The status of yellow pufferfish, *Xenopterus naritus* (Richardson, 1848) from the Southwest coast of Sarawak, Northwestern Borneo, Malaysia

[1]Ahmad Syafiq Ahmad Nasir, [1]Samsur Mohamad, [2]Mohammed Mohidin

[1] Department of Aquatic Science, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia; [2] Fisheries Research Institute Bintawa, Bintawa, Kuching, Sarawak, Malaysia. Corresponding author: A. S. A. Nasir, anahmadsyafiq@gmail.com

Abstract. The yellow pufferfish, *Xenopterus naritus* is a commercially important target species for the artisanal fishermen in Sarawak. There is concern over its conservation and population structure. Therefore we provided a baseline data on size distribution, sex ratio, length-weight relationship and condition factor of 65 specimens of this species, landed from May 2015 to July 2014 from eight distinct locations (Kabong, Sematan, Buntal, Paloh, Sadong Jaya, Pusa, Sebangan and Spaoh) representing the Southwest coast of Sarawak waters. Specimens were obtained by hiring local fishermen to catch them and purchasing from fish markets. Generally, males were significantly smaller and lighter than females. Total length, standard length and body weight of combined sexes of *X. naritus* was found in the size range of 10.6–29.5 cm, 8.8–26.7 cm and 20.16–646.76 g respectively. Male to female sex ratio was 1M:2.8F. Length–weight relationships of *X. naritus* exhibited positive growth allometry in males but negative growth allometry in females, whereas positive growth allometry in combined sexes. Condition factor in overall specimens was 2.279±0.434 which reflects the healthiness of *X. naritus* and favorable environmental conditions in Sarawak waters. Findings of the present study contribute as important baseline data for future studies not only on the fisheries and stock management of *X. naritus* but also on conservation and aquaculture development of this commercially important species.
Key Words: Tetraodontidae, size distribution, length-weight relationship, condition factor, aquaculture.

Introduction. Fisheries and aquaculture have been important sources of food, generated lucrative income and supported livelihoods for hundreds of millions of people around the globe (FAO 2016). In Sarawak, the total landings of capture fisheries in 2015 was 147,579 metric tons and worth USD 169.35 million (DOF 2015). Various management strategies have been formulated and implemented to control fishing effort and promote rehabilitation and conservation of valuable marine resources and marine ecosystems (Saad et al 2012).

Most of the management strategies are based on knowledge that is adequate to conclude cause-and-effect relationships between management actions and fish population (Radomski & Goeman 1996). Frequent assessments are vital because population size, structure, and species distribution often changes in response to environmental variations from anthropogenic activities and natural disturbances (Shelton & Mangel 2011; Van Dover 2014; Micheli et al 2016). Thus, status and trends in size distribution and growth pattern of fish in a population are important baseline data for sustainable fisheries management.

The yellow pufferfish, *Xenopterus naritus* (Richardson, 1848) (Teleostei: Tetraodontidae), is widely distributed in China, Thailand, Indonesia, Vietnam, Myanmar, India and Malaysia. In Malaysia, this species can only be found in Southwest coast of Sarawak, starting from Tg. Datu in Sematan further up to Mukah, central Sarawak (Figure 1). *X. naritus* is considered as trash fish in commercial fishery, but an important target species among the small-scale, artisanal fishermen along coastal and major estuaries in Sarawak. Today, it is one of the fish species with higher commercial value and its market demand is on the rise, to the extent that it has raised interest in culturing it (Nasir et al

2016). Generally inhabited coastal waters and areas fringing the mangroves, *X. naritus* is known to migrate towards river upstream for spawning at lower salinity environment. The high demand in local markets for fresh and salted roe of *X. naritus*, coupled with the practice of local fisheries of selling all sizes of individuals, have triggered the need for research on the size distribution, length–weight relationship and condition factor of *X. naritus* in Sarawak waters.

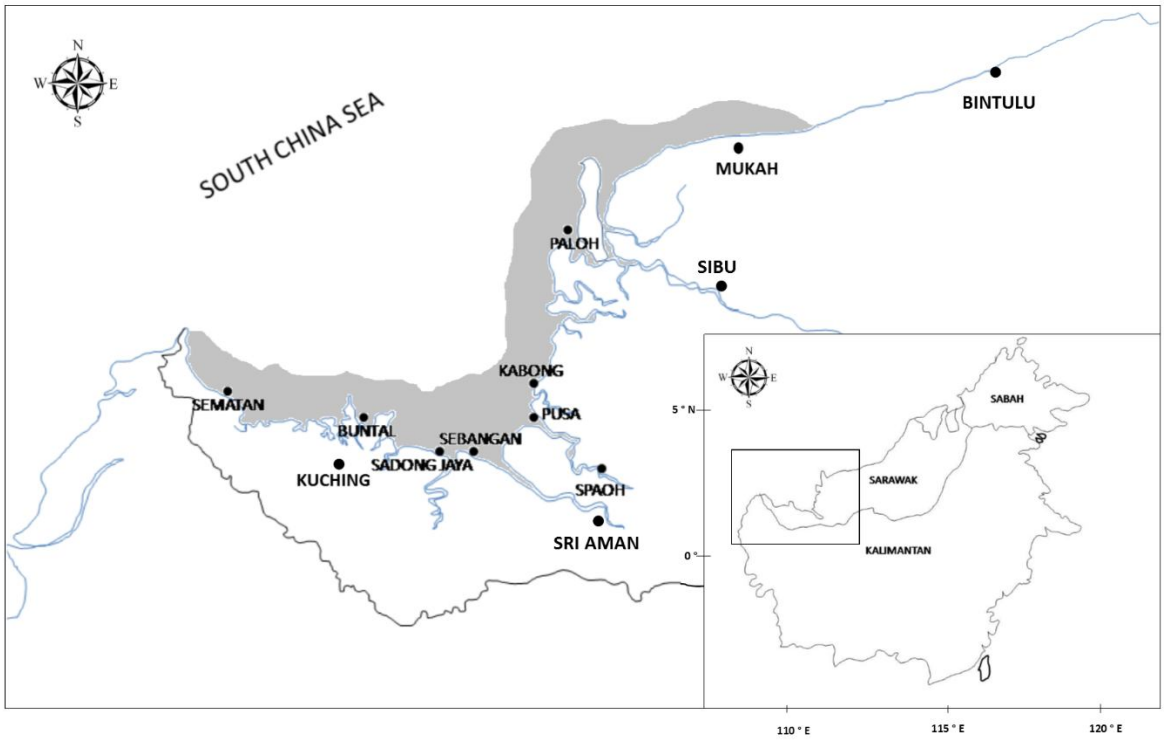

Figure 1. Distribution of yellow puffer, *Xenopterus naritus* along the Southwest coast of Sarawak, Northwestern Borneo.

