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Variations of Basic Nutritional Compositions by Seasons and Sizes in Four Freshwater Fishes as Common Food Sources in Lao PDR

Kaori FUJITA[1], Philavanh BOUTSAVATH[2], Xaypunya MAHATHILATH[2], Masataka SAITO[3], Bounsong VONGVICHITH[4], Katsumi HASADA[1] and Shinsuke MORIOKA[1]*

[1] Japan International Research Center for Agricultural Sciences, Tsukuba, Japan
[2] Planning and Cooperation Division, National Agriculture and Forestry Research Institute, Vientiane, Lao PDR
[3] Laboratory of Food Science and Technology, Kagawa Nutrition University, Sakado, Saitama, Japan
[4] Living Aquatic Resources Research Center, Vientiane, Lao PDR

Abstract

Common freshwater food fishes such as the Walking Catfish (*Clarias batrachus*), Broadhead Catfish (*Clarias macrocephalus*), Climbing Perch (*Anabas testudineus*), and Striped Snakehead (*Channa striata*) are widely consumed in Southeast Asia, including Lao PDR. Quantitative differences in the nutritional value of these fishes were evaluated by seasons and sizes as essential nutritional information toward improving the nutritional status of each country's residents. Size (weight and total length) and proximate composition (moisture, protein, fat, and ash contents) of the above fishes were measured quarterly over a year, with the sample fishes being separated into three size groups (large, medium, and small). Fishes of the "small" group tended to have higher moisture, protein, and ash contents than those of the "large" group across the species. In contrast, the "large" group tended to have higher fat content than those of the "small" group. In addition, seasonal fluctuations of fat content were observed in three species except the Walking Catfish, and are considered to be relevant to the reproductive cycles of each species. All the results obtained here are essential information for informing consumers of the nutritional value of the above species by species and by seasons/sizes.

Discipline: Food
Additional key words: food fishes, nutritional value, nutritional variation by seasons and sizes

Introduction

Freshwater fish are reliable sources of essential nutrients for humans in inland regions, containing protein, fat, and micronutrients such as vitamins and minerals. The major food resource for inlands in Southeast Asia is freshwater aquatic animals from the Mekong River basin, which provides essential nutrients for people that otherwise subsist on cereal crops (Garaway et al. 2013, Halwart & Bartley 2014, Hortle 2007, Jams 2006, Poulsen et al. 2004). The estimated total yield of aquatic animals as a food resource from the Mekong River basin is about 2.6 million tonnes/year, and on average approximately 33.7 kg per person per year is consumed in countries such as Cambodia, Lao People's Democratic Republic (PDR), Thailand, and Vietnam (Hortle 2007).

The Lao PDR is one of most dependent countries on these resources for its nutrient supply (Pedersen et al. 2014, Phonvisay 2013), and is still classified as the world's least developed country. In Lao PDR, the annual consumption of freshwater fish is estimated to be 24.5 kg per capita, accounting for 43.2% of all animal protein consumption (Hortle 2007). Although more than 481 fish species have been identified in Lao PDR (Phonvisay 2013), the number of species of aquatic animals (fishes, crabs, shrimps, and molluscs) consumed on a daily basis is reportedly much more limited (FAO 2003), and we found that 27 species of fishes were commonly consumed in one village (Nameuang) of Vientiane province (Fujita et al. 2019).

The Walking Catfish (*Clarias batrachus*), Broadhead Catfish (*Clarias macrocephalus*), Climbing

*Corresponding author: e-mail moriokas@affrc.go.jp
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Perch (*Anabas testudineus*), and Striped Snakehead (*Channa striata*) are popular edible freshwater fishes throughout western and southeastern Asia, including Lao PDR. These species are considered irreplaceable as commonly consumed food resources due to their high nutritional benefits, which include protein and fat as well as macro/micro nutrients (Bogard et al. 2015), such as vitamin A and minerals such as Ca, Fe, and Zn (Nurhasan et al. 2010). However, there is little information on the differentiations in the nutritional value of these fishes by seasons and sizes, although the fishes are regularly consumed during the year regardless of size. Thus, seasonal and size variations in the nutritional value of these fishes are important information for consumers in the country. In this study, we thus aimed to determine the differences in the macro nutrients (protein, fat and ash) of the above major fishes regularly consumed in Lao PDR, in order to identify the differences in nutrients in these fishes by seasons and sizes.

