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# ACTIVITY, HABITAT UTILIZATION, FEEDING BEHAVIOUR, AND DIET OF THE SAND MORAY *Gymnothorax ocellatus* (ANGUILLIFORMES, MURAENIDAE) IN THE SOUTH WESTERN ATLANTIC

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## Abstract

Activity, habitat utilization, feeding behaviour, and diet of the sand moray *Gymnothorax ocellatus* (Anguilliformes, Muraenidae) in the South western Atlantic.

The sand moray *Gymnothorax ocellatus* is a nocturnal predator from the western South Atlantic that actively forages on the bottom, preying mostly on crustaceans (mainly shrimps and crabs) and ray-finned fishes, which are located primarily by the sense of smell. The individuals stay stationary during the day, almost always being hidden in individual tunnels dug by animals other than the morays in the muddy sand bottom.

**Key words:** *Muraenidae*; *Gymnothorax ocellatus*; habitat use; feeding behaviour; diet.

## Resumo

Atividade, utilização do habitat, comportamento alimentar, e dieta da moréia-de-areia *Gymnothorax ocellatus* (Anguilliformes, Muraenidae) no Atlântico sudoeste.

A moréia-de-areia *Gymnothorax ocellatus* é um predador noturno do Atlântico ocidental que forrageia ativamente o fundo, predando principalmente crustáceos (em especial camarões e siris) e peixes actinoptérgios, os quais são localizados principalmente pelo olfato. Os indivíduos permanecem inativos durante o dia, quase sempre escondidos em túneis individuais escavados por outros animais, que não moréias, em substrato areno-lodoso.

**Palavras-chave:** *Muraenidae*; *Gymnothorax ocellatus*; utilização do habitat; comportamento alimentar; dieta.

## 1. INTRODUCTION

Moray-eels of the family Muraenidae are specialized secretive and largely nocturnal reef-dwelling predators, which typically hunt fish and crustaceans deep in rock crevices (Lowe-McConnell 1987, Böhlke & Chaplin 1993, Randall 1996). The prey is located primarily by smell, and some moray species are known to use a knotting behavior to break up large prey items (Miller, 1987, 1989). The muraenid genus *Gymnothorax* has a worldwide distribution and is represented by five species off the southeastern coast of Brazil: *G. funebris* Ranzani, 1839, *G. moringa* (Cuvier 1829), *G. vicinus* (Castelnau 1855), *G. conspersus* Poey, 1867, and *G. ocellatus* Agassiz, 1831 (Figueiredo & Menezes 1978, Böhlke *et al.* 1989). The first three *Gymnothorax* species are associated with coral or rock reefs, whereas the sand moray *G. ocellatus* is associated with gravel, sand, or mud substrates of open sedimentary bottoms (Figueiredo & Menezes 1978, Carvalho-Filho 1999), and *G. conspersus* is a poorly known species living below 200 m (Böhlke & Böhlke 1980).

The biology of the central and south west Atlantic morays dwelling in clear water reefs is relatively well known (e. g., Bardach *et al.* 1959, Bardach & Loewenthal 1961, Dubin 1982, Abrams & Schein 1986). However very little is known about the biology of *G. ocellatus*, an abundant species over mud/sand bottoms (Carvalho-Filho 1999). This lack of knowl-

edge may be due to the flat, turbid water sites occupied by the sand moray, which are unappealing to divers. This article provides the first published information on the activity period, spatial distribution, habitat use, feeding behavior and diet of *G. ocellatus* on a coastal stretch of the State of São Paulo, southeastern Brazil.

## 2. MATERIAL AND METHODS

### 2.1. STUDY SITE

The field observation were carried out monthly from May 1996 to May 1998, in a 12.5 km stretch of the continental margin of the São Sebastião Channel, south-eastern Brazil (Fig. 1). Underwater activities were conducted within an approximately pentagonal open bottom area 0.5-5 m deep in front of the 50 m long Cabelo Gordo beach (23°49'30" S, 45°25'18" W). The study area was limited by the surf line, the two bordering rocky shores and three tethered floating markers. This site is characterized by a muddy sand substrate (71.7-90.4% sand, 4.3-19.4% silt and 5.3-8.9% clay) and the occurrence of green seagrass *Halodule wrightii*. During the study period, water temperature at the surface varied 17.4-24.2° C (average 21.5° C) and horizontal transparency of water, measured with a Secchi disk, varied 0.85-1.9 m (average 1.4 m).

