A REVIEW OF LENGTH-WEIGHT RELATIONSHIPS OF FRESHWATER FISHES IN MALAYSIA

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ABSTRACT

This manuscript reviews the length-weight relationships (LWRs) of freshwater fishes in Malaysia. A total of 102 LWRs of fishes gathered from literature pertaining to 64 freshwater fish species were analysed. A meta-analysis from 13 previous reports showed that the *b* values was ranged from 2.19 (*Clarias batrachus*) to 4.106 (*Barbodes binotatus*). Out of 64 observed species, 47 species (11 families) experienced positive allometric growth, while another 23 species (eight families) and 31 species (12 families) were recorded under isometric and negative allometric growth, respectively. The fish LWRs observed can be used as an indicator of environmental changes and fish ecological health for freshwater fishes in Malaysia.

ZUSAMMENFASSUNG: Eine Überprüfung der Länge-Gewicht Beziehungen von Süßwasserfischen in Malaysia.

Vorliegende Arbeit befasst sich mit der Überprüfung der Längengewichtsverhältnisse (LWRs) von Süßwasserfischen in Malaysia. Insgesamt wurden 102 LWRs von 64 Süßwasserfischarten anhand von Literaturangaben analysiert. Eine Metaanalyse aus 13 früheren Berichten zeigte, dass die b-Werte von 2,19 (*Clarias batrachus*) bis 4.106 (*Barbodes binotatus*) reichen. Von 64 beobachteten Arten zeigten 47 Arten (elf Familien) ein positives allometrisches Wachstum, während weitere 23 Arten (acht Familien) und 31 Arten (12 Familien) unter isometrischem und negativem allometrischem Wachstum aufgezeichnet wurden. Die beobachteten Fische LWRs können als Indikatoren für Umweltveränderungen und Bewertung der ökologischen Gesundheit von Süßwasserfischen in Malaysia verwendet werden.

REZUMAT: O revizuire a relaţiilor lungime-greutate a peştilor de apă dulce din Malaezia.

Acestă lucrare analizează dinamica în timp a relațiilor lungime-greutate (LWRs) la specii de pești de apă dulce din Malaezia. Au fost analizate un total de 102 LWRs selectate din literatura de specialitate, referitoare la 64 de specii de pești de apă dulce. O meta-analiză a datelor din 13 rapoarte anterioare a arătat că valorile b a variat între 2,19 (*Clarias batrachus*) și 4,106 (*Barbodes binotatus*). Din 64 de specii observate, 47 de specii (11 familii) au cunoscut o creștere alometrică pozitivă, în timp ce alte 23 de specii (opt familii) și 31 specii (12 familii) au fost înregistrate în creștere alometrică izometrice și negative, respectiv. LWRs observat a peștilor poate fi folosit ca un indicator al schimbărilor de mediu și de sănătate ecologică pentru pești de apă dulce din Malaezia.

INTRODUCTION

A total of 1,951 species of freshwater and marine fish belonging to 704 genera and 186 families have been recorded in Malaysia (Chonget al., 2010). In Peninsular Malaysia alone, about 278 native species were recorded by Lim and Tan (2002). The IUCN Red List of Threatened Species listed 1,275 fish species that are threatened from around the world and surprisingly, Malaysia hosts over 49 threatened fish species (Vié et al., 2008). At present, the indigenous species such as Jullien's golden carp (*Probarbus jullieni*), mahseer (*Tor tambroides*), Hoven's carp (*Leptobarbus hoeveni*), hampala barb (*Hampala macrolepidota*), climbing perch (*Anabas testudineus*), giant snakehead (*Channa micropeltes*), Asian arowana (*Scleropages formosus*), pangasiid catfishes (*Pangasius nasutus, Pangasigodon waandersii*), giant river catfish (*Wallago leerii*), catfish (*Clarias macrocephalus*) and giant gourami (*Osphronemus goramy*) have dwindled in great numbers continuously due to unsustainable fishing activities and could only be conserved probably in the inaccessible or remote areas of the country (Chew and Zulkafli, 2007). Moreover, freshwater ecosystems are demarcated due to the potential impacts of anthropogenic activities, giving them precedence for research, conservation, and sustainable management. Chong et al., (2010) reported that freshwater fishes recently encompassed the highest percentage of threatened fish species followed by estuarine among the aquatic systems. The diversity and distribution of freshwater fishes in Malaysia has been disrupted rapidly due to developmental pressure and modification of fish habitat. Future declines can therefore negatively affect freshwater biodiversity (Zakaria-Ismail, 1991; Bowen et al., 2003).