Materials and methods

1. Sample collections

The four fish species—Walking Catfish (*Clarias batrachus*), Broadhead Catfish (*Clarias macrocephalus*), Climbing Perch (*Anabas testudineus*), and Striped Snakehead (*Channa striata*)—were analysed after being selected based on interviews conducted during the previous study (Fujita et al. 2019), which provided perspectives on the use of different fish sizes and their consumption over a single year by the residents of Lao PDR. Target sample sizes for the fish were divided into three size groups that were defined based on interviews with the sellers in each market. Sampling was mainly conducted in the three domestic markets of Vientiane: the Nanga market in the northern part of the city, the HuaKua market in the eastern part, and the Dongmakkhay market in mid-eastern part. These markets were selected due to the abundance of natural fish being traded directly between fishermen and traders, and not through a hub market.

The samples were collected during four different sampling periods from March, June, and September 2017 and January 2018, with each sampling period lasting two weeks (Table 1). Two sampling periods were in the rainy/warmer season that lasts from early May to late September, and the other two sampling periods were in the dry season that lasts from November to May. With respect to the number of fish, the number sampled was dependent on the size of each species, but at a minimum of approximately 600 g (on a wet basis) for each pooled sample of each species.

Table 1 lists the total number and total weight of the samples at each size, along with the seasons in which they were sampled, but sufficient quantities of the "small" group fishes were not obtained in any of the markets in March 2017 (Table 1).

2. Sample pretreatment

Fresh or live samples were collected and packed in plastic bags at the collection sites, and then transported in ice boxes with ice to the Living Aquatic Resources Research Center (LARReC), National Agriculture and Forestry Institute, Ministry of Agriculture and Forestry, on the same day. The samples were washed with tap water, packed in polyethylene bags, and then stored at −30°C in a freezer. Frozen samples were transported in a sealed insulated box lined with ice gel to a laboratory at the Japan International Research Center for Agricultural Sciences (JIRCAS) for nutrient composition analysis. The temperature of each sample was measured to confirm that the sample remained frozen during transportation.

The weight and total length of individual fish in a semi-frozen state were measured, and filet portions (filets with skin) were weighed after the head, guts, scales, bones, and other parts were removed. The filet rates were calculated using following formula:

$$\textit{Filets}\ (\%) = \frac{\textit{total weight of filet with skin}\ (g)}{\textit{total weight}\ (g)} \times 100$$

The samples were homogenized as separate parts for analysis, with subsamples of the homogenate being taken at a size appropriate for individual analytical tests.

3. Proximate composition

Moisture, protein, fat, and ash contents were analysed according to the Standard Tables of Food Composition in Japan - 2015 (Ministry of Education, Culture, Sports, Science and Technology - Japan 2015), which is based on AOAC methods. In summary, the moisture content was determined using the air drying method in a heated air oven for 5 hours at 105°C, at which point the samples reached a stable dried weight. The crude protein content was determined using the Kjeldahl method, and the content was calculated as 6.25 multiplied by the nitrogen content. The crude fat content was analysed by the Soxhlet extraction method. Ash content was determined using the incineration method at 600°C for 2 hours. These contents were analysed in duplicate and presented in results tables, according to the methods of Fujita et al. (2019).

4. Data analysis

The morphometric and physicochemical parameters of the samples were analysed in triplicate, and the results are presented as mean ± standard deviation. The data obtained were subjected to one-way analysis of variance, and the levels were differentiated with post-hoc Tukey-Duncan's multiple range tests using XLSTAT-Premium Solution. The significance was ascertained at $P < 0.01$.

