INAUGURAL LECTURE series

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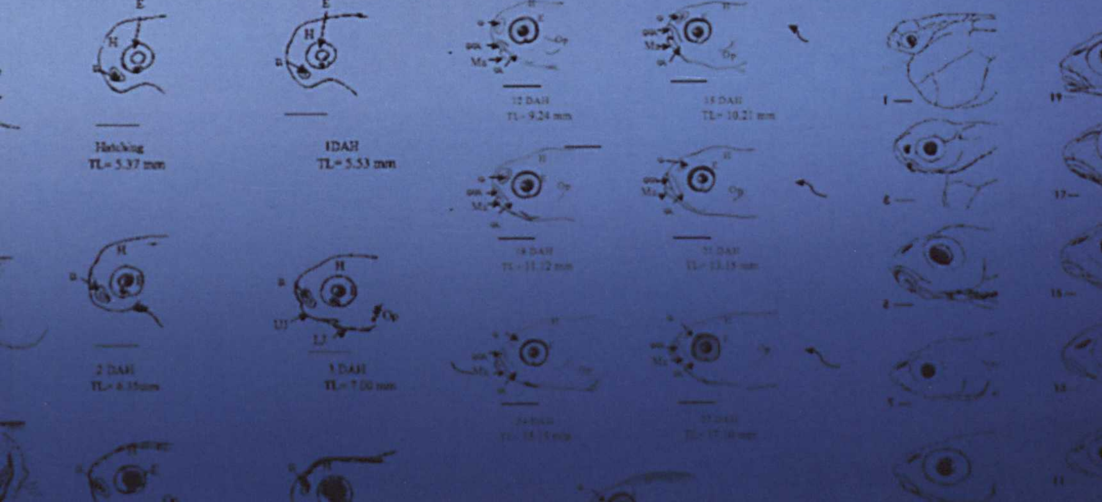
Feeding & Nutritional Requirements of YOUNG FISH



Feeding & Nutritional Requirements of YOUNG FISH

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Feeding & Nutritional Requirements of YOUNG FISH

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10 April 2015

Dewan Pertanian
Fakulti Pertanian
Universiti Putra Malaysia

Universiti Putra Malaysia Press
Serdang • 2015
http://www.penerbit.upm.edu.my

First Print 2015

UPM Press is a member of the Malaysian Book Publishers Association (MABOPA)
Membership No.: 9802

Typesetting : Sahariah Abdol Rahim @ Ibrahim
Cover Design : Md Fairus Ahmad

Design, layout and printed by
Penerbit Universiti Putra Malaysia
43400 UPM Serdang
Selangor Darul Ehsan
Tel: 03-8946 8855 / 8854
Fax: 03-8941 6172
http://www.penerbit.upm.edu.my

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ABSTRACT

The world annual total fisheries catch continues to decline, a trend observed since 1996. If timely remedial actions are not taken, scientists believe that the ocean seafood stocks and supply will soon be depleted. Aquaculture seems to be the only realistic solution to reduce the pressure on capture fisheries and to supply most of the seafood in the future. Currently, almost half of the world's total fisheries production is contributed by the aquaculture industry.

On average, a Malaysian consumes almost 60 kg of seafood per year. Malaysia is tied with Korea for 7th place among the top world seafood consumers. Although Malaysia has achieved ≥ 100% self sufficiency level (SSL) in seafood supply, more than 80% of its seafood comes from capture fisheries. Meanwhile, Malaysia's aquaculture industry has been experiencing an average annual growth rate of 23.4% over the last ten years, although most of the growth has been contributed by seaweed production rather than food fish. Thus, in terms of ensuring its food security, Malaysia must increase its cultured food fish production to meet at least 50% of its seafood SSL.

The main bottleneck in the expansion and growth of food fish aquaculture in Malaysia is the insufficient seed or fry supply. Despite breakthroughs in the induced breeding of many fish species, use of the right feed remains a major obstacle during the larviculture stage as larval feeding behavior, mouth gape, digestive capacity and nutrient requirements vary with species, growth stage or age. For successful larval and postlarval rearing, each fish species must be given a specific diet comprising the right particle size and nutrients at the correct feeding ration and frequency at each growth stage.

INTRODUCTION

Capture Fisheries

Lao Tzu is believed to be the one who said "Give a man a fish and you feed him for a day; teach a man how to fish and you feed him for a lifetime." Man quickly came to realise that he could earn a living from fishing and later that fishing is a good business. Fishing can generate great wealth although it is a well known fact that the majority of small-scale fishermen and their families living in developing countries, particularly in Asia and Africa, are relatively poor due to poor infrastructure and the extreme profiteering and economic manipulation by middlemen.

In 1950, the world total fisheries catch was about 19.2 million tons (FAO, 2015d). With the availability of better and larger vessels, gear and technology, the catch tripled by 1970 and rose to around 90+ million tons by 1994 (Table 1). Fishing activities are more intense in the marine section as compared to inland. Man has become greedy over time and overexploitation or overfishing has thus become rampant. Since 1996, the world total catch has shown a declining trend at an average of 0.2% y^{-1} or 70,718 tons y^{-1} (0.5% y^{-1} for marine fisheries). Further, Smith *et al.* (2010) has stated that total fisheries catch is unlikely to increase in the future.

The first massive fisheries stock collapse due to overfishing was reported in the Americas in 1972 (Figure 1), specifically in the Peruvian anchovy fishery (FAO, 2015d). The catch in the Americas seemed to recover in early 1974 and steadily increased for nearly two decades, not due to the recovery of anchovy stock but due to the increase in catch of other fish species.