Length-weight analysis is a useful analysis in estimating average weight of fish caught from samples of lengths of fish caught (Hilborn and Walters, 2001; Adaka et al., 2015). The length-weight relationship (LWR) of fishes is important in fisheries and fish biology studies to provide information regarding growth patterns and the condition of fish species (Bagenal and Tesch, 1978). The study of LWRs is also important for the conservation and management of fishes in aquatic system, including freshwater system (Lawson, 2011), which are the most plausible area of efficacious pollutant sources due to the frequency, duration and magnitude of anthropogenic influences (Rahel, 2007; Francis, 2012).

Ricker (1975) has expressed the relationship between length (*L*) and weight (*W*) as $W = aL^b$. The constant value, *a*, has the ability to interpret body shape. For example, when the *a* value is 0.001, it shown that the fish is more eel-like, 0.008 more elongated, 0.013 more fusiform and 0.018 more short and deep (Froese, 2006). The value of *b* exponent depicts very important information of fish growth capability to predict the health of the fish. When *b* is equal to 3, the increase in weight is isometric which means the fish length and weight increases proportionally (Santos et al., 2002). If the value $b > 3$ (positive allometric), then there is a significant positive relationship between weight and fish length which indicates that weight will increase with increasing length, thus as the fish length increases the more rotund the fish will become; while when $b < 3$ (negative allometric), then the weight will decrease with increase of fish length, thus as fish length increase the less rotund the fish will become (Jones et al., 1999). Negative allometric growth pattern shows that there are possibilities of unsuitable environmental conditions which influence the condition to these species. Fish growth may be influenced by many biotic and abiotic factors such as phytoplankton abundance, predation, water temperature, and dissolve oxygen concentrations among others which may not favour the survival of all the species in the ecosystem (Atama et al., 2013).

Currently, researchers also use Bayesian length weight to compare between genera. Bayesian methods combine existing knowledge (prior probabilities) with additional knowledge derived from new data (the likelihood function) (Froese et al., 2014). This results in updated knowledge (posterior probabilities), which can be used as priors in subsequent analyses and thus provide learning chains in science (Kurikka et al., 2014). This method uses FishBase (www.fishbase.org) as an online tool that facilitates the analysis of existing parameters and of new weight-at-length data (Froese et al., 2014). In FishBase, the Bayesian approach has been also used in the analysis of LWRs for estimating LWR for species for which this information is not available by using over 5,000 LWR records for over 1,800 species (Froese et al., 2014). In this review, we gathered 102 LWRs from the literature compromising of 64 freshwater fish species from Malaysian inland waters in order to determine their robustness and condition.

MATERIAL AND METHODS

All fish LWRs presented here are collected data of field studies conducted during 2000-2015 in freshwaters environment of Malaysia, and are consistent with the format suitable for inclusion in FishBase. The sources of these LWRs are gathered from various journals and technical reports. The majority of the original LWRs stated in this study were presented in $W = aL^b$ equation form. But, there were several studies that provide *a* and *b* values only without the full equation. To standardize the review, the value was arranged in $W = aL^b$ equation form. All reported *a* and *b* values are analysed to obtain the descriptive statistical analysis (mean, minimum and maximum values). Ten fish species that have three or more LWRs were chosen to be compared with Bayesian LWRs obtained from FishBase (Froese and Pauly, 2016).

RESULTS AND DISCUSSION

A total of 102 LWRs were gathered from the literatures, referring to 64 species and belonging to 20 families of Malaysian fresh water fishes (Tab. 1). The value of the slope of regression, *b*, in the plot of log W against log L ranged from 2.190 for *Clarias batrachus* collected in Pahang, to 4.106 for *Barbodes binotatus* collected from Kerian River, Perak. The *a* value ranged from 0.0011 for *Barbodes binotatus*, collected from Kerian River, Perak, to 0.0933 for *Clarias batrachus* collected from Pahang.