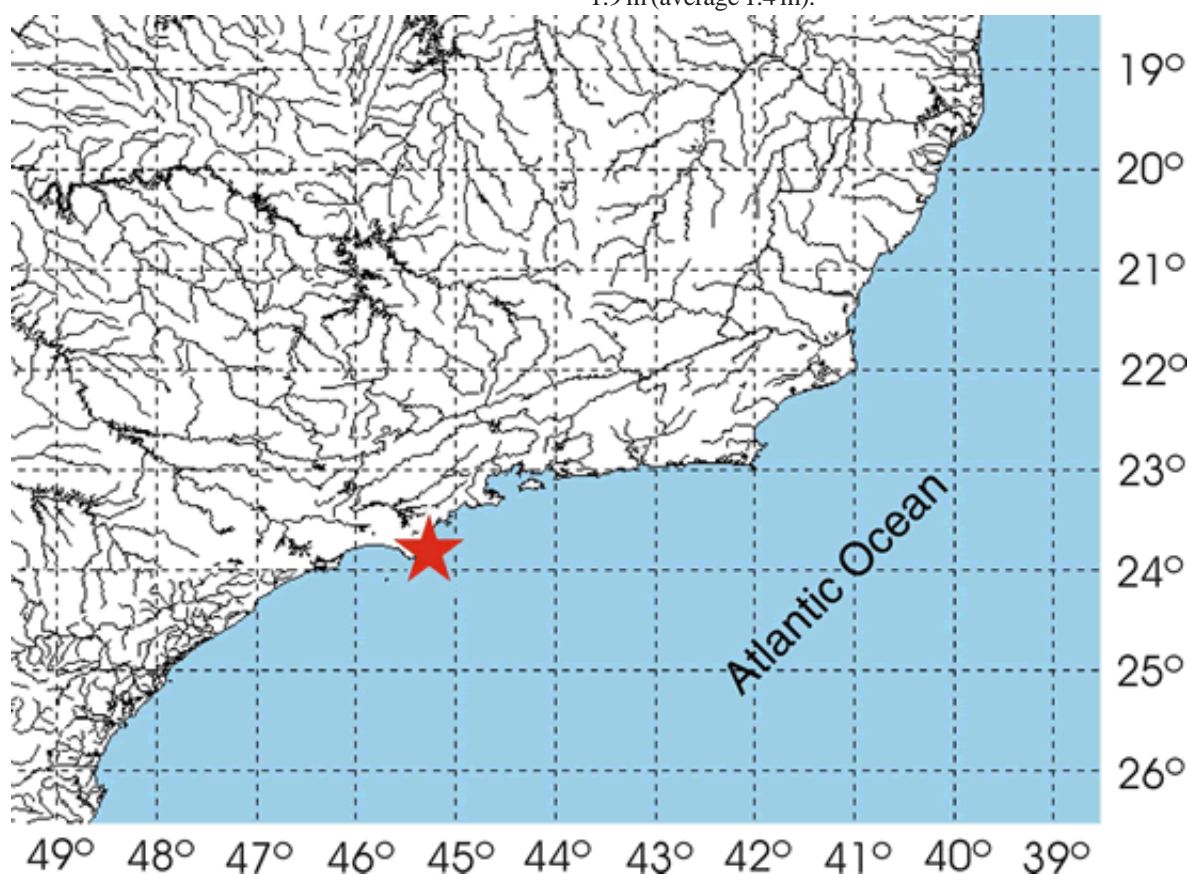


Fig. 1. Position of the study site in the Brazilian coast.

## 2.2. PROCEDURE

The 66 examined specimens were collected on muddy sand bottoms shallower than 13 m using hook-and-line baited with sardines (n=64, 97%), a nylon beach seine (n=1, 1.5%) and a hand net during scuba dives (n=1, 1.5%). The specimens were fixed in 10% formalin on capture and latter transferred to ethanol 70%. Voucher specimens (LIRP 2281-2303) were deposited in the fish collection of the Laboratório de Ictiologia de Ribeirão Preto (LIRP), at the FFCLRP-Universidade de São Paulo, São Paulo, Brazil.