Results and discussion

1. Fish weight and total length

Although the weight and length of food organisms are important factors not only for deciding their marketable values for consumers but also as useful nutritional indicators to estimate daily intake, such information has not been well evaluated in Lao PDR. Table 2 lists the differences in weight and total length of the three size groups across all four seasons. The Striped Snakehead (*Channa striata*) had the widest level of size variation, and their size varied by a magnitude of approximately 2.6 times (17.8-46.0 cm) between size groups. For the other species, the size varied by 1.5 times (17.0-26.4 cm) for Broadhead Catfish (*Clarias macrocephalus*), 1.7 times (17.6-29.7 cm) for Climbing Perch (*Anabas testudineus*), and 1.8 times (12.0-22.1 cm) for Walking Catfish (*Clarias batrachus*). And greater differences in the average body weights of individual fish were shown than in the length variations in all fish species. Striped Snakeheads were approximately 16 times heavier (55.1-880.2 g) between size groups, whereas Broadhead Catfish were only 3.5 times heavier (44.0-156.6 g), Walking Catfish 4.6 times heavier (42.9-193.4 g), and Climbing Perch 6.7 times heavier (34.7-228.8 g). Thus, fishes with wide size/weight ranges were commonly sold in the markets.

Another important factor affecting nutrition value is the edible portion rate of the body weight (%). In this study, we determined the filet rate (%) as the edible portion by size groups and seasons (Fig. 1). The filet rates for Climbing Perch were the lowest among the four species (ca. 30-40% (Fig. 1) due to the relatively greater head length ratio by total length. For instance, the head length ratio was > 40% (Morioka et al. 2009b) in Climbing Perch, and 21% (Morioka et al. 2013) in Broadhead Catfish.

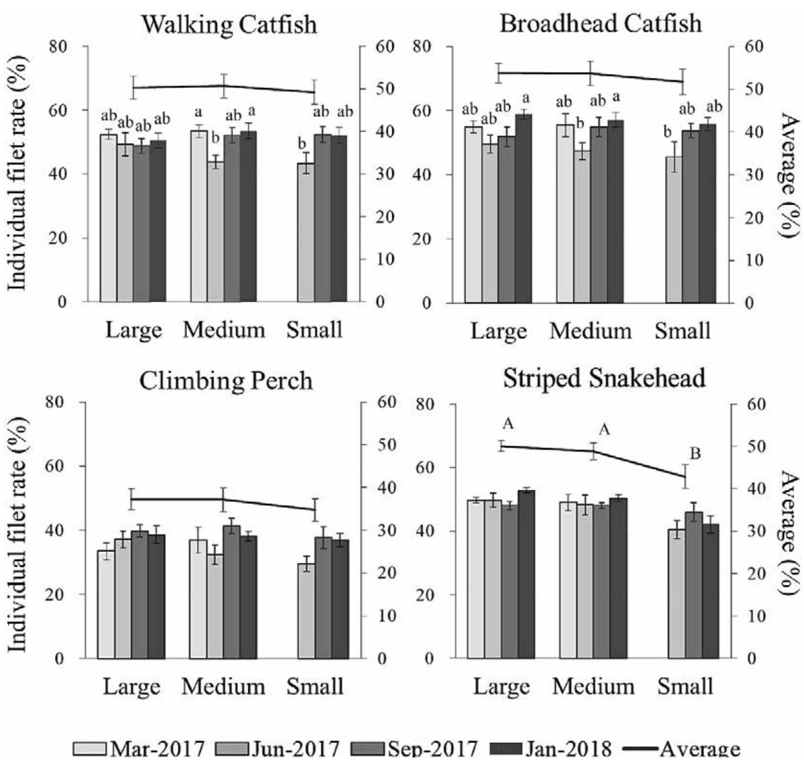

Fig. 1. Filet rates as percentages in different size groups for all four fish species by seasons and sizes

The different characters show significant differences ($P < 0.01$); uppercase letters show significant differences in the averages, lowercase letters show significant differences in individual seasons.

Table 1. Total number and total weight (g) of the samples of four fish species collected from March 2017 to January 2018