Table 1 Global fisheries catch (tons) in 10 years intervals (FAO, 2015d)

Fisheries	Continent	1950	1960	1970	1980	1990	2000	2010	2011	2012
Marine	Asia	5,491,451	11,704,857	18,577,609	24,753,081	32,476,338	38,496,600	41,372,044	41,777,233	42,656,028
	Americas	4,041,225	8,127,913	19,405,518	14,413,800	23,149,158	25,524,243	17,408,811	22,485,179	18,352,397
	Europe	5,729,168	7,612,164	11,606,116	12,018,136	19,441,040	16,137,774	13,706,033	13,184,261	12,974,667
	Africa	803,613	1,689,713	2,666,702	2,397,360	3,243,636	4,678,010	5,093,115	4,915,085	5,558,198
	Oceania	76,530	135,529	210,963	420,004	744,638	1,082,741	1,196,054	1,155,531	1,248,724
	Others	1,173,794	2,404,213	6,766,210	9,158,415	512,284	240,864	19,214	19,566	37,360
Inland	Asia	813,411	1,488,246	2,378,313	2,550,668	3,452,905	5,452,677	7,671,780	7,405,202	7,953,550
	Americas	191,328	238,738	276,720	438,129	523,992	551,568	563,241	556,162	575,558
	Europe	76,545	113,625	119,702	193,424	583,828	429,541	384,850	373,975	377,746
	Africa	325,787	580,605	1,076,190	1,271,489	1,860,651	2,134,034	2,603,272	2,703,654	2,705,519
	Oceania	500	700	1,100	10,381	22,326	20,714	16,934	17,832	18,307
	Others	521,430	662,240	778,100	640,970	0	0	0	0	0
GRAND TOTAL		19,244,782	34,758,543	63,863,243	68,265,857	86,010,796	94,748,766	90,035,349	94,593,680	92,458,054

The Peruvian anchovy catch remained low for two decades (Figure 2). The lowest catch (22,988 tons) was seen in 1984, which was less than 0.2% of the maximum catch (12,277,000 tons) in 1970. The anchovy stock showed signs of recovery in 1992 and showed good increase for just two years before the onset of another declining trend prompting a sharp cut in catch in 1998. The move appeared to have work temporarily but the catch gradually decreased from 2000. The Peruvian anchovy fisheries seemed to influence the Americas total fisheries catch again from 1989, indicating that the other fish stocks were also experiencing overfishing or had reached maximum catch levels. Worm et al. (2009) estimated that 14% of assessed fisheries collapsed in 2007, including some fish stocks in the Bering Sea, Eastern Canada and the Northeast US Shelf.

In Europe, the fisheries catch started to decline after 1989 (Figure 1). In contrast, the catch kept increasing in Asia from 5.5 million tons in 1950 to 38.0 million tons in 1996 when the catch started to level off until 2005. Looking at this trend, it is felt that it is possible that fishery collapse may also happen in Asia if the overexploitation of fishing continues.

In general, inland fisheries contribute less than 13% of total fisheries catch (FAO, 2015d). In Asia and Africa, the inland fisheries continue to grow without any sign of slowing down, particularly in Asia. In contrast, the combined fisheries catch in Europe and Soviet blocs continue to show a decline which has been observed since 1971, while the fisheries in the American continent reached an almost constant level by 1988.

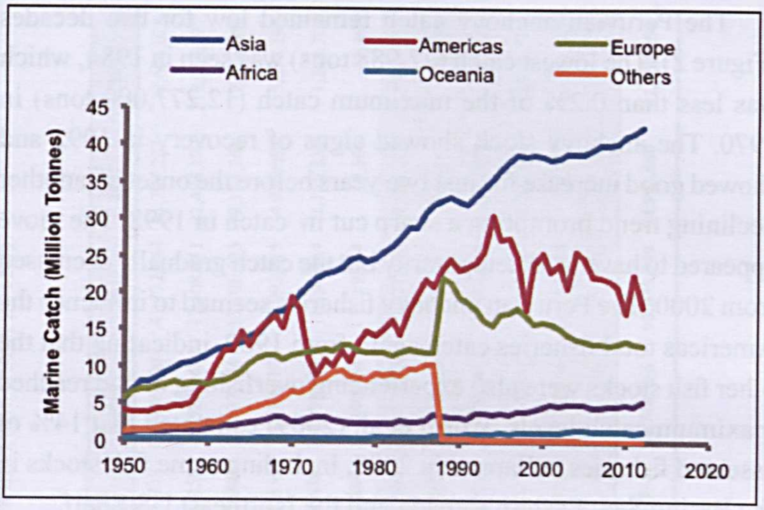


Figure 1 Total marine fisheries catch by continent (FAO, 2015d)

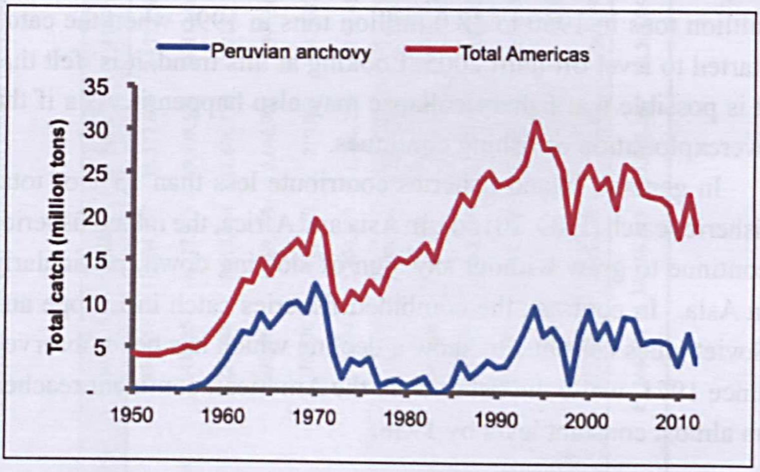


Figure 2 Trends in the Peruvian anchovy catch and total Americas fisheries catch (FAO, 2015d)