Length-weight relationship (LWR) study is one of an important tool to support fisheries management. It is frequently used to estimate and compare the size and fitness of specific animal populations, especially aquatic species with high commercial value (Hsu 1999; Rosa et al 2006; Mahomoud et al 2011; Başusta et al 2013; Fauzi et al 2016). Concurrently, Fulton's condition factor (CF) is a reliable physiological index of fish growth and health status (Fulton 1902). It also indicates the changes in food reserves and therefore an indicator of the general fish condition (Datta et al 2013).

Nevertheless, information about *X. naritus* fisheries and comprehensive study on its biological parameters including LWR and CF in Sarawak is scarce. To our knowledge, no study has been done in the past related to LWR and CF of *X. naritus*. Previous studies were only focusing on its general morphometric measurements, geographical distribution, morphology, toxicity, proximate composition and gut content (Gambang & Hiok 2004; Atack 2006; Imelda et al 2012; Mohd Nor Azman & Wan Norhana 2013; Mohd Nor Azman et al 2013, 2014, 2015).

Therefore, this study was conducted to provide a baseline data on size distribution, sex ratio, length-weight relationship and condition factor of *X. naritus* from its core spawning area of river upstream and adjacent waters which reflects its current status in Sarawak. This comprehensive study is essential for understanding the population, behavior and migration of the stock in different environments so as to embark on measures for management and propagation of this important species.

Material and Method

Study site and specimen collection. Eight distinct sampling locations representing the Southwest coast of Sarawak waters were selected in this study, namely: Kabong,

Sematan, Buntal, Paloh, Sadong Jaya, Sebangan, Pusa and Spaoh (Figure 2). These locations were identified as a landing site of *X. naritus* in Sarawak based on the preliminary survey at wet market of the area and rough information provided by the locals. The fish specimens were collected from May 2015 to July 2016 (Table 1). Specimens were obtained in two ways: (1) By hiring local fishermen to fish at Spaoh, (2) by purchasing freshly caught fish of known origin from fish markets at Kabong, Sematan, Buntal, Paloh, Sadong Jaya, Sebangan and Pusa. The specimens were stored in ice box and transported back to the laboratory for further analysis.

Table 1

Sampling locations of *Xenopterus naritus* with different geographical regions, sampling month, fishing methods and GPS coordinates

Geographical region	*Locality*	*Sampling month*	*Fishing method*	*GPS coordinates*
Coastal	Kabong	May-15	Gill net[2]	1°51'10.8"N 111°03'51.6"E
	Sematan	Mar-16	Gill net	1°49'24.1"N 109°46'45.2"E
	Buntal	Mar-16	Gill net	1°42'07.5"N 110°22'42.0"E
	Paloh	Apr-16	Gill net	2°30'13.1"N 111°09'53.2"E
	Sadong Jaya	Apr-16	Gill net	1°34'57.0"N 110°42'42.2"E
	Pusa	Jul-16	Gill net	1°37'07.0"N 111°16'43.5"E
	Sebangan	Jul-16	Gill net	1°35'55.0"N 110°46'25.9"E
River	Spaoh[1]	Sep-15	Gill net & Sagang[3]	1°30'15.5''N 111°20'33.4"E

[1]Spaoh – Located approximately 90 kilometers upstream of Saribas River.
[2]Gill net – 2 and 4-inch mesh size, monofilament, 30 to 50 meter length.
[3]Sagang - A traditional fishing method consists of fishing line and shark meat as a bait, wrapped around the cylindrical weight/sinker with aluminum wire.

Morphometric measurements. Fish specimens were sexed according to Nasir et al (2016). The total length (TL) and standard length (SL) of each specimen was measured to the nearest 0.1 centimetre (cm) by using measuring board (Wildco) and the body weight (BW) was measured to the nearest 0.01 gram (g) by using electronic balance (AND Model FY-300). Species identification was based on taxonomic keys by Gray et al (1850), Roberts (1982), Kottelat (1999), Atack (2006) and Kottelat (2013).

Sex ratio. Sex ratio was given as males:females (M:F), calculated using the equation: total number of females / total number of males. The chi-square (χ^2) was used to verify the existence of significant differences between the sex ratio of the study species and commonly expected 1:1 sex ratio (Sokal & Rohlf 1987).