In Malaysia, Cyprinidae is the family most often studied for these LWRs, constituting of 46%, followed by families of Clariidae and Pangasidae (6%), Ambassidae, Bagridae and Sisoridae (5%), Notoperidae and Clupeidae (3%) and only 2% each for Cobitidae, Eleotrididae, Elopidae, Latidae, Megalopidae, Mugilidae, Pristolepididae, Scatophagidae, Schilbeidae, Siluridae and Tetraodontidae. Geographically, 94 (92%) of the LWRs studies have been conducted in West Malaysia compared to East Malaysia, where only eight (8%) studies have been reported. In West Malaysia, 50% of LWR studies were conducted in the East Coast area (Pahang and Terengganu), while Northern states (Perak and Kedah) have contributed to 35% of the studies. The Southern and West Coast area of West Malaysia remain the lowest at about 5% and 2%, respectively.

Table 1: Length-weight relationships of 64 freshwater fishes in Malaysia.

Families	Species	Sampling area	N	*a*	*b*	References
Ambassidae	*Ambassis interrupta*	Lutong River, Sarawak	118	0.0131	2.98	Nyanti et al., 2012
	Ambassis kopsii	Lutong River, Sarawak	43	0.0152	2.94	Nyanti et al., 2012
	Ambassis urotaenia	Lutong River, Sarawak	8	0.0214	2.65	Nyanti et al., 2012
Aaridae	*Arius malculatus*	Pulai River, Johor	161	0.0295	2.62	Arshad et al., 2008
	Arius tenuispinis	Pulai River, Johor	70	0.0026	2.66	Arshad et al., 2008
	Plicofollis argyropleuron	Kuala Muda and Merbok, Kedah	539	0.0070	3.09	Nor Aziella and Mansor, 2012
Bagridae	*Batasio fluviatilis*	Pelus River, Kuala Kangsar	28	0.0323	2.44	Ikhwanuddin et al., 2016
	Hemibagrus nemurus	Pahang River, Temerloh	20	0.0068	3.07	Zulkafli et al., 2015
		Perak*	30	0.0052	3.15	Yusof et al., 2011
		Tembeling River, Pahang	47	0.0064	3.09	Zulkafli et al., 2016
	Pseudomystus siamensis	Negeri Sembilan	30	0.0060	3.20	Yusof et al., 2011
Clariidae	*Clarias batrachus*	Pahang*	30	0.0933	2.19	Yusof et al., 2011
	Clarias gariepinus	Selangor*	30	0.0138	2.76	Yusof et al., 2011
	Clarias leiacanthus	Pahang River, Maran	34	0.0192	2.75	Zulkafli et al., 2014
	Clarias macrocephalus	Pahang*	30	0.0151	2.79	Yusof et al., 2011
Clupeidae	*Anodontostoma chacunda*	Pulai River, Johor	133	0.0118	3.09	Arshad et al., 2008
	Hilsa kelee	Pulai River, Johor	499	0.0448	2.54	Arshad et al., 2008
Cobitidae	*Acantopsis dialuzona*	Kerian River basin, Perak	56	0.0190	2.43	Mohd-Shafiq et al., 2012
Cyprinidae	*Amblyrhynchichthys truncatus*	Pahang River, Maran	175	0.0047	3.31	Zulkafli et al., 2014
		Pahang River, Temerloh	14	0.0084	3.08	Zulkafli et al., 2015
	Anematichthys repasson	Tembeling River, Pahang	10	0.0063	3.19	Zulkafli et al., 2016
	Barbichthys laevis	Pahang River, Maran	98	0.0124	2.90	Zulkafli et al., 2014
		Tembeling River, Pahang	60	0.0059	3.13	Zulkafli et al., 2016

Table 1 (continued): Length-weight relationships of 64 freshwater fishes in Malaysia.