Other than overfishing, due to the development of better catching and finding gears, the decline in fisheries stock and catch are also caused by many other factors. Among them are:

a. Poor fisheries stock management and enforcement

b. Use of destructive fishing methods such as demersal trawling and fish bombing which destroy fish habitats and breeding grounds; illegal mesh size, which not only catch the intended targets but also catch unwanted young fish, etc.

c. Decline in water quality (Worm *et al.*, 2006) due to pollution (sea and land) and global warming

d. Harmful algal blooms

e. Fish kills as collateral damage

f. Coastal flooding

g. Coastal development and reclamation

h. Poor management of mangrove logging

i. Sand mining

Worm et al. (2006) shocked the world when their research group predicted that seafood from the ocean will be gone by 2048. Environmentalists and NGOs lauded their findings while the newspapers had a field day. While agreeing that the present data pointed to the imminent depletion of fisheries stock, some researchers questioned the methodology used by Worm and his colleagues and the accuracy of their conclusions. Jaenike (2007) meanwhile suggests that the predicted depletion would occur much later, around the year 2114 rather than by 2048.

Aquaculture

While agriculture began some 12,000 years ago, aquaculture is believed to have started much later, around 2000 BC. The total world aquaculture production rose from a mere 0.6 million tons in 1950 to 7.3 million tons in 1980, i.e. 3.2% and 9.7% of total fisheries production, respectively (FAO, 2015b). Since 1980, the aquaculture industry has developed at a rapid rate doubling its total production every decade. Aquaculture now contributes about half (49.4% in 2012) of the total fisheries production. The strong growth and contribution indicate that aquaculture will play a key dominant role in providing the future seafood supply of the world.

China leads the world aquaculture industry, contributing about 60% or more of the total global production. Further, Indonesia has recently become a fast emerging force in the industry, edging out the long-time former no. 2 India (Figure 3) since 2009.

The scenario of the aquaculture industry in ASEAN countries in the last decade has been very interesting. With the exception of Thailand, the aquaculture production in the ASEAN countries has generally shown increasing trends (Figure 4). The total aquaculture production of ASEAN countries in 2012 was 18.4 million tons ((FAO, 2015b). Indonesia became the leading ASEAN aquaculture producer in 2005, where prior to that, the Philippines had been the top ASEAN producer for decades. Since taking the lead, the aquaculture industry in Indonesia has experienced rapid expansion mainly through its seaweed production and it eventually overtook India as the world's second leading aquaculture nation. Vietnam is also making impressive progress, from being the 4th largest Asean producer in 2004 to the 2nd largest producer in 2008. Meanwhile, although its total production has increased, Malaysia has dropped in ranking to become the 6th largest producer in Asean, behind Thailand (4th) and Myanmar (5th).

Table 2 Global aquaculture production (tons) at every 10 years (FAO, 2015b)

Environment	Continent	1950	1960	1970	1980	1990	2000	2010	2011	2012
Marine	Asia	170,458	853,223	1,744,637	4,340,766	7,924,306	20,299,108	37,177,560	39,465,022	43,583,761
	Americas	59,593	100,443	135,179	107,266	286,283	848,167	1,612,744	1,859,445	2,014,888
	Europe	144,860	209,397	363,322	532,928	901,417	1,601,910	2,066,360	2,229,456	2,422,158
	Africa	700	2,450	3,278	11,292	45,369	364,000	917,299	976,088	1,059,625
	Oceania	4,000	8,500	8,421	11,571	51,635	134,870	197,140	204,389	204,535
	Others	100	950	1,400	520	0	0	0	0	0
Freshwater	Asia	173,932	721,657	1,012,437	1,850,869	6,573,433	17,321,470	34,163,533	36,879,234	38,917,512
	Americas	5,030	7,133	38,314	93,039	300,318	608,843	978,552	1,096,803	1,177,452
	Europe	24,241	67,211	134,576	225,850	710,501	454,819	466,614	451,540	461,095
	Africa	1,693	4,535	6,993	14,910	44,726	87,318	508,447	563,819	586,770
	Oceania	0	0	0	653	1,780	3,807	3,660	3,519	4,309
	Others	53,970	53,760	77,400	157,385	0	0	0	0	0
GRAND TOTAL		**638,577**	**2,029,259**	**3,525,957**	**7,347,049**	**16,839,768**	**41,724,312**	**78,091,908**	**83,729,313**	**90,432,105**

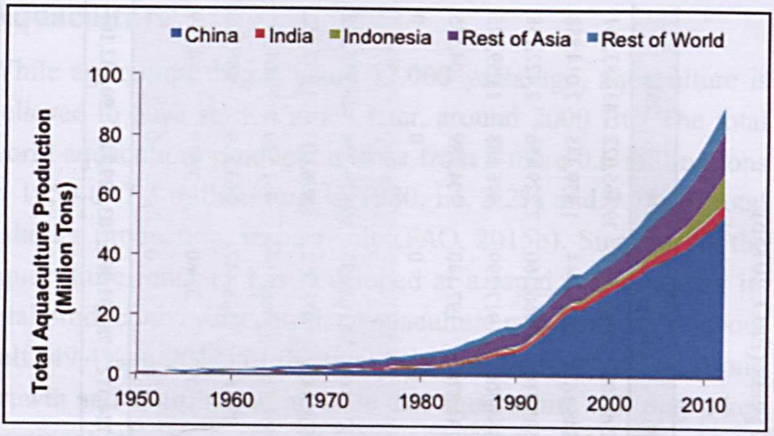


Figure 3 The aquaculture production of China and the rest of the world (FAO, 2015b)