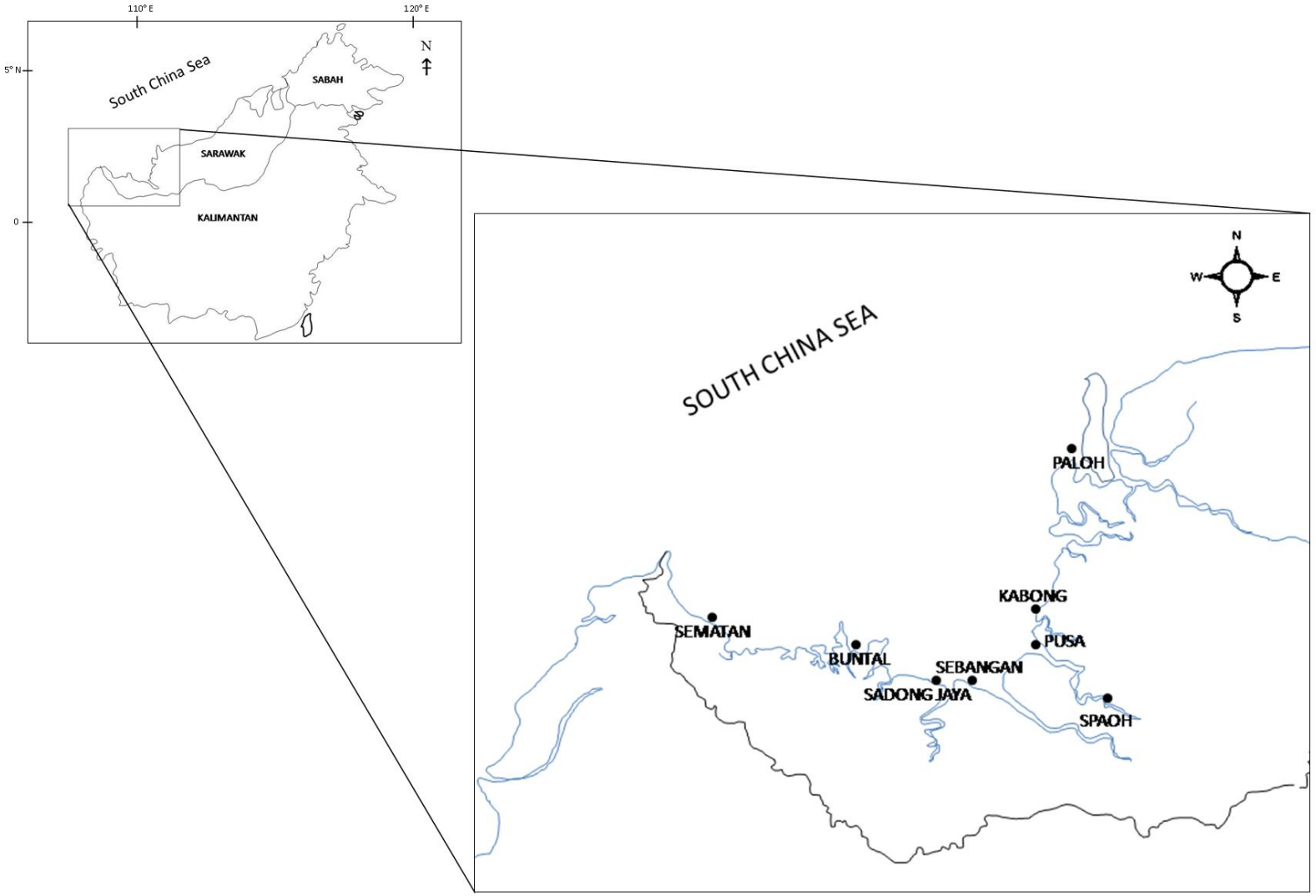

Figure 2. Map of Sarawak showing the sampling location of *Xenopterus naritus* in this study.

Length-weight relationship. The length-weight relationship was determined by the equation, $W = a L^b$, where W is the total weight (g), L is the total length (cm), *a* is the intercept (initial rate of growth or condition factor) and *b* is allometric coefficient (coefficient of growth or relative growth rate of fish) (Le Cren 1951; Hayes et al 1995). The t-test was performed to confirm whether the value of *b* departed significantly from the isometric value of 3 (Sokal & Rohlf 1987).

Condition factor. Condition factor (CF) is a reliable physiological index of fish growth and health status (Fulton 1902). As a general rule, CF-value greater than 1 (>1) should be regarded as an indicator for good growth and health. Fish condition factor (CF) was estimated using the equation $K=100W/L^3$ (Fulton 1902; Adeogun et al 2016) where W=wet weight (g), L=total length (cm).

Results

Size distribution. A total of 65 individuals were examined in this study. Summary of size distribution of *X. naritus* collected is presented in Table 2. Generally, female *X. naritus* tended to be longer and heavier than male. The mean TL, SL and BW of male were 16.0±3.0 cm, 13.6±2.5 cm and 102.40±63.24 g, ranges from 11.0 to 20.5 cm, 8.8 to 17.0 cm and 30.72 to 274.05 g respectively. For female *X. naritus*, the mean TL, SL and BW were 21.1±1.9 cm, 24.06±2.1 cm and 324.62±97.72 g, ranges from 19.6 to 29.5 cm, 17.3 to 26.1 cm and 155.34 to 646.76 g respectively. The biggest male and female specimens were found from Sematan and Paloh, while the smallest male and female were found from Buntal and Kabong. There was a significant difference in mean total length, standard length and body weight between male and female of *X. naritus* ($p<0.05$).

The length frequency distribution of *X. naritus* is shown in Figure 3. A bimodal distribution was observed in specimens collected. There is an overlapping between the largest male and the smallest female at 20–21 cm length classes which suggest the probability of hermaphroditism in *X. naritus*.

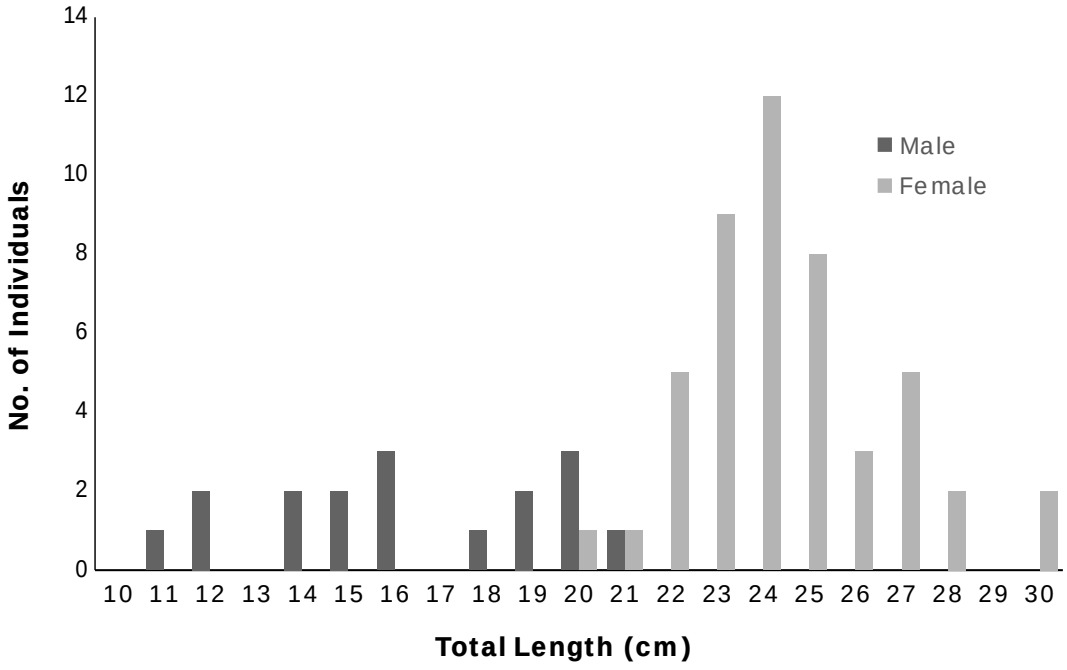

Figure 3. Length frequency distribution of *Xenopterus naritus*.

