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On the Biology and Bioacoustic Characteristic of Spotted Catfish *Arius maculatus* (Thunberg 1792) from the Malaysian Estuary

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Abstract: Estuaries of Matang mangrove reserves in Perak provide an ideal habitat for *Arius maculatus* population. Results of our survey showed that most of the fish species caught were in their sub-adult stages with size ranged between 11 – 21 cm SL as shown in length frequency analysis. The relative growth condition of the fish population was allometrically negative with "b" value < 3.0 ($W = 0.040L^{2.78}$) respectively. Study on reproductive biology of the species showed that almost half of the specimens caught were comprised of maturing males and female's gonad development attained stage II – III. Stomach content analysis demonstrated that *A. maculatus* was an excellent benthic feeder in muddy water environment. Three major food items have been listed and dominated by zoobenthos and benthic crustacean. Meanwhile bioacoustic study showed that the fish produced a distinct sound resulted from stridulation of pectoral fins. The roles played by Matang mangrove systems as an integral breeding and nursery ground for this particular species was also discussed.

Key words: Biology, bioacoustic, *Arius maculates,* Malaysia

INTRODUCTION

A study on the biology of spotted catfish (*A.maculatus*) in Malaysian water is still scarce. Mohsin and Azmi[13]. briefly described the general biology of the species based on the samples bought from fish markets all over Malaysia. Similar studies in the selected localised areas are yet to be done. The spotted catfish in the Malaysian waters are chiefly marine or brackish water and occasionally enter the freshwater systems through flooding tides. This species is well distributed in tropical and subtropical waters throughout the continents[11]. Detail studies on the systematic and eco-biology of the marine catfish families in Tropical Asia waters needed to be revised over time (Kimura, Per. comm.).

This is because confusion defined from its recent systematic classification. Scott[16]. has provided an extensive key to the species of Ariidae as listed in this manuscript. Since the systematic classification of this family is so complex, the use of this key to the species should be applied with cautious. The most recent classification work published by Nakabo *et al.*[14]. only described 3 species of marine catfish that included *Arius maculatus* and other two co-existing species.

Meanwhile, study on the bioacoustic of catfishes in Malaysia is almost unknown. Many catfishes are well known to emit sounds; however reports in the literature are very and sporadic. Although lacking precise acoustic measurement tools, pioneering work by Agassiz (1850) briefly discussed the fact that catfishes and other fishes grunt by forcing air out of the swim bladder through the pneumatic duct while Dufosse (1874) mentioned the sounds produced by *Silurus glanis* as being eructations or "bruits de souffle." Tavolga[20]. has reported on the mechanisms of sound production in the Ariid catfishes *Galeicthys felis* and *Bagre marinus* highlighting the skeletal and muscle architecture involved. However, since that, catfish bioacoustic studies have focused on 5 families of catfishes (Pimelodidae, Doradidae, Mochoidae, Callichthyidae and Ictaluridae). A comparison between and within families of the same order demonstrated family and species specific patterns of vocalization[10]. Generally several catfish families demonstrate two sonic mechanisms- a swimbladder vibration established by 'drumming muscles' that differ in origin and insertion between families and a pectoral spine

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stridulatory apparatus[11]. Nevertheless the behavioural and social context in which stridulatory sounds are produced and their functional significance are poorly understood[15]. This paper aimed to highlight the preliminary observation on the biology and bioacoustic of the spotted catfish in the Matang mangrove reserves of Perak.