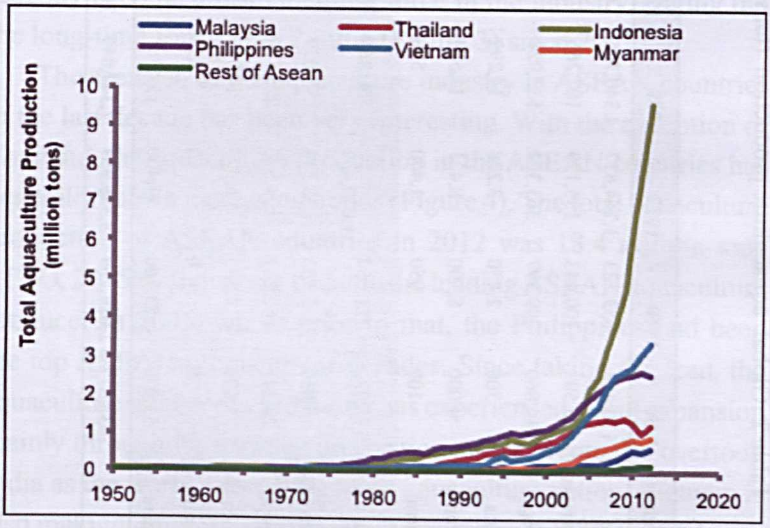


Figure 4 Total aquaculture production in ASEAN countries (FAO, 2015b)

AQUACULTURE IN MALAYSIA

The growth of the aquaculture industry in Malaysia (Figure 5) from 1950 to 2013 had its ups and downs but generally showed an overall increasing trend (DOF, 2014; FAO, 2015b). Rapid growth averaging at 23.4% y^{-1} was achieved in the last decade, mainly due to its seaweed culture. Marine aquaculture contributes about 68-77% of the total seafood production in the country. The highest annual production was achieved in 2012 with 615,270 metric tons, valued at USD 896.7 million. The total production dropped by 13.8% to 530,205 metric tons in 2013 (DOF, 2014) due to the drop in production of seaweed, whiteleg shrimp, tilapia, pangasid catfish and bighead carp. The production of whiteleg shrimp has continuously dropped since 2010 due to early mortality syndrome (EMS) outbreaks. The recent big floods in certain areas in Peninsular Malaysia could further affect aquaculture production for 2014-2015.

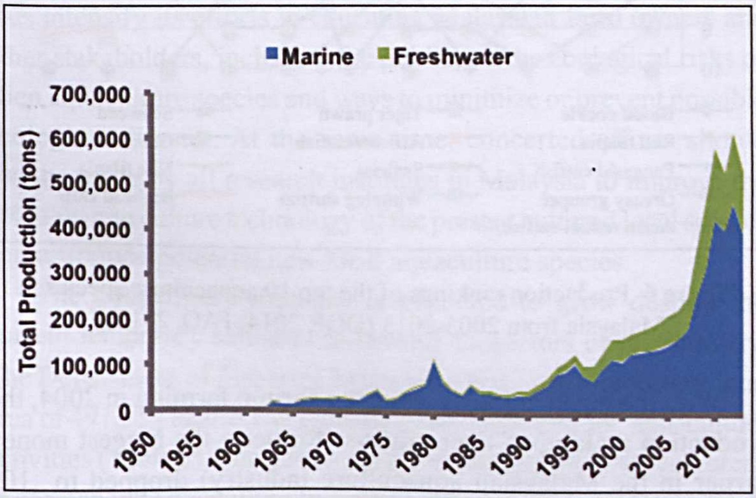


Figure 5 Aquaculture Production in Malaysia for the period 1950-2013 (DOF, 2014; FAO, 2015b)

The changes in the top 10 species produced over the last 10 years are also interesting (Figure 6). Cockle which is still being cultured extensively through sea ranching (bottom culture), was the Malaysian top aquaculture product for more than half a century until 2006. Unfortunately local research into improving its culture methods, genetics and growth has been almost nonexistent. Since seaweed became the leading aquaculture product, cockle production has dropped to fourth position in 2012-13.

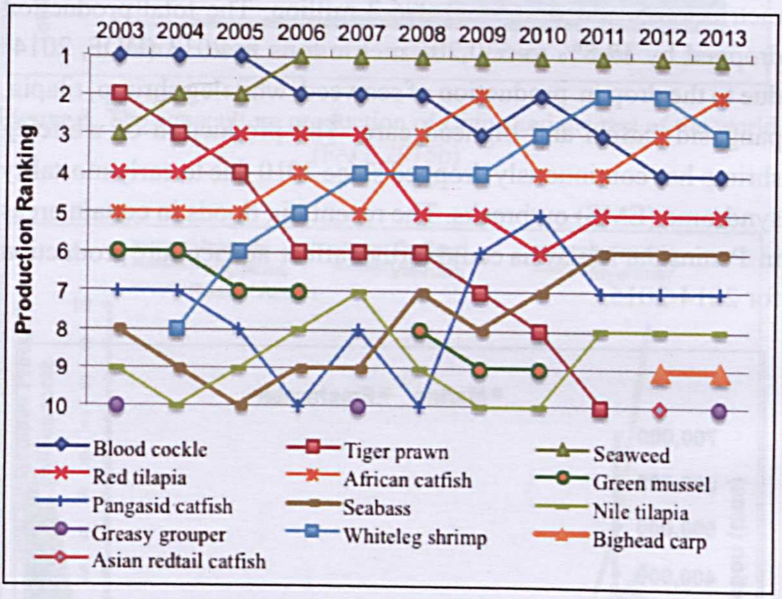


Figure 6 Production rankings of the top 10 aquaculture species in Malaysia from 2003-2013 (DOF, 2014; FAO, 2015b)