Families	Species	Sampling area	N	a	b	References
Cyprinidae	*Barbodes binotatus*	Kerian River, Perak	76	0.0011	4.11	Isa et al., 2010
		Langkawi Island, Perak	49	0.0130	2.99	Samat et al., 2012
		Kerian River basin, Perak	92	0.0500	3.81	Mohd-Shafiq et al., 2012
		Pelus River, Kuala Kangsar	16	0.0062	3.30	Ikhwanuddin et al., 2016
	Barbonymus gonionotus	Pedu Lake, Kedah	32	0.0058	3.23	Isa et al., 2010
	Barbonymus schwanenfeldii	Pedu Lake, Kedah	246	0.0168	2.86	Isa et al., 2010
		Pahang River, Maran	145	0.0112	3.08	Zulkafli et al., 2014
		Tembeling River, Pahang	124	0.0162	2.93	Zulkafli et al., 2016
		Pahang River, Temerloh	88	0.0141	3.00	Zulkafli et al., 2015
	Chela sp.	Pedu Lake, Kedah	88	0.0158	2.67	Isa et al., 2010
	Cirrhinus caudimaculatus	Tembeling River, Pahang	152	0.0067	3.08	Zulkafli et al., 2016
	Crossocheilus atrilimes	Pelus River, Kuala Kangsar	36	0.0062	3.09	Ikhwanuddin et al., 2016
	Cyclocheilichthys apogon	Kerian River, Perak	46	0.0033	3.51	Isa et al., 2010
		Kerian River basin, Perak	56	0.0020	3.63	Mohd-Shafiq et al., 2012
		Temengor Reservoir, Perak	233	0.0080	3.16	Muzzalifah et al., 2015
	Cyclocheilichthys apogon	Pahang River, Maran	203	0.0071	3.22	Zulkafli et al., 2014
		Tembeling River, Pahang	215	0.0072	3.15	Zulkafli et al., 2016
		Pahang River, Temerloh	48	0.0095	3.05	Zulkafli et al., 2015
	Devario regina	Pelus River, Kuala Kangsar	58	0.0132	2.82	Ikhwanuddin et al., 2016
		Kerian River, Perak	112	0.0057	3.3	Isa et al., 2010
		Langkawi Island, Perak	52	0.0080	3.06	Samat et al., 2012
		Kerian River basin, Perak	124	0.0130	3.25	Mohd-Shafiq et al., 2012
	Hampala macrolepidota	Kenyir Lake, Terengganu	2057	0.0148	2.88	Zakaria et al., 2000
		Temengor Reservoir, Perak	207	0.0100	3.02	Muzzalifah et al., 2015
		Tembeling River, Pahang	23	0.0105	2.99	Zulkafli et al., 2016

Table 1 (continued): Length-weight relationships of 64 freshwater fishes in Malaysia.

Families	Species	Sampling area	N	*a*	*b*	References
Cyprinidae	*Hypsibarbus pierrei*	Pahang River, Maran	60	0.0115	3.03	Zulkafli et al., 2014
	Hypsibarbus wetmorei	Pahang River, Maran	231	0.0079	3.15	Zulkafli et al., 2014
		Tembeling River, Pahang	19	0.0118	3.01	Zulkafli et al., 2016
		Pahang River, Temerloh	49	0.0094	3.11	Zulkafli et al., 2015
	Labiobarbus festivus	Pahang River, Temerloh	56	0.00892	3.00	Zulkafli et al., 2015
		Tembeling River, Pahang	103	0.0072	3.07	Zulkafli et al., 2016
	Labiobarbus leptocheilus	Kerian River basin, Perak	104	0.0280	2.86	Mohd-Shafiq et al., 2012
		Temengor Reservoir, Perak	73	0.0150	2.85	Muzzalifah et al., 2015
	Labiobarbus lineatus	Kerian River, Perak	58	0.0095	2.99	Isa et al., 2010
	Luciosoma setigerum	Pahang River, Temerloh	9	0.0088	2.86	Zulkafli et al., 2015
	Mystacoleucus marginatus	Tembeling River, Pahang	32	0.0074	3.17	Zulkafli et al., 2016
	Mystacoleucus obtusirostris	Pedu Lake, Kedah	65	0.0230	2.70	Isa et al., 2010
		Pahang River, Maran	31	0.0137	2.94	Zulkafli et al., 2014
		Temengor Reservoir, Perak	83	0.0070	3.15	Muzzalifah et al., 2015
	Neolissochilus hexagonolepis	Pelus River, Kuala Kangsar	128	0.0099	3.04	Ikhwanuddin et al., 2016
	Osteochilus microcephalus	Pedu Lake, Kedah	35	0.0075	3.05	Isa et al., 2010
	Osteochilus vittatus	Temengor Reservoir, Perak	357	0.0100	3.04	Muzzalifah et al., 2015
		Pahang River, Maran	89	0.0093	3.12	Zulkafli et al., 2014
		Tembeling River, Pahang	10	0.0168	2.85	Zulkafli et al., 2016
		Pahang River, Temerloh	19	0.0137	2.93	Zulkafli et al., 2015
	Osteochilus waandersii	Pahang River, Temerloh	24	0.0075	3.12	Zulkafli et al., 2015
	Oxygaster anomalura	Temengor Reservoir, Perak	171	0.0200	2.60	Muzzalifah et al., 2015
	Puntioplites bulu	Pahang River, Maran	43	0.0108	3.04	Zulkafli et al., 2014
		Tembeling River, Pahang	18	0.0119	3.01	Zulkafli et al., 2016
	Puntioplites proctozysron	Tembeling River, Pahang	241	0.0087	3.15	Zulkafli et al., 2016
	Probarbus jullieni	Pahang River, Maran	89	0.0080	3.09	Zulkafli et al., 2014