MATERIAL AND METHODS

The fish specimens were collected using trammel and gill nets. The nets were set in the mangrove creeks and in small channel within one kilometre stretch from the Forest Department Jetty and were checked every 2-3 hours. The nets were checked frequently in order to avoid the strangled fish from being eaten by the otters, crabs and mangrove reptiles. The collected specimens were systematically identified using the available references including Mohsin and Ambak, Mansor *et al*[12]. and Nakabo *et al*[14]. All specimens caught were measured for their length and weight. Sub-samples of the catches were divided according to their minimum and maximum size ranges and brought back to laboratory. Details biological analysis such as growth conditions, reproductive biology and stomach content analysis were also carried out. The stomach content analysis was performed based on the procedure described by Hyslop[7]. whilst reproductive biology study were based on the procedures outlined by Cailliet *et al.* [3]. and Jayaseelam [8]. Lengths data of *Arius maculatus* recorded from adjacent waters were obtained with courtesy of FAO-FishBase Programme and American Museum of Natural History[4,1]. These data were analysed for the length frequency together with data obtained from the present study. The length frequency analysis was performed using FAO-ICLARM Stock Assessment Tools (FiSAT) computer program[6]. Length-weight relationship was performed based on non-linear regression analysis of Lavenberg-Marquart iterative algorithm approaches incorporated in MicroCalc. Origin^{tm} computer software. As for bioacoustic study, we conducted a brief passive acoustic survey (day and night) using a single hydrophone (HPA1, Burns Electronic Hydrophone System) connected to a digital recorder (Edirol R1, Roland) to record the sound production of a wild population of *A. maculatus* in the Matang Mangrove Reserve. Subsequent sound analysis was done using the acoustical analysis software SoundRuler ver 0.9.6.0 written by Marcos Gridi Papp.

RESULTS AND DISCUSSION

General systematic description and meristic characteristic: *Arius maculatus* established a distinguished morphological characteristic by having forked caudal fin with a single black spotted adipose fin present in between the dorsal fin and caudal peduncle (Fig. 1a, b). The large black spot starting from the base to the tips of the adipose fin are the prominent systematic characteristic of *Arius maculates.* Both pectoral and dorsal fin possesses a leading hollow serrated poisonous spine. Maxillary barbels present usually in 3 pairs and rarely 2 pairs. This species has no nasal barbels. As in other similar genera, conspicuous bony plates present on head and near dorsal fin. Comparative key to this species and other species of Ariidae in the Malaysian coastal water are as shown in Table 1. Species name with asterisk denoted the common co-existing species found nowadays with *Arius maculatus.*

Table 2 showed a general meristic counts relative to the total length (TL) and head length(HL) (expressed as %) for *Arius maculatus* species. The results showed that the meristic characteristic of *Arius maculatus* in Matang mangrove reserves was closely similar and comparable to the meristic counts of the similar adult's species elsewhere [4].

Length frequency analysis: Fig. 2 demonstrated the length frequency analysis pattern of the sample caught in the study areas in comparison to the other sample sizes obtained from the trawler samples in the adjacent water fishing areas[4,1]. The results showed that, the length frequencies of the specimens collected from the Matang mangrove reserves were relatively smaller (11- 21 cm SL) in comparison with specimens from adjacent waters (20 – 45 cm SL). The results of this study are comparable with the length ranges of *Arius* spp. reported by several workers working in the mangrove environments[19,18].

Length weight relationship: The growth conditions of *Arius maculatus* in Matang mangrove reserves were modelled using a non-linear regression of length and weight ($W = aL^b$) relationship as shown in Fig. 3. The results showed that the b value is less than 3, which indicated that this fish species in Matang mangrove reserves display an allometrical negative growth condition. This means that the rate of increased in weight is lesser than that of length. There are many factors affecting the value of 'b' through out the fish life history. Several important factors such as gonad development and the availability of the food in their natural habitats can greatly effects the value of 'b'. In this study, the initial stages of gonadal development found in most of the fish caught were believed in resulting the lower b value. This is because, during the gonadal development stages, most of the inner energy (including reserve energy) were utilised for the gonad development instead for building up the new body tissues.

Food and feeding habits: The food and feeding habits of *Arius maculatus* are as shown in Table 3.The results of stomach contents analysis classified food items into three major categories. Food item 1 comprised mainly the macro-zoobenthos that contributed a major food item. Food item II comprised mainly of benthic crustacean and food item II comprisesd mixture of wide spectrum of macro/micro-benthic faunas. The results showed that *Arius maculatus* or other catfish species that commonly found in the mangrove waters are benthic feeder. They can locate their prey efficiently in the muddy waters through their well developed sense of smell and visions. The present of maxillary barbels served as an important sensory organ in search for embedded prey in the muddy sediment of the mangrove forest.