With the legalization of white leg shrimp farming in 2004, the production ranking of tiger prawns (formerly the biggest money earner in the Malaysian aquaculture industry) dropped to 10th place by 2011. It subsequently dropped out of the list of the top ten species by 2012. The whiteleg shrimp has since replaced tiger shrimp in almost all shrimp farms and reached the second place ranking twice, in 2009 and 2013, despite recent EMS outbreaks.

Nevertheless the whiteleg shrimp still remains the top overall money earner (2013) since it took over the position of the tiger shrimp in 2008 (DOF, 2014). The recent drop in white leg shrimp production has created a shortfall in supply even in the local market. Its price thus soared to almost double which successfully maintained whiteleg shrimp as the top earner. The 2^{nd} top earner is red tilapia followed by African catfish, seabass and seaweed.

It should be pointed out that seven introduced alien species dominate the list of top ten producers. The African catfish and tilapias are considered highly invasive as they can breed naturally in Malaysian waters. If these species are accidentally or intentionally released into the natural waters, such as during floods or harvesting, they could disrupt or destroy the indigenous natural biodiversity and ecology of our natural waters through cannibalism, feeding competition and habitat destruction. The relevant authority should thus intensify its efforts in educating Malaysian farm owners and other stakeholders, including the public, on the ecological risks of alien aquaculture species and ways to minimize or prevent possible ecological disaster. At the same time, concerted efforts should also be made by all research institutes in Malaysia to improve the breeding and culture technology of the present cultured local species and introduce potential new local aquaculture species.

The aquaculture industry is expected to grow despite the current temporary setbacks in several subsectors of the industry. The Department of Fisheries Malaysia (DOF) has identified a total area of 491,359 ha that can potentially be developed for aquaculture activities (Table 3). The government has also gazetted several areas as permanent Aquaculture Industrial Zones, covering a total area of 70,000 ha. The projected aquaculture production for this year (2015) and 2020 are 662,000 tons and 1.76 million tons, respectively.

Table 3 Potential resources for aquaculture development in Malaysia (Kamarudin *et al.*, 2010)

Resource	**Area (ha)**			
	Peninsular Malaysia	**Sarawak**	**Sabah**	**Total**
Open Coastal Waters (marine fish)	58,980	19,350	19,390	97,720
Lagoon Resources (seaweeds)	x	x	102,413	102,413
Protected Coastal Waters (marine fish, mussels and oyster)	x	na	1,229	1,229
Mudflats (cockle)	8,330	na	na	8,330
Coastal Land (shrimps)	3,376	14,116	8,050	25,542
Freshwater Land Resources (freshwater fish)	60,000	na	51,178	111,178
Ex-mining pools (freshwater fish)	3,451	na	na	3,451
Lakes/Reservoirs (freshwater fish)	25,496	116,000	na	141,496
Total	**159,633**	**149,466**	**182,260**	**491,359**

SEAFOOD SECURITY

Seafood Consumption

The average animal meat consumption among Malaysians has almost quadrupled in the last 50 years, from a total of 33.1 kg capita^{-1} y^{-1} in 1961 to 111.4 kg capita^{-1} y^{-1} in 2011 (FAO, 2015a). At the same time, seafood remains the most consumed protein source in Malaysia (Figure 7). Its consumption has continued to increase from an average of 20.3 kg capita^{-1} y^{-1} in 1961 to a peak of 62.8 kg capita^{-1} y^{-1} in 2002 and has remained at about 56-60 kg capita^{-1} y^{-1} since then. The breakdown of seafood consumption (Table 4) shows that marine fishes are the main seafood choice (70%) among Malaysian consumers.

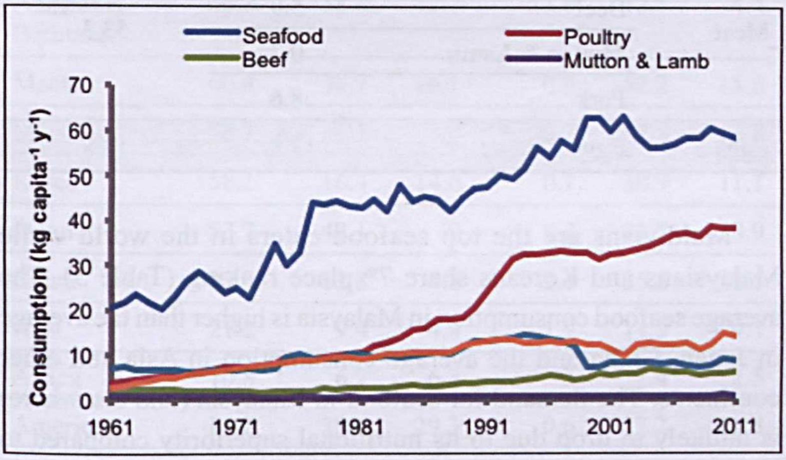


Figure 7 Average protein consumption of Malaysians from 1961-2011 (FAO, 2015a)