A total of 91 hours of underwater observations were made during scuba (85 h) and skin diving (6 h) over bottoms 5 meters deep or shallower. Data on activity period, habitat use, and feeding behavior were obtained during 51 diurnal, 27 nocturnal and 13 crepuscular observation hours, distributed throughout the 24-h cycle (daytime is defined here as the period between the end of sunrise and beginning of sunset and night as the period between the end of sunset and the beginning of sunrise). During the observational sessions *ad libitum* and focal animal sampling were used (Altmann 1974, Lehner 1996). During each dive the number of observed *G. ocellatus* individuals was recorded together with the type of substrate on which they were found and also the type of shelter used during inactivity periods. Activity was assessed based on food searching behavior, and mobility was categorized as follows: stationary while total or partially hidden, laterally undulating immediately over the bottom, with the body vertical axis perpendicular to the bottom or with the specimen swimming on its side with strong lateral undulations about 0.15 m over the bottom; and searching for prey or taking offered baits. During night and crepuscular dives, an underwater torchlight with a red filter was used to diminish the disturbance caused to white-light sensitive sand morays (cf. Helfman 1992).

To locate the shelters of *G. ocellatus* within the study site, we used four circular 1-10 m radius concentric transects - derived from the common "search-in-circles" scuba procedure (Shreeves *et al.* 1991) - centered in four 1.3 m high upright PVC cylinders permanently fixed to the bottom. Once located, the shelters were marked with tethered floating markers (Helfman 1992). Three PVC tubes (one straight; one C-shaped; and one U-shaped) 60 cm long and 7 cm wide, were experimentally positioned on the substrate of the study site for about four months to verify the opportunistic shelter use by *G. ocellatus*.

Contents of the whole digestive tracts of 62 specimens (43 individuals collected during the day, 14 during the night and five during twilight) of *G. ocellatus* were analyzed. Collecting was carried out evenly through the year. The ratio of digestive tube length/standard length was calculated ( $L_{DT} : L_S$  index - intestinal ratio - see Knöppel 1970), as well as the frequency of occurrence (Bowen 1992) and the per cent composition (Hynes 1950) for each broad category of food item.

## 3. RESULTS

### 3.1. ACTIVITY PERIOD

Thirty eight (48.7%) sightings of *G. ocellatus* occurred during daytime, when the individuals were hiding within shelters (n=36, 94.7%) (Fig. 1), swimming (n=1, 2.6%) or eating offered baits (n=1, 2.6%). Thirty seven (47.4%) sightings occurred at night, when individuals were hiding within shelters (n=13, 35.1%), swimming (n=6, 16.2%), searching for prey (n=2, 5.4%), eating offered baits (n=12, 32.4%), or feeding or trying to feed on live crustaceans and fish (n=4, 10.8%). During the three (3.8%) sightings recorded at twilight, the individuals were swimming between the sunset time and 1 h after it (n=1, 33.3%), and entering shelters between sunrise time and 1 h after it (n=2, 66.6%).

### 3.2. SPATIAL DISTRIBUTION AND HABITAT USE

All 78 sightings of *G. ocellatus* were between depths of 1.5-3.5 m on muddy sand open bottom with seagrass, *Halodule wrightii*, an isolated group of three boulders and a variable number of small patches of debris discarded from recreational and fishing boats. On no occasion *G. ocellatus* was seen associated with adjacent rocky habitats.

Sand morays were recorded hidden total or partially within shelters during the day (94.7%, n=36) and at night (35.1%, n=13). We recorded three shelter types: 1) individual holes dug in the muddy bottom (n=23, 46.9%) (Fig. 2a); 2) small patches of debris (plastic and ceramic tubes, plank fragments, bottle fragments and pieces of ironwork) dis-



Fig. 2a. *Gymnothorax ocellatus* within shelter almost totally hidden in a hole in the muddy sand bottom during the day (photograph by H. F. dos Santos)

carded from recreational and fishing boats, usually accompanied by approximately 60 mm young *Epinephelus niveatus* (Valenciennes, 1828) (n=11, 22.5%); 3) an isolated group of three large boulders (n=2, 4 %) (Fig. 2b). All individuals recorded in shelters were alone except for two individuals found sharing a shelter in the isolated group of boulders and another two within a small patch of debris. On 13 occasions *G. ocellatus* was found using the U-shaped tube, four (=30.7%) of them at night and nine (=69.2%) during daytime. Neither the straight tube nor the C-shaped were used as shelter. No excavation activity was recorded throughout the study and the seven individuals seen entering their shelters did so tail first. All individuals recorded outside shelters during the daytime (n=2, 6.9%), nighttime (n=24, 82.7%), or twilight (n=3, 10.3%) were actively searching for prey on the bottom and accepted offered dried sardine baits.