English name (*Scientific name*) Local name	Size*	March 2017		June 2017		September 2017		January 2018	
		Total number of samples	Total weight of collected fish	Total number of samples	Total weight of collected fish	Total number of samples	Total weight of collected fish	Total number of samples	Total weight of collected fish
Walking Catfish	Large	14	2,551	14	3,093	12	2,250	14	2,330
(*Clarias batrachus*)	Medium	24	2,516	25	1,971	49	4,487	32	2,641
Pa Duk en	Small	-	-	-	2,310	105	3,082	42	2,426
Broadhead Catfish	Large	13	1,897	19	2,319	17	3,077	15	2,491
(*Clarias macrocephalus*)	Medium	22	2,640	30	2,811	36	2,961	30	2,413
Pa Duk oui	Small	-	-	-	2,407	111	2,607	61	2,645
Climbing Perch	Large	13	3,065	15	2,992	15	2,986	13	3,206
(*Anabas testudineus*)	Medium	23	3,279	38	2,741	24	3,013	34	2,668
Pa Keng	Small	-	-	47	1,848	167	3,160	108	2,905
Striped Snakehead	Large	9	7,692	9	9,906	9	6,490	6	5,070
(*Channa striata*)	Medium	14	2,594	9	4,281	12	2,067	9	3,619
Pa Kor	Small	-	-	29	1,844	71	2,409	75	2,270

* Size categories (Large, Medium, and Small) were defined based on interviews with the sellers in each market.

Table 2. Average total length and body weight of four fish species in each size group on a wet basis for four seasons from March 2017 to January 2018

English name (*Scientific name*) Local name	Size	Average total length (cm)					Average weight (g)				
		Mar. 2017	Jun. 2017	Sep. 2017	Jan. 2018	Average of four seasons	Mar. 2017	Jun. 2017	Sep. 2017	Jan. 2018	Average of four seasons
Walking Catfish	Large	28.2 ± 1.3	32.7 ± 1.4	29.6 ± 1.8	28.2 ± 3.2	29.7 ± 1.9	185.8 ± 21.2	227.4 ± 25.7	183.2 ± 36.7	177.1 ± 52.0	193.4 ± 33.9
(*Clarias batrachus*)	Medium	24.2 ± 1.7	23.1 ± 1.7	21.8 ± 2.7	23.0 ± 1.5	23.1 ± 1.9	103.8 ± 20.8	79.3 ± 14.6	80.1 ± 24.8	97.1 ± 16.6	90.1 ± 19.3
Pa Duk en	Small	-	17.7 ± 1.7	15.6 ± 2.0	19.3 ± 1.9	17.6 ± 1.9	-	40.3 ± 11.9	30.4 ± 9.0	57.8 ± 13.3	42.9 ± 11.4
Broadhead Catfish	Large	25.6 ± 0.5	25.6 ± 2.1	27.4 ± 1.1	26.9 ± 1.0	26.4 ± 1.2	146.5 ± 13.8	131.6 ± 35.8	179.0 ± 24.3	169.2 ± 19.0	156.6 ± 23.3
(*Clarias macrocephalus*)	Medium	23.5 ± 1.1	22.7 ± 1.0	22.2 ± 2.1	21.2 ± 1.2	22.4 ± 1.4	120.0 ± 11.9	98.0 ± 11.4	86.5 ± 19.8	83.0 ± 15.3	96.9 ± 14.6
Pa Duk oui	Small	-	20.4 ± 1.5	14.1 ± 1.9	16.6 ± 1.6	17.0 ± 0.7	-	66.3 ± 9.3	22.9 ± 7.2	42.9 ± 9.2	44.0 ± 8.6
Climbing Perch	Large	22.4 ± 0.9	23.4 ± 1.0	20.2 ± 0.9	22.0 ± 0.6	22.1 ± 0.9	236.1 ± 32.8	205.3 ± 12.9	197.5 ± 16.7	276.2 ± 26.0	228.8 ± 22.1
(*Anabas testudineus*)	Medium	18.0 ± 1.0	19.1 ± 1.4	17.3 ± 0.9	18.1 ± 0.8	18.2 ± 1.0	122.5 ± 17.3	115.8 ± 17.8	122.2 ± 17.1	125.7 ± 14.9	121.6 ± 16.9
Pa Keng	Small	-	13.5 ± 1.2	11.2 ± 1.5	11.2 ± 1.5	12.0 ± 1.4	-	40.5 ± 10.4	34.0 ± 11.4	29.7 ± 8.3	34.7 ± 10.1
Striped Snakehead	Large	46.7 ± 1.7	49.4 ± 2.8	42.1 ± 2.0	45.5 ± 1.0	46.0 ± 1.9	854.8 ± 64.2	1,100.0 ± 168.6	721.1 ± 62.4	845.0 ± 37.3	880.2 ± 83.2
(*Channa striata*)	Medium	27.2 ± 1.4	38.2 ± 0.9	31.2 ± 1.3	35.4 ± 1.0	33.1 ± 1.2	201.0 ± 21.9	475.6 ± 24.2	274.6 ± 25.7	401.4 ± 38.1	338.2 ± 27.5
Pa Kor	Small	-	20.0 ± 1.3	15.9 ± 2.2	17.4 ± 1.7	17.8 ± 1.8	-	64.5 ± 13.2	35.3 ± 13.0	65.6 ± 10.4	55.1 ± 12.2

The data are shown as mean ± SD.