Table 4. Protein consumption in Malaysia in 2011 (FAO, 2015a)

Protein Group	Commodity	Consumption (kg capita^{-1} y^{-1})	Total Consumption (kg capita^{-1} y^{-1})
Seafood	Cephalopods	2.5	58.1
	Crustaceans	4.7	
	Demersal Fish	9.4	
	Freshwater Fish	6.7	
	Marine Fish, Other	12.2	
	Molluscs, Other	3.2	
	Pelagic Fish	19.4	
Meat	Poultry	38.1	53.3
	Beef	5.9	
	Mutton & Lamb	0.7	
	Pork	8.6	
Eggs	Eggs	13.8	13.8

Maldivians are the top seafood eaters in the world while Malaysians and Koreans share 7th place ranking (Table 5). The average seafood consumption in Malaysia is higher than the average in Japan, China and the average consumption in Asia and other continents. The demand for seafood in Malaysia (and elsewhere) is unlikely to drop due to its nutritional superiority compared to other meats (Kamarudin *et al.*, 1987; Sargent and Tacon, 1999). Welch et al. (2010) reported that total omega-3 polyunsaturated fatty acid (PUFA) intake of fish-eaters is 57–80% higher than that of non-fish-eaters. Omega-3 PUFA is good for the human heart.

Table 5 Average protein consumption in Malaysia, Korea, Japan, China, Asia and others (FAO, 2015a)

Country	Average Consumption (kg capita^{-1} y^{-1})					
	Seafood	**Poultry**	**Beef**	**Mutton & Lamb**	**Pork**	**Egg**
Maldives	165.7	12.9	6.7	0.8	1.3	10.4
Iceland	90.1	24.5	13	21.5	20	9.2
Hong Kong	71	67.1	21.5	2.1	60.4	13.7
Micronesia	70.7	20.2	9	0	10.1	0
Kiribati	70.7	15.6	6.5	0	9.2	2.4
Antigua & Barbuda	68.2	58.8	12.7	3.6	12.5	4.4
Macau	60.4	36.7	16.1	0.9	52.2	15.6
Malaysia	58.1	38.1	5.9	0.7	8.6	13.8
Korea	58.1	16.4	14.6	0.1	30.9	11.1
Japan	53.7	42.1	9	0.2	21.5	18.9
China	32.8	12.8	4.8	2.1	35.8	18.5
Asia	21.2	9.4	4.4	1.9	14.9	9.1
Africa	10.8	6.2	6.3	3	1.4	2.5
Americas	14.2	38.6	29.3	0.6	17.2	11.8
Europe	21.8	21.7	15.2	1.9	21.5	12.9
Oceania	26.5	42.1	39.2	12	21.5	7.4

Self Sufficiency Level

The self sufficiency level (SSL) of seafood in Malaysia remained above 100% from 1962 to 1998 (Figure 8). Subsequently, it dropped below 100% for some brief periods, in 1999-2002 and 2005-2006. In 2011, the SSL barely met the 100% level with the drop in aquaculture production by 86,075 tons less than the previous year (FAO, 2015b). Although the cultured fish production (seaweed production is excluded) helps the country in meeting the SSL, the sector only contributes less than 20% of national needs.

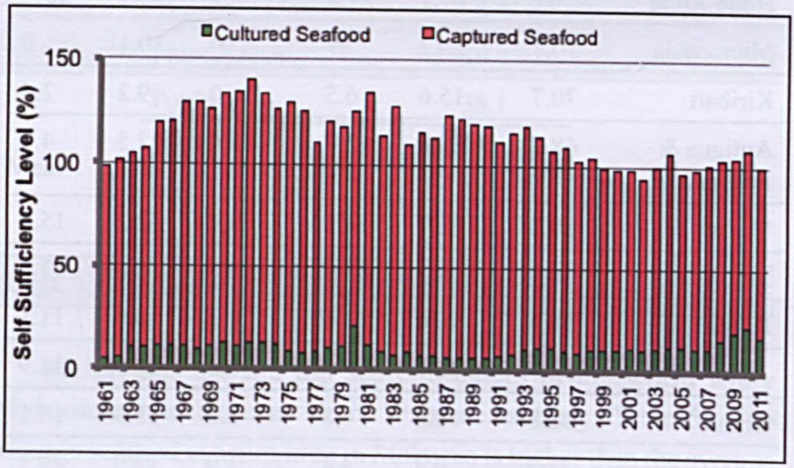


Figure 8 Self sufficiency level (1961-2011) of seafood in Malaysia (FAO, 2015a; b; d; WorldBank, 2015)

In terms of food security, the situation is considered "vulnerable or risky" as Malaysia is still strongly dependent on the "hunting" rather than the culturing of fish. Fisheries stocks can always be overfished or collapse. Managing the Malaysian fisheries stocks and the natural fish breeding or nursery grounds is an uphill task for the relevant authority. More often than not the implementation or enforcement of new fishing regulations (e.g. the new minimum mesh size for trawl nets) to safeguard the fisheries resources is met with a lot of resistance from the fishermen and politicians from their constituencies. As a result, such measures are always postponed, sometimes indefinitely. The illegal encroachment of foreign fishing vessels has also put more pressure on the Malaysian fisheries resources.

The supply and food safety of "hunted" fish are also vulnerable to monsoons, climate change, pollution and harmful postharvest measures taken by some unscrupulous middlemen. The recent fish kill in the Straits of Johor is a good reminder to the public on the safety of our captured seafood (The Star, 3 March 2015). In contrast, the safety and quality of an aquaculture product can be monitored and assured if the recently rebranded Malaysia Good Agriculture Practice (MyGAP) certification is enforced and made mandatory for every aquaculture farm.