Reproductive biology: It was reported that *Arius maculatus* only breed once a year with a prolonged spawning season between January - April off the Bombay coast and during September - October off the Karnataka coast in India [8]. The spawning mode was periodic, although the individual fish of the species breed only once a year, a different population of the species seems to breed almost all year round. Similar situation is predicted to occur in Malaysian coastal waters. *Arius maculatus* mode of reproduction is dioecism. The mature females and males developed gonad separately and fertization of the gametes occurred externally. The males collected the fertilised eggs and incubate in the buccal cavity. During incubation, males starve which sometimes make them resort to swallowing one or two eggs probably to maintain basal metabolism. Early hatching embryos commence feeding on inhaled particles by the females when still in possession of large yolk[2,8]. The hatchling developed into fingerlings which normally swim in small schooling in the shallow coastal waters and mangrove creeks[8]. The rate of survival for the fingerling to sub adults followed by recruitment into the exploitable stock are expected to be higher in the coastal water of Malaysia since this group of fish species are not popular food fish. The results of our study shows that most of the fish caught were in sub-adult maturity stages with size ranges between 11 - 21 cm SL. However, we found that at this size, the fish have already being able to reproduce as indicated by the presence of male and female gonads (stage II – III) in the belly (Fig. 4). This also shows that, the length at first maturity (L_m) been reached quite early for the species. Further details studies will undoubtedly be important especially on the reproductive biology, life history and population dynamic of the particular species in the Matang mangrove reserves. Preliminary observation through this study perhaps on the other hands exposed the important roles of Matang mangrove forest reserve as an ideal breeding and nursery ground for demersal and pelagic fishes of the Straits of Malacca.

General bioacoustical aspects of *A. maculatus:* Preliminary results from our observations demonstrated that *A. maculatus* emit both drumming sounds (low frequency modulated pulsed sounds) as well as stridulation sounds made by the pectoral spines apparatus (high frequency modulated pulsed sounds). Both of the sound types emit pulsed sound sequentially forming a sound train with varying length. Some of the basic acoustical parameters of this sound is given in Table 4. The drumming sound of *A. maculatus* is hypothesized to be produced by sonic swimbladder muscles which originate at various cranial elements and insert onto an 'elastic spring' that vibrates the swimbladder. Swimbladder sounds are known to be a common mechanism of sound production for many fish. However, at present the behavioral context of this sound production in *A. maculatus* could not be determined. It has been reported for other catfish *Orinocodoras eigenmanni* (family: Doradidae), that swimbladder sound are produced in the disturbance context (restrained) and during conflicts over resting sites[9]. In comparison with *O. eigenmanni*, *A. maculatus* showed a smaller range of sound duration (140 ms) as well lower dominant frequency component (667 ± 91 Hz). However, interestingly it can be seen from the waveform that individual pulses have double peaks similar to those of *O. eigenmanni* although they seem to reduce in amplitude over time (Figure 5).

At a glance, the stridulation sound of *A. maculatus* is different from it's drumming sound in terms of the waveform where it's sound pulses can be seen lacking the double pulse characteristrics. Other than that, it can be seen that the mean sound duration (100.65±11.6ms) and dominant frequency (1130±76) for the stridulation sound much exceeds those of drumming sounds (Table 5). It is evident from the waveform (Figure 6) that the sound train is also longer with rather maintained sound amplitude throughout the call. In the armoured catfish *C. paleatus* the stridulatory sound producing mechanism consisted mainly of a ridged dorsal process at the proximal end of the thickened pectoral fin ray (spine), a curved groove of the shoulder girdle and enlarged abductor muscle [15]. It is likely that the mechanics of *A. maculatus* pectoral fin stridulation may share some similarities with *C. paleatus* or even other member of the catfish family*;* nevertheless detailed anatomical investigations are required for exact verification of the mechanism of sound production in this species

Table 1: Key to the species of Ariidae in the Malaysian Coastal Water (Scott, 1959) (Fishes with asterisk denoted the common co-exist species with *Arius maculatus*)

