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Species-specific liver moisture content of coral reef fishes in the Malaysian South China Sea

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Abstract: Moisture content is an important measure of seafood quality as the flesh including liver naturally has high water content. Furthermore, moisture content is an important measure of ecological and environmental monitoring studies on coral reef fishes. However, few studies have reported the moisture content in coral reef fishes. Liver moisture contents and biological factors such as condition factor, hepatosomatic index (HSI) and gonado somatic index were examined in twenty-one coral reef fish species collected in Malaysian South China Sea. Four species of parrotfishes genus *Scarus* spp. were found to have significantly lower liver moisture relative to other reef fish species. A significant negative correlation was found between moisture content and HSI.

Key words: Bidong Island, conservation, coral reef fish, Malaysia, moisture, South China Sea.

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Southeast Asia is recognized as the global center for coral reefs, both in terms of extent and species diversity. An estimated 34 % of the Earth's coral reefs are located in the seas of Southeast Asia, which occupy only 2.5 % of the Earth's total sea surface (Burke *et al.* 2002). Furthermore, more than half of Southeast Asia's hard coral species diversity is found in the South China Sea (UNEP 2004). Marine biological diversity in the South China Sea is also immensely rich with at least 3,365 species of marine fishes inhabiting the area (Randall & Lim 2000). Ecologically, the coral reefs of the South China Sea are sources of larvae and juveniles for many commercially important reef fish (Arai 2015). Approximately one-quarter of the diet of pelagic and trans-boundary migratory fish such as yellowfin tuna comes from reef-associated organisms (Grandperrin 1978). Reef fisheries remain one of the most basic and essential commodities for the impoverished but growing coastal populations (Arai 2015) forming an important source of protein and income in Southeast Asia.

The four major constituents in the edible portion of fish are water, protein, lipid (fat or oil) and ash (minerals). Moisture content is an important measure of seafood quality, as the flesh naturally has high water content. Furthermore, moisture content is an important measure of environmental monitoring studies on coral reef fishes. Past studies showed the status of pollutant levels in coral reefs using coral reef fishes as bioindicators (e.g. Chouvelon *et al.* 2009; Hédouin *et al.* 2011; Metian *et al.* 2013). However, pollutant data were variably reported as a proportion of

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either wet or dry weight making comparisons between studies difficult. The average moisture content of fish flesh is reported as approximately 70 % (Murray & Burt 2001). However, few studies considered variations of moisture content among coral reef fish species. A more accurate investigation of moisture content among the species might provide useful information to convert pollutant levels from dry weigh to wet weight or vice versa.

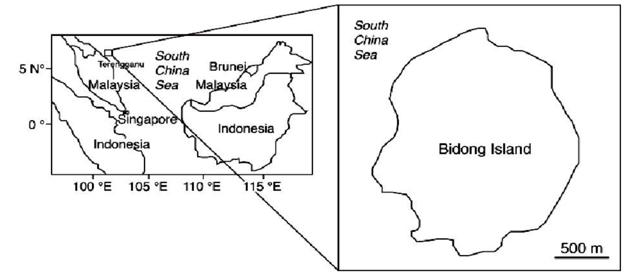

Fig. 1. Map showing the location of the study site at the Bidong Island in Malaysian South China Sea, off the Terengganu State in the east coast of Peninsula Malaysia.

In the present study, liver moisture contents and biological factors such as condition factor, hepatosomatic index and gonadsomatic index were examined in twenty-one coral reef fish species. This is the first study to evaluate fish liver moisture content levels in coral reef fishes in the Malaysian South China Sea.

All coral fish specimens were collected at Bidong Island in the South China Sea, Malaysia (Latitude 5.62°, Longitude 103.07°) between 27th and 28th October 2013 (Fig. 1). Bidong Island is located off Terengganu State on the east coast of Peninsular Malaysia, known for its history as a Vietnamese refugee settlement. The island possesses well-developed coral reef ecosystems comprised of a variety of coral and rocky reef associated fishes (Matsunuma *et al.* 2011). Coral reef fishes were collected by dip net, trap and hook and line. A total of 88 coral reef fishes comprising twenty-one species were collected (Table 1). After collecting, all fishes were immediately stored on ice for transport to the laboratory where they were stored in a -20 °C freezer for 10 to 14 days.