2. Moisture content

The moisture content in the filets of the four fishes ranged from 63.9 to 79.6 g/100 g, as listed in Table 3, with Climbing Perch having the lowest content. These results are comparable to the findings of Nurhasan (2010) that presented these species as having moisture content ranging from 73 to 79 g/100 g, except for Climbing Perch that showed lower moisture content (ca. 66-74 g/100 g) (Table 3), which coincided with the report by Fujita et al. (2019). In Climbing Perch, Nargis (2006) reported seasonal differences in moisture content, but no distinctive seasonal variations were observed in this study for all the species (Table 3). However, a significant increasing trend in moisture content by sizes ($P < 0.01$) revealed that the "small" groups showed higher moisture content than the "large" groups for three species except the Striped Snakehead (Table 3). These findings show that the substantial contents (e.g., protein and fat) in tissues increase as the fish grow in size while the moisture content decreases, such as observed in Japanese Red Sea Bream (*Pagrus major*) (Takii et al. 1992) and Climbing Perch (S. Morioka, data not published).

3. Protein, fat, and ash contents

In general, the nutritional composition (i.e., crude protein, fat, ash contents of sea fish) was reported to vary based on environmental conditions, spawning, the harvest season, migration, weather, and feeding conditions (Boran and Karaçam 2011, Saoud et al. 2008, Tsighe et al. 2018). Among the four species analysed in the present study, protein content was relatively higher in Walking Catfish, Broadhead Catfish, and Striped Snakehead (mostly > 80 g/100 g) than that of Climbing Perch (60-80 g/100 g), but no significant difference was observed by seasons and sizes in Walking Catfish (Fig. 2). However, for the other three species, the "small" fishes tended to have significantly higher protein content ($P < 0.01$), although obvious seasonal differences were not observed (Fig. 2).

Fat content in Climbing Perch was the highest (20-40 g/100 g) followed by Walking Catfish (7-12 g/100 g) and Broadhead Catfish (10-23 g/100 g), while the content in Striped Snakehead was the lowest (3-9 g/100 g) (Fig. 3). This finding indicates the unique characteristic of Climbing Perch as a very rich fat holder that can provide more energy to consumers. Although no significant difference in fat content was observed by