1	One pair of maxillary barbels present, but without mandibular barbels.	*Osteogeneiosus militaris**
2	Barbel on upper and lower jaws at least	2
	Mouth very wide, reaching behind eye. A single row of incisor-like teeth in each jaw	*Ketengus typus*
	Mouth narrow, ending before eye. Teeth not incisor-like	3
3	Adipose fin commences anterior to anal fin	*Hemipimelodus borneensis**
	Adipose fin commences opposite anal fin	4
4	Length of base of the adipose fin goes into the distance between adipose fin and dorsal fin 3 x	5
	4 x	8
	more than 4 x	9
5	Adipose fin completely black	*Arius caelatus*
	Adipose fin with a large black spot	*Arius macronotacanthus*
	Not as above	6
6	Base of adipose fin less that that of dorsal fin	*Arius utik**
	Base of adipose fin equals that of dorsal fin	7
7	Middle rays of anal shorter that end rays	*Arius truncatus*
	Middle rays of anal longer than end rays	*Arius sagor*
8	Adipose fin with a large black spot	*Arius maculatus*
	Adipose fin with no black spot	*Arius venosus*
9	19 – 20 anal rays	*Arius argyropleuron*
	Less than 19 anal rays	10
10	Base of adipose fin equals base of dorsal fin	*Arius thalassinus**
	Base of adipose fin less than that of dorsal fin	11
11	18 anal rays	*Arius tonggol*
	15 – 17 anal rays	12
12	Dorsal fin with a dark tip	*Arius leiotetocephalus*
	No dark tip on dorsal fin	*Arius polystaphylodon*

Table 2: Comparison of standard meristic measurements of *A. maculatus* in Matang mangrove reserves and in adjacent waters.

Parameter	Measurements* (n = 20)	Measurements** (n=10)
Standard length:	83.2% TL	83.6%TL
Fork length:	89.9% TL	80.1%TL
Pre-anal length:	54.2% TL	53.4%TL
Pre-dorsal length:	28.1% TL	29.0%TL
Pre-pelvic length:	40.6% TL	41.7%TL
Pre-pectoral length:	19.2% TL	18.2%TL
Body depth:	20.0% TL	18.8%TL
Head length (HL):	21.9% TL	22.5%TL
Eye diameter:	16.2% HL	13.4%HL
Pre-orbital length:	33.1% HL	37.2%HL
Aspect ratio of caudal fin:	1.56	

Sources:
*Dwiponggo *et al.* 1986.
**Present study

Table 3: Category of the food items obtained from stomach contents analysis.

Food I	Food II	Food III	Food name	Pred.Stage
detritus	detritus	debris	unidentified	juv./adults
zoobenthos	benth. crust.	amphipods	unidentified	juv./adults
zoobenthos	benth. crust.	benth. copepods	unidentified	recruits/juv.
zoobenthos	benth. crust.	crabs	unidentified	recruits/juv.
zoobenthos	benth. crust.	crabs	unidentified	recruits/juv.

Table 3: Continued.

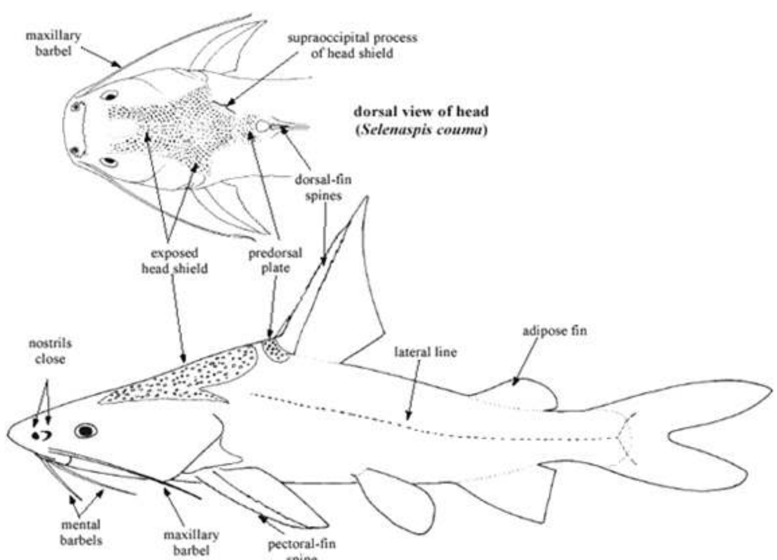
zoobenthos	benth. crust.	n.a./other benthic crustaceans	unidentified	recruits/juv.
zoobenthos	benth. crust.	ostracods	unidentified	juv./adults
zoobenthos	benth. crust.	shrimps/prawns	unidentified	juv./adults
zoobenthos	benth. crust.	shrimps/prawns	unidentified	recruits/juv.
zoobenthos	benth. crust.	shrimps/prawns	unidentified	recruits/juv.
zoobenthos	benth. crust.	stomatopods	unidentified	juv./adults
zoobenthos	mollusks	bivalves	unidentified	juv./adults
zoobenthos	mollusks	bivalves	unidentified	recruits/juv.
zoobenthos	other benthic invertebrates	n.a./other benthic invertebrates	unidentified	juv./adults
zoobenthos	other benthic invertebrates	n.a./other benthic Invertebrates	unidentified	adults
zoobenthos	worms	polychaetes	unidentified	juv./adults
zoobenthos	worms	polychaetes	unidentified	recruits/juv.
zooplankton	fish (early stages)	fish eggs/larvae	unidentifed	juv./adults