Total length (TL, mm) and body weight (BW, g) were recorded and morphological characters were used to identify the species. Liver and gonads were removed and weighed and the sex determined by visual examination. The moisture content of the fish liver was determined by oven drying each liver at 105 °C until a constant weight was obtained for approximately 12 hours (AOAC 1998) then reweighing the sample. Moisture content (MC) was calculated from the sample weight before and after drying. Condition factor (CF), hepatosomatic index (HSI), and gonadosomatic index (GSI) were calculated with the formulas:

$$CF = BW/TL^3 \times 100$$
$$HSI = LW_i/BW \times 100$$
$$GSI = GW/BW \times 100$$

where LW_i is the initial liver weight (g) of each fish; and GW is the gonad weight (g) of each fish.

Sex-based differences in moisture content were analyzed using the Mann-Whitney *U*-test. Differences in moisture content, condition indices (HSI, CF, GSI), total length, and weight among species were also examined using the Kruskal-Wallis test while using the Mann-Whitney *U*-test for post hoc two-group comparisons. The significance of the correlation coefficient and the regression slope were determined using a t-test (Sokal & Rohlf 1995).

A total of seventy-two liver samples from twenty-one coral reef fish species were examined for moisture contents. For each species, sample sizes ranged from 1 to 19 specimens (Table 1). Species biological information such as TL, BW, CF, HSI, GSI, and MC, was summarized in Table 1. All fishes examined were in the immature stage of maturity. Because no significant differences in moisture content were observed between sexes, these were combined for subsequent statistical comparisons.

Moisture contents among species ranged from 30 % to 80 % (Table 1, Fig. 2). Moisture content was not significantly different (Mann-Whitney *U*-test, n = 1 - 12, F = 1.6 - 19.1, $P > 0.05$) between sexes in any of the species analyzed. Therefore, the combined samples of male and female livers were used to compare moisture content among the fish species. It was noteworthy that moisture contents in four species of parrotfishes, *Scarus rivulatus*, *S. quyoi*, *S. psittacus*, and *S. ghobban* (approximately 30 %) were significantly lower than the other coral reef fish species (approximately 60 - 80 %) (Kruskal-Wallis test, n = 3 - 6, F = 3.8 - 30.5, $P < 0.0001$) (Table 1, Fig. 2). The average moisture content of fish flesh is reported as approximately 70 % (Murray & Burt 2001), although no data have been reported on coral reef fish species. The results were similar to those of coral reef fish species except for *Scarus* spp. (Table 1). In the present study, all fishes were collected at the same time and area, and thus their habitats could be similar and overlapped.

Table 1. Biological information for coral fish species collected in Bidong Island in Malaysian South China Sea.

Species	Sex	Total length (mm)		Body weight (g)		Condition factor		Hepatosomatic index	
		mean±SD	range	mean±SD	range	mean±SD	range	mean±SD	range
Thalassoma lunare	F	16.6±4.0	12.7-24.2	53.9±35.5	24.2-123.2	1.08±0.16	0.87-1.37	1.09±0.29	0.51-1.42
	M	18.2±3.0	13.7-23.5	66.1±27.5	33.0-123.4	1.07±0.15	0.91-1.31	1.04±0.64	0.08-2.01
	UD	18.7, 19.7		70.7, 80.7		1.06, 1.08		0.19, 0.65	
Abudefduf vaigiensis	F	14.1, 14.3		52.3, 55.3		1.87, 1.89		0.92, 1.13	
	M	15.4±1.4	13.0-16.7	67.3±17.3	41.1-88.9	1.81±0.11	1.69-1.96	0.54±0.17	0.38-0.81
Abudefduf sexfasciatus	F	12.8±0.2	12.6-13.0	39.8±3.0	35.0-43.3	1.89±0.10	1.75-1.97	0.87±0.31	0.43-1.23
	M	12.8±1.8	9.4-14.4	41.6±13.6	18.5-53.8	1.93±0.20	1.75-2.22	0.76±0.25	0.62-1.34
Cephalopholis boenak	F	13..8±2.7	11.2-18.5	47.7±24.2	24.8-82.6	1.73±0.22	1.30-2.00	0.85±0.32	0.36-1.31
	M	15.8		67.6		1.71		0.60	
Cephalopholis cyanostigma	F	30.1		486.6		1.78		0.95	
Cephalopholis formosa	F	29.5		432.3		1.68		0.38	
Epinephelus fuscoguttatus	F	23.0±2.3	20.7-25.3	247.5±104.8	145.7-349.2	1.90±0.31	1.59-2.16	0.69±0.47	0.50-1.44
Scolopsis affinis	F	17.7±1.8	15.7-21.1	83.0±25.5	52.6-129.7	1.48±0.08	1.36-1.57	0.81±0.21	0.54-1.22
	M	21.5		150.9		1.52		0.44	
Scolopsis monogramma	F	22.7, 22.9		136.2, 170.5		1.13, 1.46		0.83, 1.16	
Hemiglyphidodon plagiometopon	F	15.9, 16.4		104.9, 108.8		2.47, 2.61		0.68, 0.83	
	M	15.7		94		2.43		0.59	
Pempheris oualensis	M	14.0, 14.5		32.9, 36.3		1.19, 1.20		0.20, 0.47	
Neoglyphidodon sp.	F	12.3, 13.4		48.4, 55.6		2.31, 2.60		1.73, 1.79	
Cheilinus trilobatus	F	26.3		374.5		2.06		0.87	
Siganus guttatus	M	26.9		350.6		1.80		0.97	
Pomacanthus annularis	F	32.9		1114.6		3.13		0.81	
Valamugil buchanani	M	32.8		353.6		1.00		0.59	
Lethrinus elongatus	M	28		247.7		1.13		0.82	
Scarus rivulatus	F	23.2±1.8	21.4-24.7	252.6±59.9	199.6-305.6	1.99±0.07	1.95-2.08	5.30±2.03	4.95-8.75
	M	20.6, 26.7		163.4, 377.5		1.87. 1.98		2.27, 7.67	
Scarus rivulatus	F	22.2±1.3	22.0-22.4	217.5±30.4	173.5-234.2	1.98±0.16	1.89- 2.20	7.31±0.70	6.60-8.00
	M	22.1		210.4		1.95		3.00	
Scarus psittacus	F	17.4±2.1	14.5-19.8	105.8±34.9	67.0-153.5	1.99±0.14	1.87-2.20	5.22±1.73	2.89-6.90
	M	17.8		106.3		1.88		6.41	
Scarus ghobban	M	23.7		252.9		1.90		3.789996046	