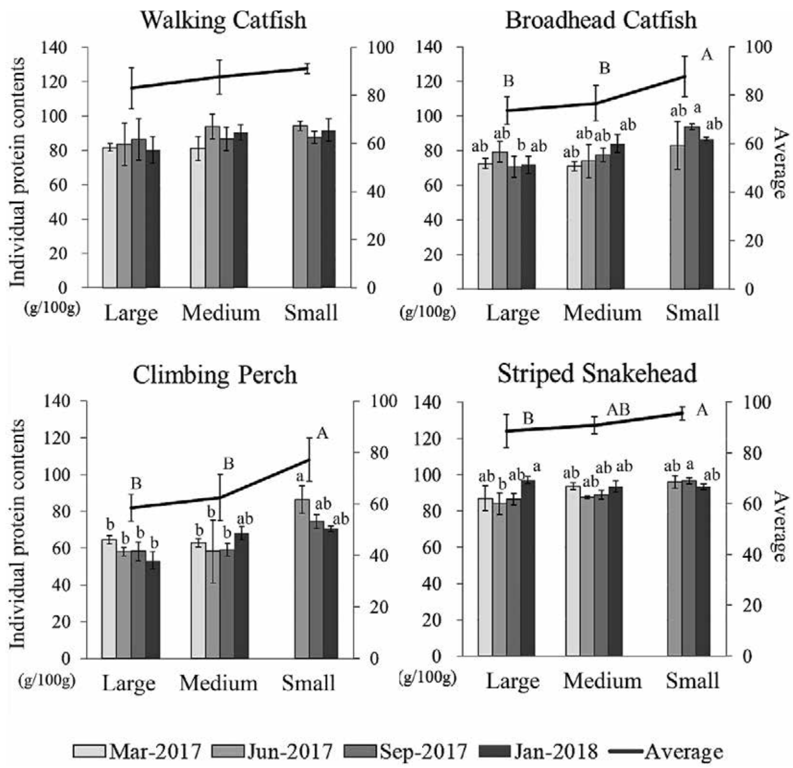

Fig. 2. Comparison of protein contents (g/100 g) in the filets of four fish species (dry weight basis) (mean ± SD) by seasons and sizes

The different characters show significant differences ($P < 0.01$); uppercase letters show significant differences in the averages, lowercase letters show significant differences in individual seasons.

Table 3. Variations in moisture contents (g/100 g) of four fish species by seasons and sizes

English name (*Scientific name*) Local name	Size	Mar. 2017	Jun. 2017	Sep. 2017	Jan. 2018	Average of the four seasons
Walking Catfish (*Clarias batrachus*) Pa Duk en	Large	75.8 ± 1.1	76.5 ± 2.9	75.8 ± 2.3	74.8 ± 1.1	75.7 ± 1.8 ^{B}
	Medium	76.2 ± 1.7	79.2 ± 1.4	77.2 ± 3.6	78.6 ± 1.9	77.7 ± 2.1 ^{AB}
	Small	-	79.1 ± 0.7	78.1 ± 1.7	79.6 ± 2.5	78.9 ± 1.7 ^{A}
Average		76.0 ± 1.3	78.2 ± 2.1	77.0 ± 2.3	77.7 ± 2.8	
Broadhead Catfish (*Clarias macrocephalus*) Pa Duk oui	Large	73.3 ± 0.6 ^{ab}	74.8 ± 2.2 ^{ab}	71.8 ± 2.3 ^{b}	73.8 ± 1.4 ^{ab}	73.4 ± 2.0 ^{B}
	Medium	72.9 ± 0.5 ^{ab}	73.3 ± 3.3 ^{ab}	74.7 ± 1.9 ^{ab}	77.4 ± 2.0 ^{ab}	74.6 ± 2.6 ^{A}
	Small	-	75.7 ± 3.4 ^{a}	79.6 ± 0.3 ^{a}	78.4 ± 0.1 ^{ab}	77.9 ± 2.4 ^{A}
Average		73.0 ± 0.5	74.6 ± 2.8	75.4 ± 3.7	76.5 ± 2.4	
Climbing Perch (*Anabas testudineus*) Pa Keng	Large	68.7 ± 0.7 ^{bc}	67.0 ± 0.9 ^{bc}	65.5 ± 2.8 ^{bc}	63.9 ± 1.8 ^{c}	66.3 ± 2.4 ^{B}
	Medium	67.7 ± 0.9 ^{bc}	67.4 ± 4.9 ^{bc}	67.1 ± 1.7 ^{bc}	69.2 ± 1.8 ^{abc}	67.7 ± 2.5 ^{A}
	Small	-	77.1 ± 1.6 ^{a}	72.8 ± 2.3 ^{bc}	73.2 ± 2.2 ^{ab}	74.4 ± 2.7 ^{A}
Average		68.2 ± 0.9	70.5 ± 5.6	68.5 ± 3.9	68.8 ± 4.3	
Striped Snakehead (*Channa striata*) Pa Kor	Large	76.9 ± 2.0 ^{abc}	74.9 ± 1.4 ^{bc}	73.9 ± 1.2 ^{c}	78.8 ± 0.7 ^{ab}	76.1 ± 2.3
	Medium	77.4 ± 0.5 ^{abc}	75.3 ± 0.3 ^{bc}	75.2 ± 1.0 ^{bc}	78.6 ± 1.7 ^{ab}	77.6 ± 1.8
	Small	-	78.3 ± 0.8 ^{ab}	79.6 ± 0.7 ^{a}	77.3 ± 0.9 ^{abc}	78.5 ± 1.1
Average		74.1 ± 1.3	76.1 ± 1.8	76.2 ± 2.7	78.4 ± 1.2	