Table 2

Mean ± SD, minimum and maximum values of total length (cm), standard length (cm) and body weight (g) of *Xenopterus naritus* from Southwest coast of Sarawak

Geographical region	*Location*	*Month*	*Sexes*	*N*	*Total length (cm)*			*Standard length (cm)*			*Body weight (g)*		
					Mean±SD	*Min*	*Max*	*Mean±SD*	*Min*	*Max*	*Mean±SD*	*Min*	*Max*
Coastal	Kabong	May-15	♂	2	17.9±2.9	15.8	19.9	14.7±1.6	13.5	15.8	134.0±43.3	103.42	164.63
			♀	3	22.2±3.6	19.6	26.3	19.6±3.0	17.3	23.0	318.4±148.6	155.34	446
	Sematan	Mar-16	♂	5	17.5±2.5	14.7	20.5	14.8±1.9	12.7	17.0	140.63±82.75	71.12	274.05
			♀	6	22.4±0.9	21.1	23.5	19.4±0.9	18.3	20.5	264.55±16.29	247.17	289.3
	Buntal	Mar-16	♂	6	14.4±3.6	11.0	19.2	12.4±3.3	8.8	16.4	81.60±57.20	30.72	156.2
			♀	0	-	-	-	-	-	-	-	-	-
	Paloh	Apr-16	♂	0	-	-	-	-	-	-	-	-	-
			♀	2	28.2±1.8	26.9	29.5	24.7±2.0	23.3	26.1	550.50±136.14	454.23	646.76
	Sadong Jaya	Apr-16	♂	0	-	-	-	-	-	-	-	-	-
			♀	5	25.5±2.4	23.5	29.5	22.1±2.1	20.1	25.6	385.3±98.5	300.51	550.03
	Pusa	Jul-16	♂	0	-	-	-	-	-	-	-	-	-
			♀	19	24.0±1.7	21.8	27.9	21.0±1.6	18.6	24.4	295.02±72.57	200.35	496.21
	Sebangan	Jul-16	♂	0	-	-	-	-	-	-	-	-	-
			♀	10	24.3±1.6	21.6	27.1	21.4±1.5	19.6	24.3	365.1±80.0	252.22	466.12
River	Spaoh	Sep-15	♂	4	15.7±1.9	14.0	18.3	13.4±1.5	12.1	15.4	68.51±24.86	48.98	104.58
			♀	3	23.4±0.6	22.8	23.9	20.7±0.3	20.4	21.0	251.93±36.13	218.93	290.54
Total			♂	17	16.0±3.0	11.0	20.5	13.6±2.5	8.8	17.0	102.40±63.24	30.72	274.05
			♀	48	24.1±2.1	19.6	29.5	21.1±1.9	17.3	26.1	324.62±97.72	155.34	646.76

Sex ratio. From the total catch of 65 *X. naritus* in Southwest coast of Sarawak in this study period, 17 (26.2%) were male and 48 (73.8%) were female. Generally, female was more numerous than male. The sex ratio variations in all sampling locations are presented in Figure 4. No male specimens of *X. naritus* were collected in Paloh, Sadong Jaya, Pusa and Sebangan during the sampling period while absent of female specimens was recorded in Buntal. Female specimens predominated in Kabong and Sematan while male predominated in Spaoh. Overall, the M:F ratio of combined sexes in all locations for *X. naritus* was 1M:2.8F.

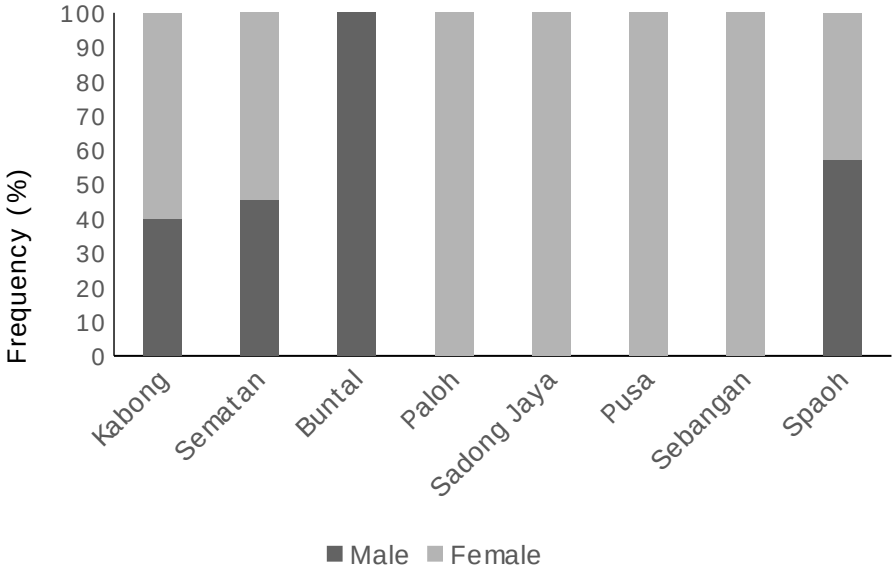

Figure 4. Sex ratio variations in eight sampling locations of *Xenopterus naritus* from Southwest coast of Sarawak.

Length-weight relationship. The length-weight relationship of male and female *X. naritus* is presented in Figure 5 and its parameters are shown in Table 3.