### 3.3. FEEDING BEHAVIOUR AND DIET

Individuals recorded actively foraging were laterally undulating immediately over the bottom, with the vertical body axis perpendicular to it. When a potential prey was located, the moray stopped for approximately 10-60 s on the

bottom, adopted a distinctly S-shaped body posture and probed the bottom or mats of seagrass with its snout, searching for prey. Two actual prey captures were recorded: on one occasion a small (about 20 mm) semi-buried crab was picked up from the substrate and swallowed in a single movement, without chewing (an almost intact true crab *Hepatus pudibundus* was found in the gut content items of this eel); on another occasion, an approximately 40 mm long silvery bony fish was captured, via a quick grabbing movement while trying to escape from the bottom after being disturbed by the moray probing movements.

On two occasions the sand morays were observed trying unsuccessfully to grab and rip off the legs of large *Callinectes* sp. true crabs (two individuals had large *Callinectes* claws in their guts, see grasping relatively large prey; Keenleyside 1979). During most nighttime observations, individuals of *Lutjanus* spp. snappers and *Diplectrum* spp. sand perches were observed following individuals of *G. ocellatus* while these searched for food, presumably to get scraps or capture animals flushed from hiding by the eels prey (followers, see Sazima 1986).

On three occasions, two during the day and one during the night, live fish baits (one 100 mm *Harengula*



Fig. 2b. *Gymnothorax ocellatus* within shelter partially hidden between three large isolated boulders at night.

*clupeola* (Cuvier, 1829) false pilchard; a 70 mm *Haemulon steindachneri* (Jordan & Gilbert, 1882) latin grunt, and a 50 mm *Bathygobius soporator* (Valenciennes, 1837) frillfin goby) were offered tethered by a nylon filament to morays hiding in holes in the substrate. On all three cases the morays left their shelters to examine the potential preys but only in the first case was the prey taken and swallowed whole. During two night dives whole dead *Sardinella brasiliensis* (Steindachner, 1789) sardines and *Auxis* sp. mackerels were used as bait to attract *G. ocellatus*. The dead fish were carried underwater tightly sealed inside intact transparent plastic bags. While the bags were kept closed, no *G. ocellatus* specimens were attracted; but approximately 30 seconds after the bags were open and the bloody water inside released into the environment, two to five morays approached from several directions, quickly moving towards the dead fish. If the dead fishes were smaller than about 25% of the moray's length, they were quickly swallowed whole. If larger, the morays applied the knotting behavior (see Miller 1987, 1989) to bend the fish or remove pieces from it (Fig. 3).

Forty two digestive tracts of the 62 specimens contained food, which were in decreasing order of frequency: decapod crustaceans (true crabs and shrimps), bony fishes (mostly non identified fragments, engraulid anchovies, followed by clupeid herrings, hemiramphid halfbeaks, triglid searobins, syngnathid pipefishes, and diodontid burrfishes, all of approximately equally frequency), followed by unidentified crustaceans fragments, and the equally frequent cephalopod molluscs (loliginid squids) and stomatopod crustaceans (mantis shrimps) (Table I). Approximately 10% of the digestive tracts contained parasitic trematode flukes.



Fig. 3. *Gymnothorax ocellatus* at the beginning of knotting behaviour to break down a provided large piece of fish, at night.

All examined digestive tracts had small amounts of sand, an apparent unintentional by-product of prey ingestion. Food items grouped in broad taxonomic categories and expressed as per cent composition values show that crustaceans (58%) and bony fishes fragments (39%) were the main diet components, followed by cephalopod mollusks (3%). The average  $L_{DT} : L_s$  index for 62 specimens was 0.54 (SD=0.09).

#### 4. DISCUSSION

Our results indicate that *G. ocellatus* is a crepuscular-nocturnal fish that during daytime remains stationary and hidden mostly inside individual holes in the muddy-sand bottom. During nighttime and twilight about 60% of the recorded individuals leave the shelters and actively forage over open muddy-sand bottoms. Nonetheless, it was possible to lure sheltered individuals temporarily out of their shelters to feed on offered preys. This tendency previously discussed by Böhlke & Chaplin (1993) for the muraenids as a whole could explain why it was possible for us to collect the majority of the specimens with baited hook-and-line during daytime. The largely crepuscular-nocturnal habits of many moray eel species are relatively well known (e.g. Bardach *et al.* 1959, Smith & Tyler 1972, Böhlke & Chaplin 1993, Randall 1996, Carvalho-Filho 1999), and *G. ocellatus* was regarded as an "eel-like nocturnal searching predator of fishes and bottom animals" by Sazima (1986).