While just barely meeting the SSL, Malaysian seafood imports continue to rise at an alarming rate, even during economic difficulties (Figure 9). The nation's seafood import bill reached almost USD 1 billion in 2011 despite a slightly lower export value. The authorities must continuously reanalyze and improve their aquaculture development strategies with all the stakeholders. This is to ensure that the industry keeps on growing and becomes sustainable with better and safer products that should be able to reduce seafood imports and increase the exports.

Improving Seafood Security

To improve Malaysia's seafood security, the aquaculture production of food fish must contribute at least 50% of the total fisheries production, with emphasis on product safety and environmental and sustainability issues. By year 2020, the Department of Fisheries Malaysia (DOF) targets to achieve production of 800,000 tons of cultured food fish which will increase the contribution of aquaculture to the total food fish production to 30% (DOF, 2015).

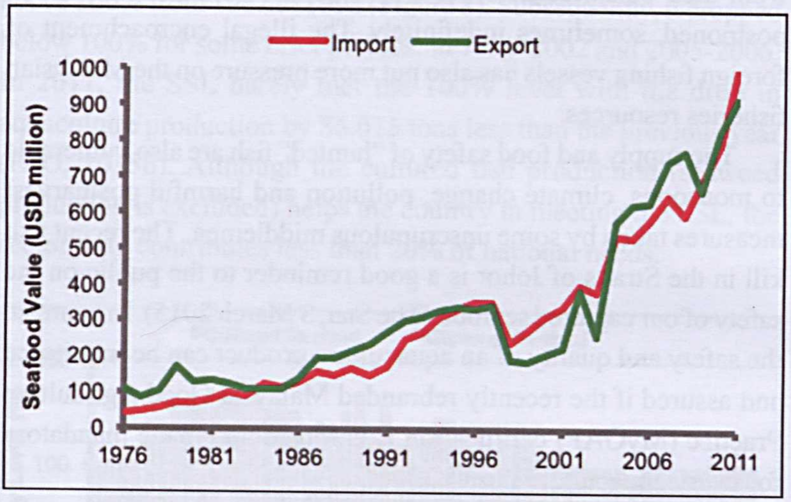


Figure 9 Seafood imports and exports (1976-2011) in Malaysia (FAO, 2015c)

To realize this target, the acreage of aquafarms must be expanded, production per ha must be increased and more aquapreneurs must be trained. In the latter aspect, UPM and several other universities are actively involved in producing aquapreneurs and aquaculture graduates for the industry. Further, acreage expansion and intensification must be focused on freshwater pond farming as there are 17,057 farm owners operating a mere 5,175 ha of ponds (2013) compared to the 984 operators managing 6,903 ha of marine ponds (DOF, 2014). As an alternative, these experienced operators could be retrained to manage other culture systems.

High quality broodstock and seed are also important for the expansion of the aquaculture industry. Insufficient fry supply has been the bottleneck in some sub-sectors, especially the the indigenous marine fish species (Figure 10) and freshwater prawns, for many years. Although significant improvements and surplus were recently seen in the seed supply of groupers and John's snapper, the Malaysian hatcheries are still not able to produce enough of seabass (only 51.7%) and red snapper (only 14.7%) fry.

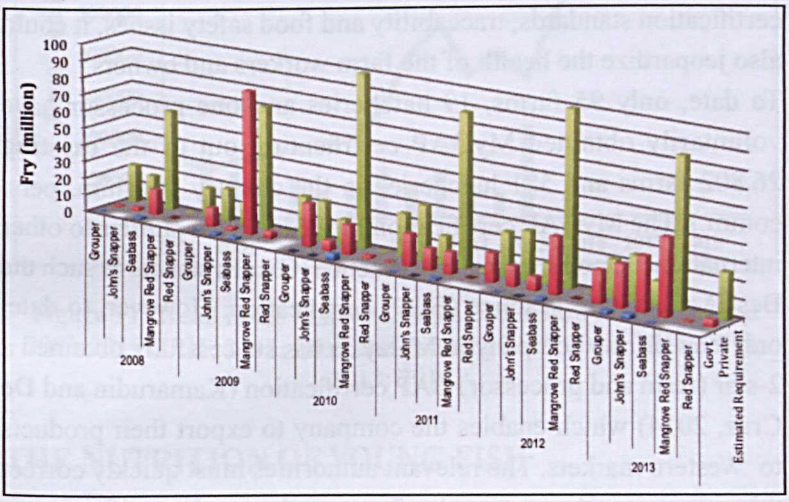


Figure 10 Trends of marine fish hatchery produced seed supply and industry estimated requirements for 2008-2013 (DOF, 2009; 2010; 2011; 2012; 2013; 2014)

Similar to the poultry industry, feed cost remains as the highest component of operational costs (up to 74%) in the aquaculture industry (Kamarudin *et al.*, 2010). However, the dietary protein requirement of fish is at least twice that of a chicken. Further, a binder, an additional cost, has to be added into aquafeed to make it water stable and to minimize nutrient leaching.

The Malaysian aquafeed industry has yet to achieve its full potential (Figure 11). There are still many farms in Malaysia that use trash fish to feed their fish. The use of trash fish will not be sustainable in the long term. In addition, farm-made aquafeeds are also widely used. Recent reports of the use of carcasses of dead pigs and chicken in farm-made aquafeeds is worrying. Such practices to reduce feed cost do not only contravene the Malaysia Standard on Good Aquaculture Practice (GAqP) guidelines, halal certification standards, traceability and food safety issues, it could also jeopardize the health of the farm workers and owners.