F: female; M: male; UD: undifferentiated.

Contd…

Table 1. Continued.

Gonadosomatic index		Moisture content (%)		Number
mean±SD	range	mean±SD	Range	
0.72±0.84	0-1.89	72.3±6.4	62.6-79.1	7
0.67±0.83	0-2.63	60.7±8.1	51.4-72.0	10
0, 0		61.6, 63.3		2
1.24, 3.64		77.6, 78.7		2
1.04±0.33	0.56-1.42	75.7±6.9	64.6-82.9	5
0.73±0.40	0.31-1.31	65.1±12.1	48.9-81.3	5
0.21±0.15	0.11-0.51	67.8±4.5	60.2-72.4	6
0.59±0.63	0.12-1.23	71.0±3.40	66.2-75.2	7
0.09		79.1		1
0.49		59.1		1
0.20		65.2		1
0.05±0.03	0-0.06	73.8±2.5	70.1-75.2	3
0.36±0.21	0.05-0.60	75.8±2.8	71.9-79.4	8
0.04		77.3		1
0.17, 0.26		75.2, 76.4		2
0.24, 0.29		76.8, 80.1		2
0.02		81.7		1
0.14, 0.27		69.9, 75.4		2
0.04, 0.21		77.9, 78.4		2
0.03		66.8		1
1.06		76.5		1
0.03		76.1		1
0.56		80.5		1
0.18		71.9		1
0.04±0.07	0.03-0.16	29.0±6.2	18.4-30.1	3
0.03, 0.07		24.1, 58.2		2
0.06±0.02	0.03-0.07	32.9±2.7	28.8-34.2	3
0.01		40.3		1
0.32±0.13	0.14-0.49	39.9±8.4	32.8-49.0	4
0.28		30.4		1
0.02		38.7		1

The hepatosomatic index for *Scarus* spp. was significantly higher than other fish species (Kruskal-Wallis test, n = 3 - 6, F = 2.6 - 28.6, $P < 0.0001$) (Table 1). A significant negative correlation was found between moisture content and HSI (t-test, n = 89, t = -33.5, $P < 0.0001$, Fig. 3), while no significant correlations were found between moisture content and other biological characteristics such as TL, BW, CF, and GSI (t-test, n = 87 - 104, t = -34.8 - 3.9, $P > 0.05$).