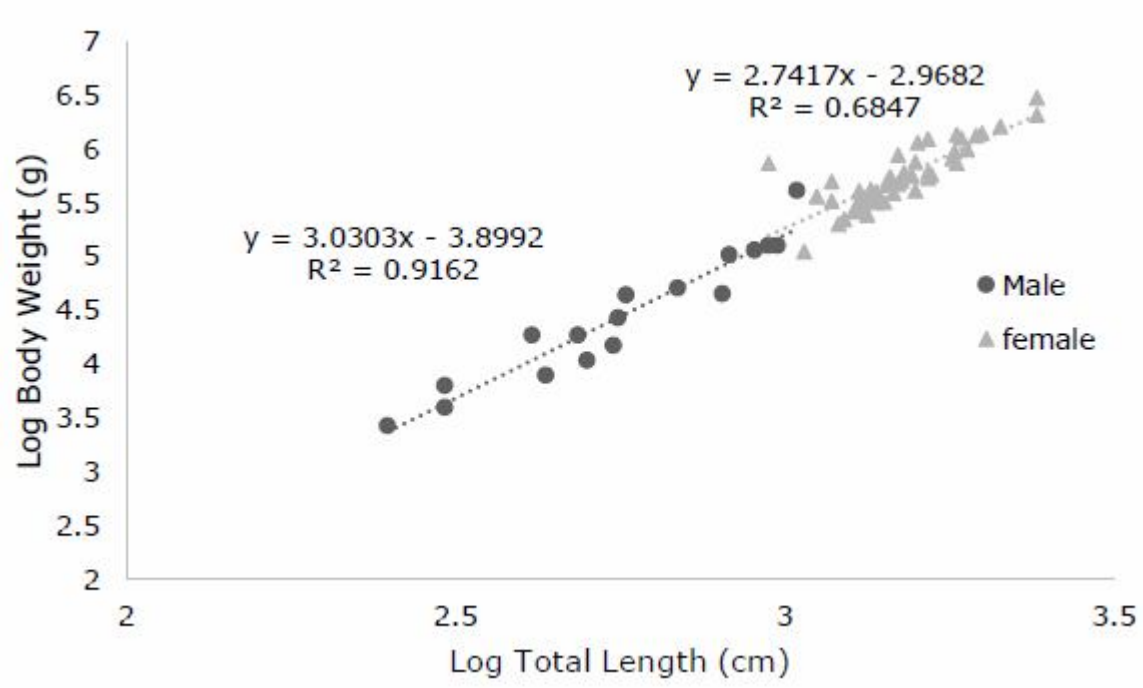

Figure 5. Length-weight relationship of male and female *Xenopterus naritus* from Southwest coast of Sarawak.

The coefficients of determination (R^2) ranged between 0.685 and 0.944. The exponent *b* of length-weight relationship ranged between 2.742 and 3.030 and the intercept value ranged between 0.0203 and 0.0514. In terms of type of growth, these results revealed that male *X. naritus* exhibited positive allometry (*b*>3), while females exhibited negative allometry (*b*<3). Nevertheless, the combined sexes of *X. naritus* exhibited the positive allometry growth type.

Table 3

Length-weight relationship parameters of *Xenopterus naritus* collected from Southwest coast of Sarawak

Sexes	*n*	*a*	*b*	*Equation*	*Growth type*	R^2
Male	17	0.0203	3.030	$W= 0.0203 L^{3.030}$	Allometric +	0.916
Female	48	0.0514	2.742	$W= 0.0514 L^{2.742}$	Allometric -	0.685
Overall	65	0.0210	3.022	$W= 0.0210 L^{3.022}$	Allometric +	0.944

Note: Values of *a* (elevation) and *b* (slope) are parameters of the equation, R^2 is the regression coefficient, and n is the sample number.

Condition factor. Condition factor of males, females and combined sexes of *X. naritus* were 2.234±0.399, 2.294±0.449 and 2.279±0.434 respectively (Table 4). The CF value which greater than 1 (>1) in all specimens were regarded as an indicator for good growth and health for *X. naritus.*

Table 4

Condition factor of *Xenopterus naritus* from Southwest coast of Sarawak

Sexes	*Condition Factor, K*
Male	2.234±0.399
Female	2.294±0.449
Combined sexes	2.279±0.434

Discussions. Based on the results obtained, the morphometric measurements and size distribution of *X. naritus* recorded in this study was within the values reported from other studies (Table 5).

The total length of *X. naritus* males ranges from 11.0 to 22.5 cm while of females ranges from 13.0 to 33.9 cm. The body weight of male *X. naritus* ranges from 28.00 to 274.05 g while female ranges from 44.00 to 711.00 g. The total length and body weight recorded in this study indicated that the specimens analyzed were mainly adults. The lack of smaller specimens in this study might be a consequence of selectivity in the fishing gear. Another explanation can be obtained from a research on other puffer fish species, *Sphoeroides annulatus* which revealed that younger organism were distributed in different habitats than older ones; i.e. juveniles inhabiting mixohaline systems and adults in the neritic zone, although large specimens can occasionally be found in estuarine-lagoon systems at low frequencies (Sánchez-Cárdenas et al 2007). Thus, present study suggested that after the spawning season end at the river upstream, the *X. naritus* larvae and juvenile will stay in this brackishwater environment and eventually move towards the estuary and coastal areas as they grow older (Figure 6). Nevertheless, further comprehensive study on larvae distribution should be conducted to prove on this hypothesis.