Table 1 (continued): Length-weight relationships of 64 freshwater fishes in Malaysia.

Families	Species	Sampling area	N	*a*	*b*	References
Cyprinidae	*Rasbora sumatrana*	Kerian River, Perak	77	0.0025	3.61	Isa et al., 2010
		Kerian River basin, Perak	92	0.0110	3.30	Mohd-Shafiq et al., 2012
	Thynnichthys thynnoides	Pahang River, Temerloh	43	0.0114	2.92	Zulkafli et al., 2015
		Pahang River, Maran	52	0.0063	3.13	Zulkafli et al., 2014
Eleotrididae	*Oxyeleotris marmorata*	Pahang River, Maran	30	0.0049	3.28	Zulkafli et al., 2014
Latidae	*Lates calcarifer*	Lutong River, Sarawak	10	0.0144	3.02	Nyanti et al., 2012
Mugilidae	*Liza melinoptera*	Lutong River, Sarawak	8	0.0149	2.95	Nyanti et al., 2012
Megalopidae	*Megalops cyprinoides*	Lutong River, Sarawak	24	0.0173	2.79	Nyanti et al., 2012
Notopteridae	*Chitala Lopis*	Pahang River, Maran	33	0.0173	2.69	Zulkafli et al., 2014
	Notopterus Notopterus	Pedu Lake, Kedah	120	0.0036	3.25	Isa et al., 2010
Pangasidae	*Pangasianodon hypophthalmus*	Pahang River, Maran	24	0.0227	2.75	Zulkafli et al., 2014
	Pangasius pangasius	Perak*	30	0.0290	2.72	Yusof et al., 2011
	Pangasius nasutus	Selangor*	30	0.0479	2.57	Yusof et al., 2011
		Pahang River, Maran	24	0.0045	3.16	Zulkafli et al., 2014
	Pseudolais micronemus	Pahang River, Maran	46	0.0069	3.02	Zulkafli et al., 2014
		Pahang River, Temerloh	33	0.0071	3.00	Zulkafli et al., 2015
		Tembeling River, Pahang	143	0.0105	2.88	Zulkafli et al., 2016
Pristole pididae	*Pristolepis fasciata*	Temengor Reservoir, Perak	31	0.0180	3.07	Yusof et al., 2011
		Pahang River, Maran	43	0.0160	3.12	Zulkafli et al., 2014

Table 1 (continued): Length-weight relationships of 64 freshwater fishes in Malaysia; note: * denotes no specific area reported by authors.