Table 4: Acoustical parameters of drumming sound by *A. maculatus*

Variable, unit (n=18)	Mean	Std Dev	Min	Max
Sound Duration (SD), unit	51.16	40.77	14.35	154.19
# of pulse (PN)	14.44	12.99	5	57
Pulse Duration (PD),ms	2.34	0.73	1.03	3.72
Inter pulse interval (IPI), ms	1.68	0.66	0.52	2.7
Pulse Period (PP), ms	3.9	1.03	1.54	5
Dominant Frequency (DF), Hz	667	91.1	544.7	854.2

Table 5: Acoustical parameters of pectoral fin stridulation by *A. maculatus*

Variable, unit (n = 3)	Mean	Std Dev	Min	Max
Sound Duration (SD), unit	100.65	11.57	87.64	109.77
# of pulse (PN)	19.67	2.08	18	22
Pulse Duration (PD),ms	3.76	0.13	3.62	3.88
Inter pulse interval (IPI), ms	1.44	0.39	1.05	1.82
Pulse Period (PP), ms	4.94	0.4	4.67	5.4
Dominant Frequency (DF), Hz	1129.8	76	1042.7	109.8



(Fig. 1a:)

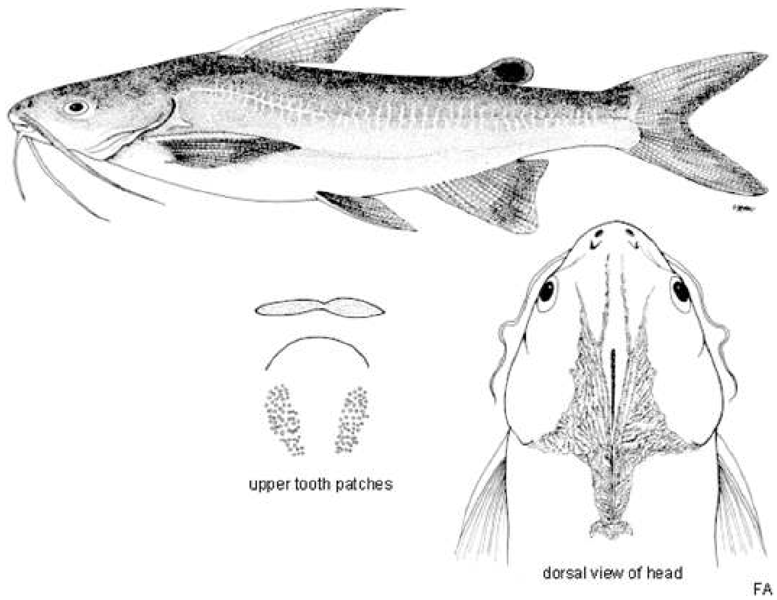


Fig. 1(a,b). Hypothetical systematic drawing and structure of *Arius maculatus*[5].