Table 5

The comparison of morphometric measurements of *Xenopterus naritus* in present and previous studies

Location	*Sexes*	*N*	*Total Length (cm)*			*Body Weight (g)*			*References*
			Mean ± SD	Min	Max	Mean ± SD	Min	Max	
Spaoh	♂	462	16.9±1.3	11.3	19.8	100.41±26.05	28.00	190.70	(Imelda et al 2012)
	♀	121	-	21.6	33.9	-	-	-	
Spaoh	♂	141	16.1±2.0	12.5	22.5	85.50±42.20	38.90	254.00	(Mohd Nor Azman et al 2013)
	♀	135	24.0±3.7	13.0	31.0	325.00±131.00	44.00	711.00	
Kuching	♂♀	28	19.6±4.3	-	-	206.00±133.00	-	-	(Mohd Nor Azman et al 2014)
Spaoh	♂♀	56	18.1±3.93	13.4	28.0	139.20±124.50	42.60	492.50	(Mohd Nor Azman et al 2015)
Kabong	♂♀	38	23.2±2.3	17.8	28.8	294.10±74.50	138.10	489.40	
Southwest coast	♂	17	16.0±3.0	11.0	20.5	102.40±63.24	30.72	274.05	Present study
	♀	48	24.1±2.1	19.6	29.5	324.62±97.72	155.34	646.76	

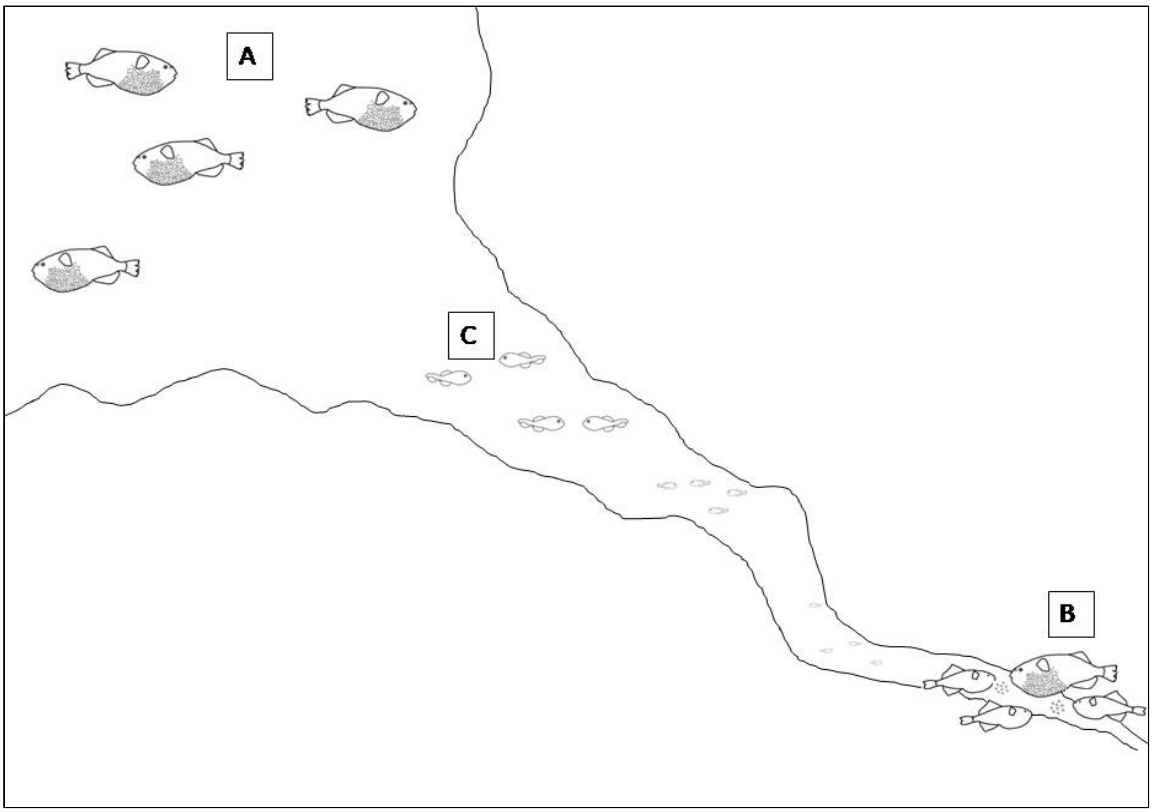

Figure 6. Hypothetical spawning migration pattern of *Xenopterus naritus* from Sarawak, Northwestern Borneo. A) Mature male and female of *X. naritus* from coastal areas migrated towards the river mouth; B) Spawning took place at the upstream of river; C) Larvae and juvenile live and grow in the brackish water environment along the river and migrated towards the open sea as they grow.

Similar result of the present study concerning length-frequency analysis which showed a bimodal distribution has been observed in most hermaphrodite species, including tropical shad, *Tenualosa toli*, a protandrous hermaphrodite (Blaber et al 1996) and European eel, *Anguilla anguilla* (Wysujack et al 2015). However, further confirmation need to be done: (1) Histology of the gonads (with evidence of a rapid decline in testicular tissue and progressive development of ovarian tissue); (2) The ageing data with males up to one-year-old and females from not less than one to at least two years old (Blaber et al 1996).

In addition, variations of sex ratio in every sampling location were also probably due to fishing gear selection and different period of sampling. The migratory behavior of this species explained the absence of males or females in some sampling locations. Fish migration is influenced by various environmental factors such as variations in water temperature, water level and light availability (Nachón et al 2016; Gosselin & Anderson 2017) and developmental factors including spawning, feeding and refuge seeking (Lucas & Baras 2000; Chen & Yang 2005; Ahsan et al 2014).

Investigations on morphometric measurements from previous authors do not included the estimation of length-weight relationship or condition factor of *X. naritus* in their study. Hence, we revealed the first reported findings of length-weight relationship for *X. naritus* in this study which exhibited positive allometric growth. Similar growth has been observed in different puffer fish species of Tetraodontidae, including obscure puffer, *Takifugu obscurus* (Yang & Chen 2003), while negative allometric growth were observed in other species, *Lagocephalus sceleratus* (Aydin 2011; Başusta et al 2013), *L. spadiceus* (Başusta et al 2013) and *Sphoeroides annulatus* (Sánchez-Cárdenas et al 2007; Valdez-Pineda et al 2014). Such discrepancies in the type of allometric growth is possibly due to the different origin of the sample and different ecological conditions in that specific habitat (Aydin 2011) or the differences of sexual maturity cycle, since these could

modify the value of the indicator of isometric-allometric growth (Valdez-Pineda et al 2014). Concurrently, the results of condition factor of the present study indicated that *X. naritus* were in good health which also reflected the suitability of the environments with regard to the feeding condition in those selected sampling stations (Mahmoud et al 2011).