Families	Species	Sampling area	N	*a*	*b*	References
Pristolepididae	*Pristolepis fasciata*	Temengor Reservoir, Perak	31	0.0180	3.07	Yusof et al., 2011
		Pahang River, Maran	43	0.0160	3.12	Zulkafli et al., 2014
Scatophagidae	*Scatophagus argus*	Lutong River, Sarawak	16	0.0359	3.03	Nyanti et al., 2012
Schilbeidae	*Laides hexanema*	Pahang River, Temerloh	17	0.0070	3.09	Zulkafli et al., 2015
		Pahang River, Maran	120	0.0043	3.24	Zulkafli et al., 2014
Siluridae	*Phalacronotus apogon*	Pahang River, Maran	49	0.0258	2.43	Zulkafli et al., 2014
		Tembeling River, Pahang	25	0.0049	3.08	Zulkafli et al., 2016
Sisoridae	*Bagarius yarrelli*	Pahang River, Temerloh	14	0.0146	2.72	Zulkafli et al., 2015
	Glyptothorax major	Pelus River, Kuala Kangsar	62	0.0074	3.15	Ikhwanuddin et al., 2016
	Glyptothorax siamensis	Pelus River, Kuala Kangsar	23	0.0089	2.98	Ikhwanuddin et al., 2016
Tetraodontidae	*Arothron reticularis*	Lutong River, Sarawak	9	0.0359	2.95	Nyanti et al., 2012

From a total of 13 conducted previous studies, it can be listed that 32 fish species from 47 LWR studies experienced positive allometric growth, where 20 fish species from 23 LWR studies experienced isometric growth and 28 fish species from 31 LWR studies experienced negative allometric growth (Fig. 1). However, there were also different types of growth suggested by researchers for the same species. For instance, the growth pattern of *Barbodes binotatus* was isometric in Langkawi Island as reported by Samat et al. (2012), but Isa et al. (2010) and Mohd-Shafiq et al. (2010) recorded positive allometric growth for this species. These observations were also identified for 12 more species, such as *Barbonymus schwanenfeldii*, *Barbichthys laevis*, *Labiobarbus festivus*, *Thynnichthys thynnoides*, *Devario regina*, *Hypsibarbus wetmorei*, *Pseudolais micronemus*, *Hampala macrolepidota*, *Mystacoleucus obtusirostris*, *Osteochilus vittatus*, *Phalacronotus apogon* and *Pangasius nasutus.* These findings might be due to different habitat conditions in terms of variations of food supply which influences the habitual preferences of the fish, fish activities, and feeding habits of fish species (Mizuno and Furtado, 1982; Lowe-McConnell, 1987).

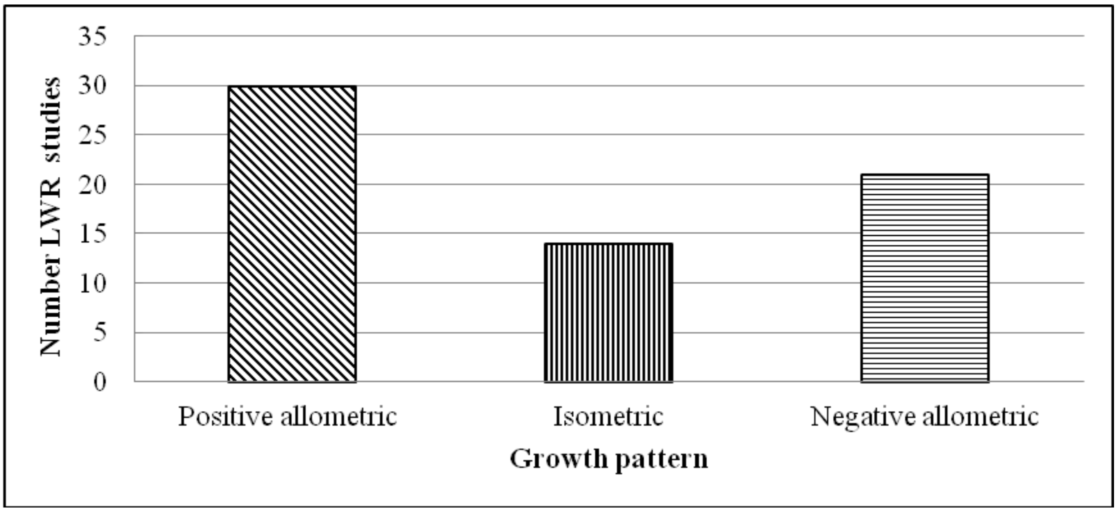

Figure 1: Growth patterns of 64 freshwater fishes
from 102 length-weight relationships studies in Malaysia.