Notes: The data are shown as mean ± SD.
Values within the same species with different characters show significant differences ($P < 0.01$) ; uppercase letters show significant differences in the averages, lowercase letters show significant differences in the individual seasons.

seasons and sizes in Walking Catfish, seasonal variations that seem to be relevant to reproductive cycles were observed in the other three species (Fig. 3). In particular, fat content in the “large” group of Broadhead Catfish was lower in June (Fig. 3), as its main breeding season is known to be from June to July (Ukkatawewat 1984). And in Climbing Perch, fat content was relatively lower in March for the “large/medium” groups and in June for the “small” group (Fig. 3). In this species, breeding is known to be active from March to June (Nagris 2006, Morioka et al. 2009a), and its minimum maturation size is > 10 cm in total length or even smaller (Morioka 2009), which covers all size groups of this species (Table 2). Moreover, the fat content in Striped Snakehead was lower from January to March (Fig. 3) in the “large/medium” groups (Fig. 3). For this species, breeding was observed to be active around April in the area (Morioka et al. 2016), and its maturation size is > 20 cm in total length (Morioka et al. 2016), thereby covering the “medium” and “large” groups (Fig. 2). Given these findings on the seasonal trends in fat content variations and the information from previous studies on the breeding periods of each species, lower seasonal fat content is considered to be caused by fat depletion from tissues for gonadal maturation during the pre-spawning and spawning periods, as commonly observed in other fishes, such as Atlantic herring (*Clupea harengus*) (Huynh et al. 2007).

The ash content of Climbing Perch was the lowest (3.0-4.5 g/100 g) compared to the other three species (4.0-5.7 g/100 g) (Fig. 4). There was no significant difference by seasons and sizes in ash content in Walking Catfish (Fig. 2). But similarly to the trends observed in protein content variations, the “small” fishes tended to have higher ash content for the other three species, although seasonal differences were not regularly distinctive (Fig. 4). In general, the ash ratio is reported to be variable with the phosphorous ratio in feeds (Tang et al. 2012, Wen et al. 2015), and the above trends in ash content variation by sizes may reflect changes in feeding habits as each species grows in size, although no information on feeding habits was obtained in this study.

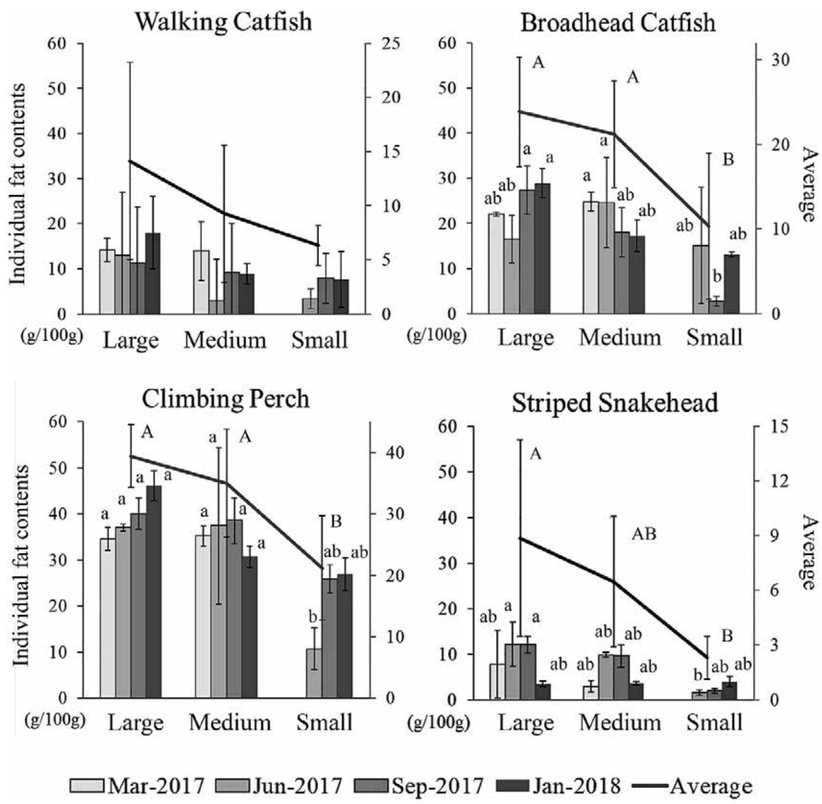

Fig. 3. Comparison of fat contents (g/100 g) in the filets of four fish species (dry weight basis) (mean ± SD) by seasons and sizes

The different characters show significant differences ($P < 0.01$); uppercase letters show significant differences in the averages, lowercase letters show significant differences in individual seasons.