The HSI is associated with liver energetic reserves and metabolic activity (Pyle *et al.* 2005). In the present study, the HSI values for most of coral reef fish species except for *Scarus* spp. were less than 2.0 (Table 1). Seasonal changes in the HSI, ranging from 1.14 to 6.67, were found in starlet *Acipenser ruthenus* (Lenhardt *et al.* 2009). The results suggest that HSI might depend on seasonal cycle. In this study HSI was similarly variable ranging from 0.2 to 6.4, and was probably

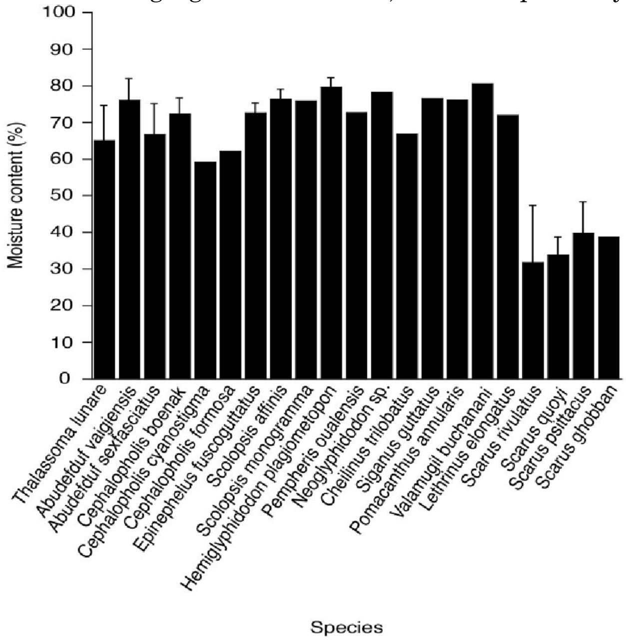

Fig. 2. Variations in the moisture contents of coral reef fishes collected at the Bidong Island in Malaysian South China Sea.

also related to differences in diets throughout the year. The variations in HSI among coral reef fishes might have an effect on the variations in the moisture content among the species. The principal constituents, such as moisture, protein and lipid contents, of fish varies greatly from one species and one individual to another depending on age, sex, environment, and season (Huss 1995). The variation in the composition of fish is closely related to feed intake, migration and sexual changes in relation to spawning (Huss 1995). Fish have starvation periods for natural or physiological reasons (such as migration and spawning) or because of external factors such as shortage of food. Usually spawning, whether occurring after long migrations or not, requires higher levels of energy (Huss 1995). Fish having energy depots in the form of lipids will rely on this. Species performing long migrations before they reach specific spawning grounds or rivers may utilize protein in addition to lipids for energy, thus depleting both the lipid and protein reserves, resulting in a general reduction of the biological condition of the fish (Huss 1995). Most species, in addition, do not usually ingest much food during spawning migration and are, therefore, not able to supply energy through feeding. Thus, such ecological, behavioral and physiological differences among fish species might be influencing the

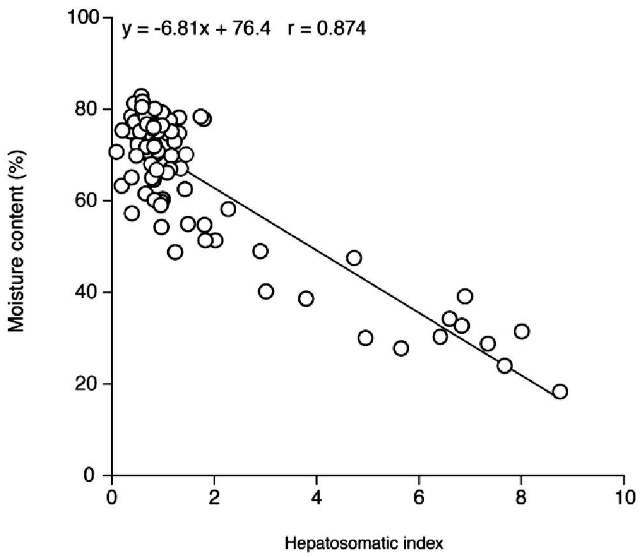

Fig. 3. Relationship between moisture content and hepatosomatic index (HSI) in the livers in of coral reef fishes collected at the Bidong Island in Malaysian South China Sea.

variations of the principal constituents in each species. Further studies are needed to understand the seasonal variations in HSI and moisture content in coral reef fish species. Nevertheless, such unique moisture contents found in *Scarus* spp. suggest this may be a species-specific characteristic.