All *G. ocellatus* specimens were found in open muddy-sand flat bottom areas, which is generally in agreement with Figueiredo & Menezes (1978) and Carvalho-Filho (1999). Muraenid eels differ from the related ophichthid eels by not having hard pointed tails without an external fin that are utilized to enter the soft bottom substrate tail first (Böhlke & Chaplin 1993, Figueiredo & Menezes 1978). The absence of this excavating tail, the observed opportunistic use of artificial shelters provided by us or by unintentional human activities (throwing trash overboard), as well as the absence of any excavating activity, lead us to believe that all substrate holes occupied by *G. ocellatus* (Fig. 2a and Fig.2b) were product of the activities of some other organisms.

The most frequent food items of *G. ocellatus* were crustaceans (true crabs and shrimps) and actinopterygian fishes (ray-finned fishes), with stomatopod mantis shrimps and squids being much less frequent (Table I). The crustacean and fish-eating benthic feeding habits of *G. ocellatus* have been already briefly noted by Sazima (1986) and Carvalho-Filho (1999), which agree with our results. The short digestive tract average length of *G. ocellatus* relative to its average standard length (0.54) also agrees with a carnivorous feeding habit (Wootton 1994). All crustaceans ingested were benthic or burrowing species (mantis shrimps). The ingested fish were either benthic (triglid searobins and

syngnathid pipefishes), demersal (diodontid burrfishes), or coastal shallow-water dwelling juveniles of pelagic species (engraulid anchovies, clupeid herrings and hemiramphid halfbeaks) which occur in deeper open waters when adults (Figueiredo & Menezes 1978, Carvalho-Filho 1999, pers. obs.). Loliginid squids were recorded swimming at nighttime in groups of 2-5 individuals about half a meter or less over the bottom.

The important role of olfaction and taste in prey location for muraenid eels and bottom and turbid water dwelling fishes is known and already documented (Bardach et. al. 1959, Bardach & Loewenthal 1961). We believe that this generally also applies to *G. ocellatus*, since during a very dark moonless night dive, fish baits tightly sealed inside clear plastic bags failed to attract sand morays before opened. The knotting behavior reported here for *G. ocellatus* was already described by Miller (1987, 1989) for

four other genera and eight species of muraenid eels. We thus regard *G. ocellatus* as a carcinophagous-piscivorous nocturnal predator feeding on bottom prey, located primarily by the sense of smell.

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Food items	FO (%)
Crustacea	24.4
Decapoda	21.3
Brachyura (true crabs)	11.0
Portunidae: <i>Callinectes</i> spp and <i>C. ornatus</i>	4.3
Calappidae: <i>Hepatus pudibundus</i>	1.2
Majidae: <i>Stenorhynchus seticornis</i>	0.6
Xanthidae	0.6
Unidentified crabs	4.3
Natantia (shrimps)	8.5
Penaeidae	3.0
Unidentified shrimps	5.5
Stomatopoda (unidentified mantis shrimps)	1.2
Unidentified crustacean fragments	1.8
Actinopterygii (ray-finned fishes)	16.5
Engraulidae: <i>Engraulis anchoita</i> Hubbs & Marini, 1935	1.2
Clupeidae: <i>Sardinella brasiliensis</i> (Steindachner, 1789)	0.6
Diodontidae: <i>Ciclichthys spinosus</i> (L., 1758)	0.6
Hemiramphidae: <i>Hyporhamphus</i> sp.	0.6
Syngnathidae: <i>Syngnathus</i> sp.	0.6
Triglidae: <i>Prionotus punctatus</i> (Bloch, 1797)	0.6
Unidentified actinopterygian fragments	12.2
Mollusca	1.2
Cephalopoda	
Loliginidae: <i>Loligo</i> sp.	1.2

TABLE I. Frequency of occurrence (FO) in percent of food items of *Gymnothorax ocellatus* (340-580 mm L<sub>s</sub>, n = 62).

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