X. naritus fishery is significantly important to supports the livelihoods of artisanal fishermen living along the coastal, major estuaries and riverine areas in Southwest coast of Sarawak. The fishing methods involved in this fishery range from the traditional fishing methods such as scoop net, "sagang", riverine trap made from rattan (bubu) and now more commercially efficient trammel net or gill net (Gambang & Hiok 2004). However, the use of modern fishing gears like gill net was to give an adverse effect on resources. Further comprehensive study on biological and ecological aspects of *X. naritus* is crucial for conservation and sustainable utilization of this species.

Conclusions. The length-weight relationship equation of combined sexes of *X. naritus* was $W=0.0210\ L^{3.022}$ which exhibited positive allometric growth while the condition factor was 2.279±0.434. Results obtained from this study reflects the current status of *X. naritus* from the Southwest coast of Sarawak and serve as a baseline data in fishery and biological aspects of this species for future management and conservation plans.

Acknowledgements. We are grateful for the close collaboration between Department of Aquatic Science, Faculty of Resource Science and Technology, University Malaysia Sarawak (UNIMAS) and Fisheries Research Institute Bintawa and Santubong, Department of Fisheries Malaysia in completing this study. We thank all fishermen for their participation and assistance during the field trips. This study was funded by Research and Innovation Management Centre (RIMC) UNIMAS under PhD Student Fund F07(DPP09)/1163/2014(10).

References

Adeogun A. O., Ibor O. R., Regoli F., Arukwe, A., 2016 Peroxisome proliferator-activated receptors and biotransformation responses in relation to condition factor and contaminant burden in tilapia species from Ogun River, Nigeria. Comparative Biochemistry and Physiology Part - C: Toxicology and Pharmacology 183–184(2):7–19.

Ahsan D. A., Naser M. N., Bhaumik U., Hazra S., Battacharya S. B., 2014 Migration, spawning patterns and conservation of hilsa shad in Bangladesh and India. Academic Foundation, New Delhi, 97 pp.

Atack K., 2006 A field guide to the fishes of Kuching Rivers, Sarawak, Malaysian Borneo. Natural History Publications (Borneo), Kota Kinabalu, Sabah, Malaysia, 194 pp.

Aydin M., 2011 Growth, reproduction and diet of pufferfish (*Lagocephalus sceleratus* Gmelin, 1789) from Turkey's Mediterranean Sea Coast. Turkish Journal of Fisheries and Aquatic Sciences 11:569–576.

Başusta A., Başusta N., Özer E. I., 2013 Length-weight relationship of two puffer fishes, *Lagocephalus sceleratus* and *Lagocephalus spadiceus* from Iskenderun Bay, Northeastern Mediterranean, Turkey. Pakistan Journal of Zoology 45(4):1047–1051.

Blaber S. J. M., Milton D. A., Pang J., Wong P., Boon-teck O., Nyigo L., Lubim D., 1996 The life history of the tropical shad *Tenualosa toli* from Sarawak: First evidence of protandry in the Clupeiformes? Environmental Biology of Fishes 46(3):225–242.

Chen Y., Yang Z., 2005 Diets of obscure puffer (*Takifugu obscurus*) and ocellated puffer (*Takifugu ocellatus*) during spawning migration. Journal of Freshwater Ecology 20(1):195–196.

Datta S. N., Kaur V. I., Dhawan A., Jassal G., 2013 Estimation of length-weight relationship and condition factor of spotted snakehead *Channa punctata* (Bloch) under different feeding regimes. SpringerPlus 2:436. doi: 10.1186/2193-1801-2-436.

Fauzi M., Dahelmi D., Zakaria I. J., Tang U. M., 2016 Biological aspects of lelan fish, *Diplocheilichthys pleurotaenia* (Cyprinidae) from the upstream and downstream of the Kampar River, Riau Province, Indonesia. AACL Bioflux 9(2):305–315.
Fulton T. W., 1902 The rate of growth of fishes. 20th Annual Report of the fishery board of Scotland, 3:326–446.
Gambang A. C., Hiok A. L. P., 2004 Yellow pufferfish (Buntal Kuning) *Xenopterus naritus* of Sarawak. FRI Newsletter 9(12):8-9.
Gosselin J. L., Anderson J. J., 2017 Combining migration history, river conditions and fish condition to examine cross-life-stage effects on marine survival in chinook salmon. Transactions of the American Fisheries Society 146(3):408–421.
Gray J. E., Richardson J., Adams A., Reeve L., White A., 1850 The zoology of the voyage of H.M.S. Samarang. Adams A. (ed), London, pp. 380.
Hayes D. B., Brodziak J. K. T., O'Gorman J. B., 1995 Efficiency and bias of estimators and sampling designs for determining length-weight relationships of fish. Canadian Journal of Fisheries and Aquatic Sciences 54(4):84–92.
Hsu C., 1999 The length - weight relationship of Albacore, *Thunnus alalunga*, from the Indian Ocean. Fisheries Research 41:87–92.
Imelda R. R., Mohammed M., Albert C. G., 2012 Preliminary study of golden yellow pufferfish, *Xenopterus naritus* in Sarawak. Proceeding International Seminar on Marine Science and Aquaculture, Universiti Malaysia Sabah, Kota Kinabalu, pp. 43-54.
Kottelat M., 1999 Nomenclature of the genera *Barbodes, Cyclocheilichthys, Rasbora* and *Chonerhinos* (Teleostei: Cyprinidae and Tetraodontidae), with comments on the definition of the first reviser. The Raffles Bulletin of Zoology 47(2):591–600.
Kottelat M., 2013 The fishes of the inland waters of Southeast Asia: A catalogue and core bibliography of the fishes known to occur in freshwaters, mangroves and estuaries. The Raffles Bulletin of Zoology 27:1-663.
Le Cren E. D., 1951 The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). Journal of Animal Ecology 20:201-219.
Lucas M. C., Baras E., 2000 Methods for studying spatial behaviour of freshwater fishes in the natural environment. Fish and Fisheries 1(4):283–316.
Mahomoud W. F., Mohamed A., Amin M., Elboray K. F., 2011 Reproductive biology and some observation on the age, growth and management of *Tilapia zilli* (Gerv, 1848) from Lake Timsah, Egypt. International Journal of Fisheries and Aquaculture 3(2):16–26.
Micheli F., Heiman K. W., Kappel C. V., Martone R. G., Sethi S. A., Osio G. C., Fraschetti S., Shelton A. O., Tanner J. M., 2016 Combined impacts of natural and human disturbances on rocky shore communities. Ocean and Coastal Management 126:42–50.
Mohd Nor Azman A., Samsur M., Mohammed M., Othman M., Imelda R. R., Shabdin M. L., Fasihuddin B. A., 2013 Tetrodotoxin in various tissues of yellow puffer fish, *Xenopterus naritus* (Richardson 1848) from Betong, Sarawak, Malaysia. Asian Fisheries Science 26(3):142–155.
Mohd Nor Azman A., Samsur M., Mohammed M., Shabdin M. L., Fasihuddin B. A., 2015 Assessment of proximate composition and tetrodotoxin content in the muscle of Yellow puffer fish, *Xenopterus naritus* (Richardson 1848) from Sarawak, Malaysia. International Food Research Journal 22(6):2280–2287.
Mohd Nor Azman A., Samsur M., Othman, M., 2014 Distribution of tetrodotoxin among tissues of pufferfish from Sabah and Sarawak waters. Sains Malaysiana 43(7):1003–1011.
Mohd Nor Azman A., Wan Norhana M. N., 2013 Detection of tetrodotoxin and saxitoxin in dried salted yellow puffer fish (*Xenopterus naritus*) eggs from Satok Market, Kuching, Sarawak. International Food Research Journal 20(5):2963–2966.
Nachón D. J., Mota M., Antunes C., Servia M. J., Cobo F., 2016 Marine and continental distribution and dynamic of the early spawning migration of twaite shad (*Alosa*