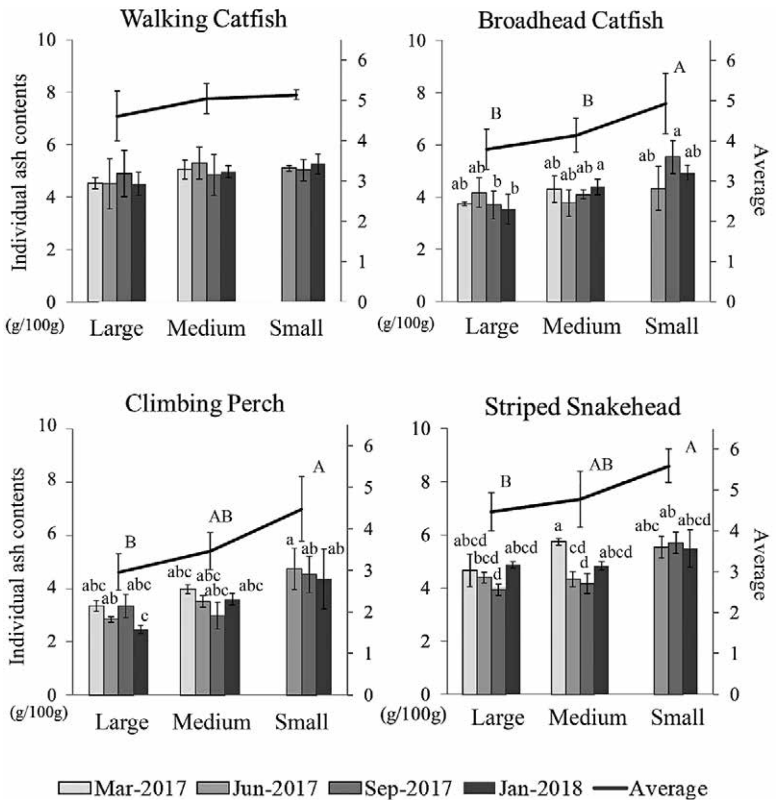

Fig. 4. Comparison of ash contents (g/100 g) in the filets of four fish species (dry weight basis) (mean ± SD) by seasons and sizes
The different characters show significant differences ($P < 0.01$); uppercase letters show significant differences in the averages, lowercase letters show significant differences in individual seasons.

Conclusions

The purpose of this study was to evaluate the nutritional composition of four fish species that are common food sources in Lao PDR. Our results demonstrate that these fishes provide important nutrients that give benefits, such as protein, fat (energy), and ash to the country's residents. Among such nutritional components, we found that the "small" group of these fishes tended to have higher protein and ash content levels than those of "large" group. Moreover, Walking Catfish, Broadhead Catfish, and Striped Snakehead were observed to be rich protein holders compared with Climbing Perch. In contrast, Climbing Perch was the richest fat holder compared to the other three species. This is useful information from a public health perspective for apprizing the residents of Indochinese areas in which these species are frequently consumed. Besides the above four species, there are rich resources of small-sized trash fishes, such as *Esomus metallicus*, *Rasbora* spp. and *Puntius brevis* of Cyprinidae (K. Fujita, data unpublished), *Parambassis siamensis* of Ambassidae, and *Trichopsis* spp. of Osphronemidae (S. Morioka, data unpublished), which are also important daily food resources, particularly in the mountainous rural areas of Lao PDR, even though their nutritional evaluations have yet to be made. Given the serious concern over insufficient animal protein intake for residents in rural areas of the country (Hasada & Yamada 2017), nutritional evaluations of these trash fishes must also be made for improving the nutritional status in such areas.

Acknowledgements

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