The present study found that moisture content was highly variable among coral reef fish species. The results suggest that conversion factors must be estimated for each species. Although the present results on 17 of 21 species showed similar moisture contents, the species-specific moisture content might affect conversion of pollutant accumulation levels from dry to wet weight basis or vice versa. Human activities are of particular environmental concern with regard to maintaining healthy coral reefs and pollution sources such as commercial fishing, dumping of debris and litter, wastewater disposal, and mariculture. Among the main human activities that generate changes in reef environments stand out fishing, tourism, aquariophily and housing occupation (Ferreira *et al.* 2015). A number of biomonitoring studies using coral reef fishes to assess their environment have been conducted. However, most of these studies did not consider moisture content in fish specimens. Thus, it is recommended that studies on the pollutant levels in coral reef environment using coral reef fishes should account for moisture content which will provide more accurate comparisons between studies.

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References

AOAC (Association of Official Analytical Chemists) 1998. *Official Methods of Analysis of Official Analytical Chemists International.* Association of Official Analytical Chemists, Arlington.

Arai, T. 2015. Diversity and conservation of coral reef fishes in the Malaysian South China Sea. *Reviews in Fish Biology and Fisheries* **25:** 85-101

Burke L., E. Selig & M. Spalding. 2002. Reefs at risk in Southeast Asia. World Resources Institute, Washingtom, DC. 72 pp.

Chouvelon, T., M., Warnau, C. Churlaud & P. Bustamante. 2009. Hg concentrations and related risk assessment in coral reef crustaceans, molluscs and fish from New Caledonia. *Environmental Pollution* **157**: 331-340.

Ferreira, L. C., M. G. G. Silva-Cunha, E. P. Aquino, G. C. P. Borges, F. A. N. Feitosa, E. Eskinazi Leça & J. C. Lima. 2015. Temporal and spatial variation of phytoplankton in a tropical reef area of Brazil. *Tropical Ecology* **56:** 367-382.

Grandperrin, R. 1978. Importance of reefs to ocean production. *In:* Crossland. J., R. Grandperrin. (ed.) *South Pacific Commission* (Noumea, New Caledonia) *FishNewsletter* **15**: 11-13.

Hédouin, L., M. Metian & R. D. Gates. 2011. Ecotoxicological approach for assessing the contamination of a Hawaiian coral reef ecosystem (Honolua Bay, Maui) by metals and a metalloid. *Marine Environmental Research* **71**: 149-161.

Huss, S. S. 1995. Quality and Quality Changes in Fresh Fish. FAO Fisheries Technical Paper 348, FAO, Rome, Italy.

Lenhardt, M., I. Jaric, P. Cakic, G. Cvijanovi, Z. Gacic, & J. Kolarevic. 2009. Seasonal changes in condition, hepatosomatic index andparasitism in sterlet (*Acipenser ruthenus* L.) *Turkish Journal of Veterinary and Animal Sciences* **33**: 209-214.

Matsunuma, M., H. Motomura, K. Matsuura, N. A. M. Shazili, & M. A. Ambak. 2011. *Fishes of Terengganu East coast of Malay Peninsula, Malaysia.* National Museum of Nature and Science, Tokyo, Universiti Malaysia Terengganu, Terengganu, and Kagoshima University Museum, Kagoshima, 251 pp.

Metian, M., M. Warnau, T. Chouvelon, F. Pedraza, A. M. Rodriguezy Baena, & P. Bustamante. 2013. Trace element bioaccumulation in reef fish from New Caledonia: Influence of trophic groups and risk assessment for consumers. *Marine Environmental Research* **87-88**: 26-36

Murray, J. & J. R. Burt. 2001. *The Composition of Fish*. Torry Advisory Note No. 38, Ministry of Technology. Torry Research Station UK 14.

Pyle, G. G., J. W. Rajotte & P. Couture. 2005. Effects of industrial metalson wild fish populations along a metal contamination gradient. *Ecotoxicology and Environmental Safety* **61**: 287-312.

Randall, J. E. & K. K. P. Lim. 2000. A checklist of the fishes of the South China Sea. *The Raffles Bulletin of Zoology Supplement* **8**: 569-667.

Roff, G., M. H. Ledlie, J. C. Ortiz, P. J. Mumby. 2011. Spatial patterns of parrot fish corallivory in the Caribbean: the importance of coral taxa, density and size. *PLoS ONE* **6**: e29133.

Sanchez, J. A., M. F. Gil, L. H. Chasqui, & E. M. Alvarado. 2004.Grazing dynamics on a Caribbean reef-building coral. *Coral Reefs* **23**: 578-583.

Sokal, R. R., F. J. Rohlf. 1995. Biometry, 3rd ed. Freeman and Company, New York

UNEP 2004. *Coral Reefs in the South China Sea.* UNEP/GEF/SCS Technical Publication No. 2.

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