The mean for *a* value from 64 LWRs was 0.0136, and ranging from 0.0011 for *Barbodes binotatus* collected in Kerian River, Perak, to 0.0933 for *Clarias batrachus* collected in Pahang. By referring to Froese and Pauly (2015), body type of all 64 species were determined (Tab. 2). From 64 species, there were 11 (17%) species that have elongated body type, 30 (47%) have fusiform body type and the other 22 (36%) species showed short and deep body type (Fig. 2). In term of the fish families, there were 15 families that exhibit short and deep body type, eight have fusiform and only six have elongated body type. There were three families (Aaridae, Cyprinidae and Sisoridae) that have multiple body types for different species of fishes. Eel-like body type is absent from the result because there was no *a* value that fit in the category (Tab. 2). It is important to note that fusiform is the most general body type and ideal for free swimming species (Khanna, 2004), compared to other body types. Helfman et al. (2009) stated that body type is one of the factors that help fish swim faster, thus determining their feeding habits and desired habitat.

The mean of *b* value for 64 LWR studies of 49 freshwater fishes in Malaysia was 3.0139, which indicated that their growth is still in the normal range for freshwater fish. Froese (2006) has confirmed that expected range of *b* is $2.5 < b < 3.5$. From the results, it is also necessary to study more about negative allometric growth (20 species), whether they are genuinely affected by environmental condition or statistical inaccuracy due to inadequate LWR data collection. However, according to Copp et al. (2013), the isometric body growth of *Barbatula barbatula* changes to allometric type when it reaches a certain standard length in order to become an adult. This indicates that body growth type sometimes changes accordingly to their physiology needs.

Low catch of fish species may be contributed by the unsuitable fishing gear used or inadequate and unfit timing. The number of sample size also affects the quality of the relationships. Only $n > 10$ should be accepted because Central Limit Theorem has been used. Also note that sampling distribution of the sample mean will approximately become normal as the sample size increases. Thus, the value of n below 10 will not provide a good approximation to the probability of interest (Kenneth, 2007). It is important to note that there are 14 LWRs that have regression value below than 0.9 ($R^2 < 0.9$). For example, *Ambassis urotaenia* have very small sample size ($n = 8$), which could have answered its low regression value ($R^2 = 0.850$) and considered statistically low for LWR study. In contrast, even a total of 70 individuals of *Arius tenuispinis* have been recorded, but the R^2 value is only recorded at 0.850. The condition is same with *Chela* sp., *Devario regina*, *Mystacoleucus obstusirostris*, *Osteochilus microchepalus*, *Lates calcarifer*, *Megalops cyprinoides*, *Rasbora sumatrana*, *Pangasius pangasius* and *Pangasius nasutus.* Moreover, even though sample size for *Luciosoma setigerum*, *Liza melinoptera* and *Arothron reticularis* are low ($n < 10$), the R^2 value is significantly strong. Kelley and Preacher (2012) stated that these observation sometimes due to a small sized sample is sometimes considered enough for certain fish species. Besides that, possibilities of human error (data collection, recording or entry) and inconsideration of outliers in the LWR calculation (Osborne et al., 2004) also makes the R^2 value lower, resulting in less confidence in the information.