fallax (Lacépède, 1803)) and allis shad (*Alosa alosa* (Linnaeus, 1758)) in the north-west of the Iberian Peninsula. Marine and Freshwater Research 67(8):1229–1240.
Nasir A. S. A., Samsur M., Mohammed M., 2016 The first reported artificial propagation of yellow puffer, *Xenopterus naritus* (Richardson, 1848) from Sarawak, Northwestern Borneo. Aquaculture Research pp. 1–8. doi: 10.1111/are.13103.
Radomski P. J., Goeman T. J., 1996 Decision making and modeling in freshwater sport-fisheries management. Fisheries 21(12):14–21.
Roberts T. R., 1982 The Southeast Asian freshwater pufferfish genus *Chonerhinos* (Tetraodontidae) with description of new species. Proceedings of the California Academy of Sciences, California, 43(1):1–16.
Rosa A., Menezes G., Melo O., Pinho M. R., 2006 Weight–length relationships of 33 demersal fish species from Azores archipelago. Fisheries Research 80:329–332.
Saad J., Hiew K., Nagarai G., 2012 Review of Malaysian laws and policies in relation to the implementation of ecosystem approach to fisheries management in Malaysia. The USAID Coral Triangle Support Partnership, Honolulu, Hawaii, 88 pp.
Sánchez-Cárdenas R., Ceballos-Vázquez B. P., Arellano-Martínez M., Valdez-Pineda M. C., Morán-Angulo R. E., 2007 Reproductive aspects of *Sphoeroides annulatus* (Jenyns, 1842) (Tetraodontiformes, Tetraodontidae) inhabiting the Mazatlan coast, Sinaloa, Mexico. Revista de Biología Marina y Oceanografía 42(3):385–392.
Shelton A. O., Mangel M., 2011 Fluctuations of fish populations and the magnifying effects of fishing. Proceedings of the National Academy of Sciences of the United States of America, Princeton, New Jersey, pp. 7075–7080.
Sokal R. R., Rohlf F. J., 1987 Introduction to biostatistics. 2nd edition, Freeman, New York, 363 pp.
Valdez-Pineda M. C., Moran-Angulo R. E., Voltolina D., Castillo-Vargasmachuca S., 2014 Population structure and reproductive aspects of puffer fish *Sphoeroides annulatus* (Jenyns, 1842) (Osteichthyes: Tetraodontidae), landed in Teacapán, Sinaloa, Mexico. Latin American Journal of Aquatic Research 42(1):121–126.
Van Dover C. L., 2014 Impacts of anthropogenic disturbances at deep-sea hydrothermal vent ecosystems: A review. Marine Environmental Research 102:59–72.
Wysujack K., Westerberg H., Aarestrup K., Trautner J., Kurwie T., Nagel F., Hanel R., 2015 The migration behaviour of European silver eels (*Anguilla anguilla*) released in open ocean conditions. Marine and Freshwater Research 66(2):145–157.
Yang Z., Chen Y., 2003 Length-weight relationship of obscure puffer (*Takifugu obscurus*) during spawning migration in the Yangtze River, China. Journal of Freshwater Ecology 18(3):349–352.
*** DOF (Department of Fisheries), 2015 Fisheries Annual Report 2015. Department of Fisheries Malaysia, Kuala Lumpur, Malaysia, 50 pp.
*** FAO (Food and Agriculture Organization), 2016 The state of world fisheries and aquaculture 2016: Contributing to food security and nutrition for all, Rome, 200 pp.

Received: 04 May 2017. Accepted: 09 June 2017. Published online: 15 June 2017.
Authors:
Ahmad Syafiq Ahmad Nasir, Universiti Malaysia Sarawak, Faculty of Resource Science and Technology, Department of Aquatic Science, Malaysia, Sarawak, 94300 Kota Samarahan, e-mail: anahmadsyafiq@gmail.com
Samsur Mohamad, Universiti Malaysia Sarawak, Faculty of Resource Science and Technology, Department of Aquatic Science, Malaysia, Sarawak, 94300 Kota Samarahan, e-mail: msamsur@unimas.my
Mohammed Mohidin, Fisheries Research Institute Bintawa, Malaysia, Bintawa, Sarawak 94744, PO Box 2243, Kuching, e-mail: aquamohd@gmail.com

How to cite this article:
Nasir A. S. A., Mohamad S., Mohidin M., 2017 The status of yellow pufferfish, *Xenopterus naritus* (Richardson, 1848) from the Southwest coast of Sarawak, Northwestern Borneo, Malaysia. AACL Bioflux 10(3):602-614.