Crushed coral was used as substrate, and pieces of coral as retreat areas. The feed for the eels comprised primarily of fishes, shrimps, cephalopods, oysters and crabs. The courtship and spawning behavior obser-

vations were recorded using Nikon Cool-pix 4500 Digital camera and Sony DCR-TRV18 DV camera. Sex identification was based on secondary sexual features which includes the shape of the abdomen. The mature females were easily distinguished from the males by their swollen abdomen during the spawning seasons.

III. RESULTS

The Records of Reproductive Behavior of the Two Moray Species:

Gymnothorax pictus (Fig. 1, Table 2)

Over 22 reproductive events including 9 spawning events were recorded by 28 adult individuals of *G. pictus*. Before spawning, the ripe female *G. pictus* swam around the shelter to attract the mature male for courtship. Sometimes, the mature male would attack other male individuals to gain mating with the ripe female. Subsequently, the male started to pursue the female, exhibiting an apparent courting behavior. The male wrapped its body around the head and abdomen of the female, with the female's head against the male's head, remaining in the position about 3 sec. The female accepted the male to grip slightly on its snout, and then rushed towards the water surface together. The snout-gripping behavior was terminated by spawning, with the female often turning its abdomen upwards when releasing the eggs.

Based on estimation, the number of eggs that the female moray ovulated was about 7081 ± 546 ($n = 9$). The fertilized eggs were spherical, buoyant, transparent, and large with an estimated 3.12 ± 0.11 mm ($n = 40$) in diameter. In this study, we had observed the process of embryonic development within the fertilized eggs. Larvae hatched about 3 to 4 days after fertilization. After hatching, the larvae survived for 5 to 10 days.

Gymnothorax thyrsoideus (Fig. 2, Table 2)

The fish were usually quiet at night before the reproductive period. Each individual stayed just above the bottom, although the fish occasionally swam slowly in a small school. However, during the spawning period, a general increase in activity occurred. The male moray had strong dominant and attack behaviors, usually it would attack until a serious injury happened to the other individuals excluding the ripe female. The fish usually exhibit courtship behavior during the pre-spawning events. Typically, the male moray would move towards the female acting as a courtship behavior. The male started his courtship behavior toward a selected female by pecking and pushing her swollen abdomen with his snout. The male moray would exhibit an apparent 'nuzzling' behavior and then the female would slightly open the mouth to invite the male gripping on its snout.

Therefore, if pairing was successful, the male moray would slightly grip the snout of the female. The pair would then ascend to the surface of the water. Courtships and mating affairs occurred about 23 times by 32 adult individuals of *G. thyrsoideus*, but without spawning.

We conclude that eight possible behavior patterns were involved in the successful spawning sequence of these two moray

eels, *G. pictus* and *G. thyrsoideus* (Figs. 1-2):

1. Searching: Just before spawning, the female moray which has a swollen abdomen and protruding anus stayed near the bottom. The male hovered around searching and gathered around the female.
2. Courting: The female swam slowly around the aquarium with the male following above and behind. Typically, the male moray started its courtship behavior toward the female by pushing and thrusting the female's snout and swollen abdomen with its snout. Only the mature male could attract the female successfully.
3. Inviting: The mature female slightly opened its mouth which acts as an invitation for the mature male. The male then wrapped its body around the female.
4. Snout-gripping: The male gripped the female's snout with its jaws, remaining in the position for 3-7 sec in *G. pictus* and 35-43 sec in *G. thyrsoideus*. It appeared no constant right or left position of the female snout which was gripped by the male. (Table 2; Fig. 1(d), Figs. 2(k)-(n)).
5. Rushing toward the water surface: When the female accepted the male, the male would grip on the female's snout and ascend quickly together toward the water surface.
6. Turning around: As the spawning time approached, the ascending movements became more rapid when approaching higher in the water column. Eventually, the mature male leading the female turned around.
7. Spawning: In an instant, as the mature male turned around, the female released the eggs and the male would also ejaculate a cloud of gametes (without spawning in *G. thyrsoideus*). After spawning, the fertilized eggs would float on the water.
8. Separating and settling to the bottom: The male loosened its grip on the female's snout, and settled individually to the bottom.

G. thyrsoideus also exhibited similar pre-spawning behaviors as *G. pictus*, but showed more aggressive behaviors between the males than *G. pictus*. Mating between the female and male for both species occurred mainly at night (8:00 PM-2:00 AM).

IV. DISCUSSION

The type of reproductive mating of the moray species showed the difference in body size. Large-sized moray species seem to show one male one female mating type. The maximum total length in records for *Gymnothorax javanicus* is 300 cm, *G. kidako* is 92 cm, *G. pictus* is 140 cm, *G. thyrsoideus* is 73.2 cm. Although there are reports of *Gymnothorax javanicus* and *G. kidako* were being entwined around one another in the pre-spawning sequences of mating, it was difficult to observe or confirm if gametes were released and spawning had occurred (Brock, 1972, Moyer and Zaiser, 1982). The mate of *G. pictus* or *G. thyrsoideus* in our study also entwined around one another before spawning. Nevertheless, the smaller-sized species tend to exhibit group spawning behaviors (the recorded maximum