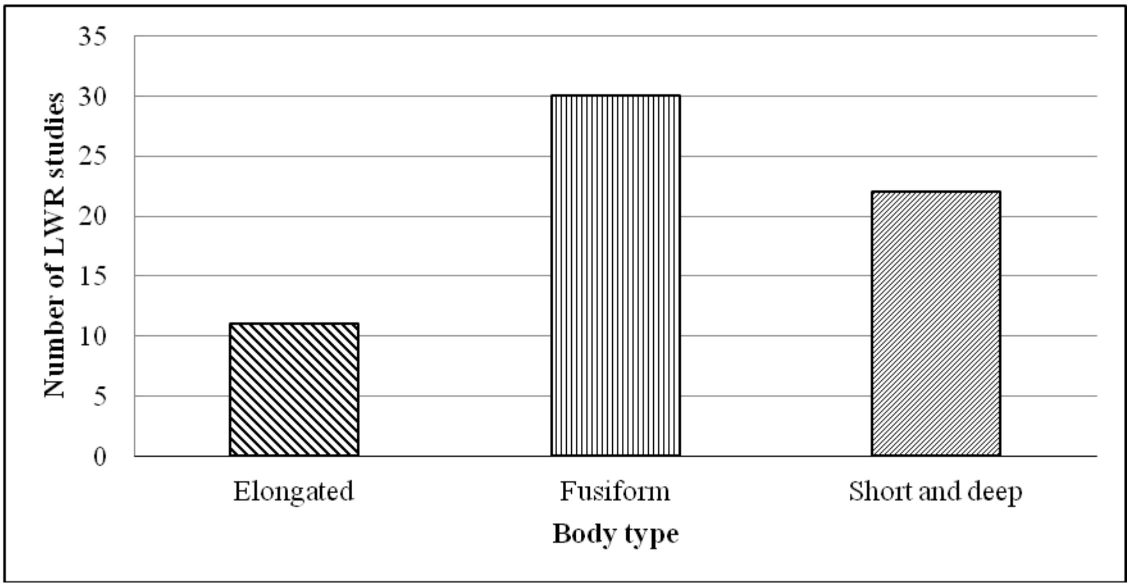

Figure 2: Body type of 64 freshwater fishes
from 102 length-weight relationships studies in Malaysia.

Table 2: Estimation of body shape mean by following Bayesian length-weight relationship (Froese and Pauly, 2015).

Body shape	Prior for *b* (mean ± SD)	Prior of log10(*a*) (mean ± SD)
Eel-like	3.06 ± 0.0896	– 2.99 ± 0.175
Elongated	3.12 ± 0.09	– 2.41 ± 0.171
Fusiform	3.04 ± 0.0857	– 1.95 ± 0.173
Short and deep	3.01 ± 0.0905	– 1.7 ± 0.175

Ten fish species that have three or more LWRs were chosen for comparison with FishBase Bayesian database in order to analyse the similarity of *a* and *b* value average and range between both methods. Only four species, namely *Hemibagrus nemurus*, *Hampala macropleidata*, *Mystacoleucus obstusirostris*, and *Osteochilus vittatus*, were available in the FishBase database. From the four species, only *Hemibagrus nemurus* observed within the Bayesian LWR range (Tab. 3). This condition may be related to lack of data of those species to calculate the range more accurately. Bayesian LWR needs a significant number of baseline data to create a meaningful mean of 95% High Density Interval of *a* and *b* values (Froese et al., 2014). Unfortunately, Cole-Fletcher et al. (2011) have observed some flaw on FishBase's LWR database where studied species minimum and maximum curves produced with the length-weight parameters at FishBase.org are notably different from each other, and in many cases predict weights that are clearly absurd. Hence, to utilize FishBase database, a few statistical tests and corrections need to be conducted to ensure the accuracy of data presentation.

Table 3: Comparison of a and b values range between normal and Bayesian length-weight relationship of four selected species.

Species	*a* value LWR range	95% of HDI of *a* value	*b* value LWR range	95% of HDI of *b* value	In range?
Hemibagrus nemurus	0.0052-0.00677	0.00379-0.00978	3.07-3.151	2.99-3.26	Yes
Hampala macropleidata	0.0100-0.148	0.00907-0.0235	2.884-3.019	2.92-3.18	No
Mystacoleucus obstusirostris	0.0070-0.0230	0.00608-0.0214	2.704-3.147	2.85-3.15	No
Osteochilus vittatus	0.0093-0.0168	0.0075-0.0227	2.85-3.120	2.97-3.24	No

CONCLUSIONS

The majority of freshwater fishes in Malaysia have fusiform body type based on mean value of *a*. The mean of *b* value for 64 LWRs studies for 49 freshwater fishes in Malaysia was 3.0139. It showed that their growth is still in the normal range for freshwater fish. Thus, it can be concluded that growth pattern for freshwater fish in Malaysia can be considered good even though some changes in *b* value within these fish species were identified. The fish LWRs observed can be used as an indicator of environmental changes and fish ecological health for freshwater fishes in Malaysia.

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