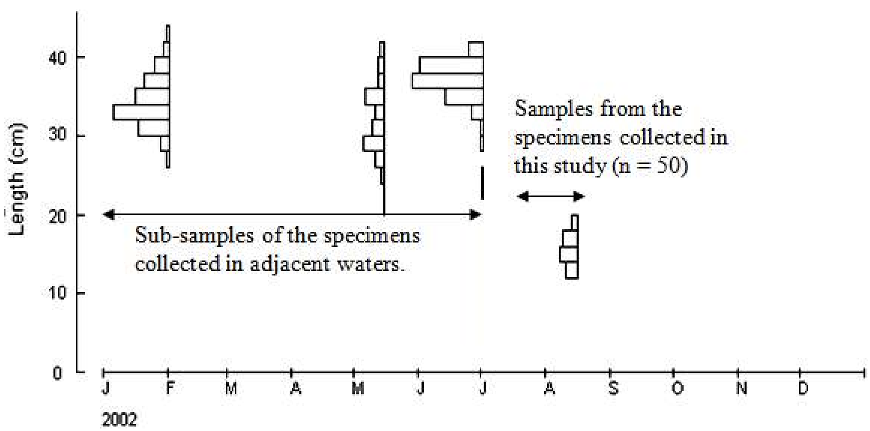


Fig. 2: Comparison of length frequency of the samples collected from Matang mangrove reserves with samples collected in adjacent waters.

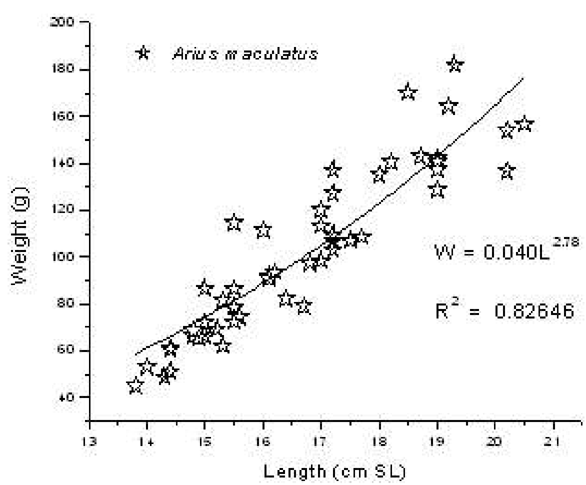


Fig. 3. The growth conditions of *Arius maculatus* in Matang mangrove reserves.