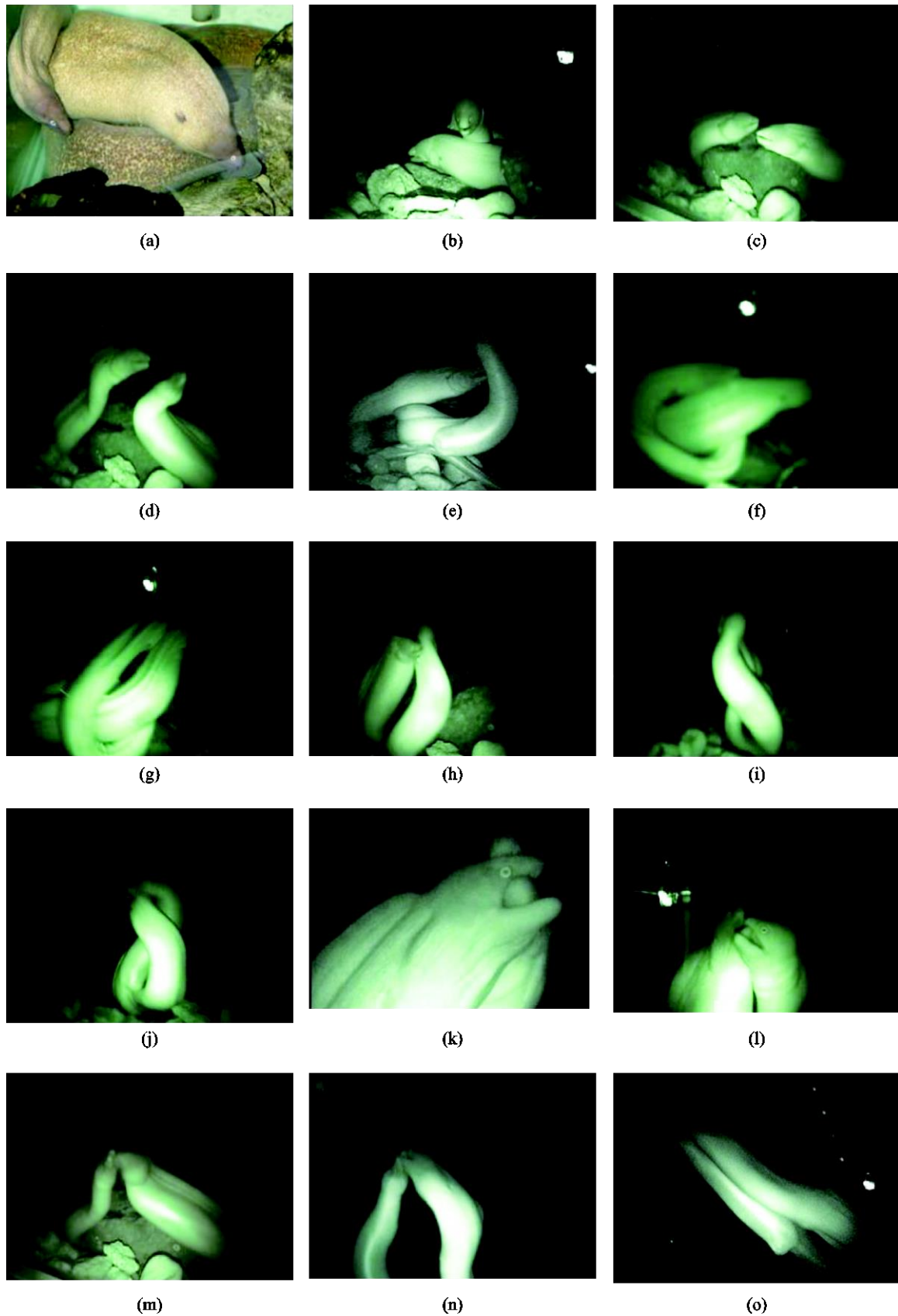


Fig. 2. The pre-spawning behavioral sequence of *Gymnothorax thyrsoideus* (a-c) searching (d-h) courting (i-j) inviting (k-n) snout-gripping (o) rushing toward the water surface.

size of *Gymnothorax herrei* and *Uropterygius macrocephalus* were 30 cm and 47 cm respectively). Group spawning had been reported between *Uropterygius necturus* and *Gymnothorax herrei*, whereby the males entwined around the female dorsally and would bite the base of the female's head (Moyer and Zaiser, 1982, Ferrais, 1985). However, we speculate that the mating type of peppered or greyface moray is one female-one male strategy (Table 1). We first recorded the distinctive and various snout-gripping behaviors of *G. pictus* and *G. thyrsoideus* in the laboratory aquaria, despite some other reproductive behaviors of moray eels had been observed in the field (Table 1).

There is a significant difference in the duration of snout-gripping between *Gymnothorax pictus* (ca. 3 sec.) and *G. thyrsoideus* (35-43 sec.). The artificial aquarium's environment does not seem to be suitable for the reproduction or spawning of these two eel species. Space is too small, lack of water depth, especially for the deeper habitat species, *Gymnothorax thyrsoideus*. However, *Gymnothorax pictus* generally inhabit the shallow waters near the tide line, so there can be some successful cases of natural spawning. Moray eels usually need to swim up to the water surface for spawning. After mating, the moray species that inhabit deeper waters might require more time to go upstream to the sea surface.

Fishelson (1992) reported the comparative gonad morphology and sexuality of the Muraenidae, and inferred *G. pictus* and *G. thyrsoideus* these two species of moray eels might be simultaneous hermaphrodites. But, we found the *G. pictus* and *G. thyrsoideus* are gonochoristic based on histological study of their gonads.

In conclusion, the snout-gripping is the most distinctive pre-spawning behavior to confirm the success of mating pair formation naturally, which has been rarely described in moray eels or the other coral reef fishes.

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