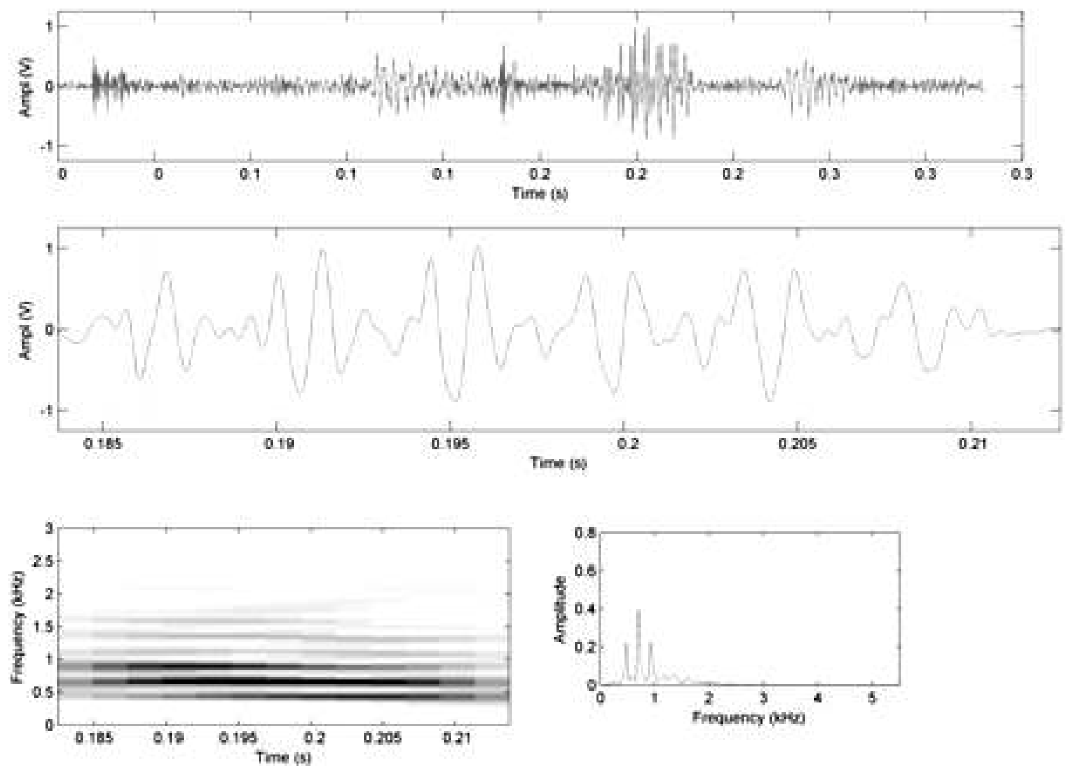


Fig. 5: Oscillogram (waveform), spectrogram (FFT length 1024) and power spectra of drumming sound (Analysed and generated using SoundRuler ver 0.9.6.0 (Marcos Gridi Papp).

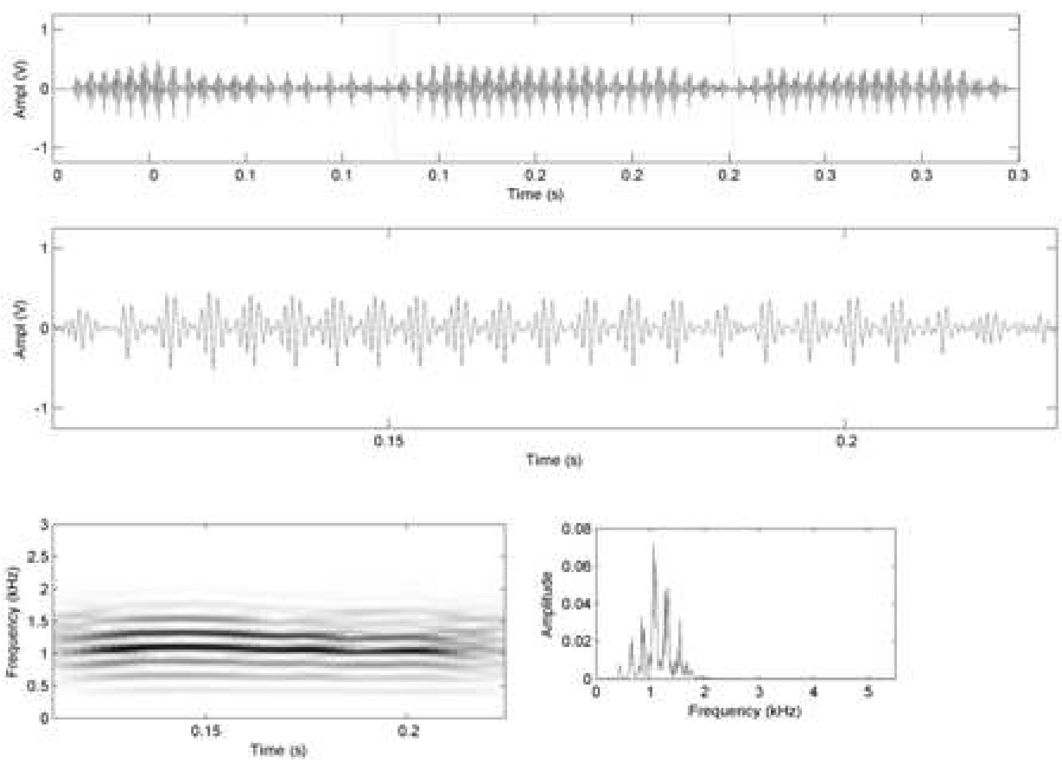


Fig. 6: Oscillogram (waveform), spectrogram (FFT length 1024) and power spectra of pectoral stridulation sound (Analysed and generated using SoundRuler ver 0.9.6.0 (Marcos Gridi Papp).

Conclusions: In conclusions, it is predicted that, the Matang mangrove reserves systems sustained high population of the catfish family. This was based on our observation in the Matang mangrove reserves water systems. Most of the fish caught were in their partially matured sub-adult cohort and this perhaps indicated that this mangrove system also play an important roles as breeding and spawning ground for this particular species and other euryhaline fish species. Distinct stridulation sound production in *Arius maculatus* denoted that this species is actively communicating in the wild. However the purpose of this bioacoustic production is still unknown and further details studies need to be planned.

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