To date, only 95 farms, 19 hatcheries and one processor have voluntarily obtained MyGAP certification out of the existing 26,802 farms and 581 hatcheries in the country (Hashim, pers. comm.). The MyGAP certification procedures are similar to other international Good Aquaculture Practice (GAqP) standards such the Best Aquaculture Practice (BAP) certification. However, to date, only one shrimp company in Malaysia has successfully obtained a 2-star (farm and processor) BAP certification (Kamarudin and De Cruz, 2014) which enables the company to export their products to Western markets. The relevant authorities must quickly correct this misperception among the farmers, that such certification is complex, through education and enforcement to ensure that every single aquaculture product in the local market is safe.

The price of aquafeed continues to rise as the price of the feed ingredients, particularly fishmeal, fish oils, soybean and corn meal, continue to soar. Alternative safe and cheaper local protein and energy sources must be found to lower the feed cost and keep the aquaculture industry sustainable and competitive. In addition, the nutrient requirements of locally important aquaculture species at every life stage need to be determined to ensure that the aquafeed given is optimally utilized by the fish to reduce feed wastage.

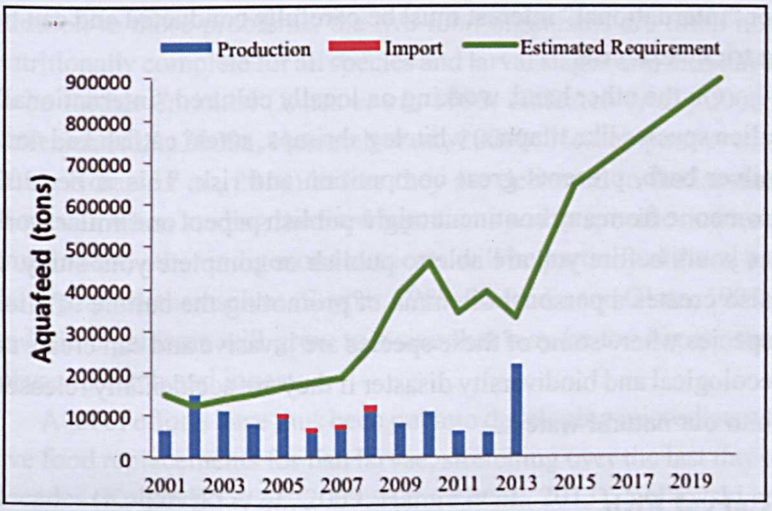


Figure 11 Trend in the Malaysian aquafeed industry for the period 2001-2015 (DOF, 2005; 2006; 2007; 2008; 2009; 2010; 2011; 2012; 2013; 2014)

THE NUTRITION OF YOUNG FISH

After successfully working on the larval nutrition of the giant freshwater prawns for several years, our aquaculture nutrition group switched to work on other local fish species, including potential new aquaculture species. Unfortunately, we found out the hard way that one of the major setbacks or risks of working with local species is the high possibility that our hard work is rejected by the editors of primary international journals. The reason frequently given is "the studied species is not of international interest", regardless of the fine quality of the work and manuscripts. These editors even kindly suggest that, "your work and findings will be best published in a local or regional journal". We found it amusing that the same ten years old "rejected" papers were subsequently accepted and published recently. Therefore, choosing a local fish species of global or "international" interest must be carefully conducted and can be a tricky exercise.

On the other hand, working on locally cultured "international" alien species like tilapias, whiteleg shrimps, sutchi catfish and now, silver barb, presents great competition and risk. This is because someone from any continent might publish papers on similar work as yours before you are able to publish or complete your study. It also creates a personal dilemma of promoting the culture of alien species where some of these species are invasive and can create an ecological and biodiversity disaster if they are accidentally released into our natural waters.

Larval Fish

To increase the production of quality seeds, high quality disease-free broodstocks and the use of the right larval feed are prerequisites. With the right induced breeding technique, high quality disease-free broodstocks will produce the desired number of eggs with high fertilization and hatching rates of healthy larvae. Once the larvae start exogenous feeding, right and complete feed or food must be provided at each larval stage or age. Live food organisms such as algae, rotifers, moinas, copepods and artemia nauplii are often used as the first larval food as they are highly digestible and may significantly contribute towards digestive processes (Munilla-Moran *et al.*, 1990; Kolkovski *et al.*, 1993; Kamarudin *et al.*, 1999; Støttrup, 2000). In addition, a large fraction of the protein in the live food organisms is in soluble form (Hamre *et al.*, 2013).

The production of live food organisms is costly, needs skilled technicians, requires extra specialized production facilities, gives inconsistent yield and quality with a potential risk of production collapse, and there is also the possibility of live food organisms carrying transmissible pathogens (Kolkovski *et al.*, 1993). In addition to those problems, the live food organisms are often not nutritionally complete for all species and larval stages and thus have to be further enriched (Jones *et al.*, 1993; Hafezieh *et al.*, 2008; Hafezieh *et al.*, 2009a; Hafezieh *et al.*, 2009b; Hosseinpour *et al.*, 2010; Kotani *et al.*, 2010) before they are delivered to the larvae. However, when loading the food organisms with a specific nutrient enrichment, other indigenous nutrients will be partially utilized by the organisms themselves (Szyper, 1989; Makridis and Olsen, 1999) and the organisms will grow to a size that may be too big for the larvae to catch and ingest.

A lot of efforts have thus been put into developing microdiets as live food replacements for fish larvae, stretching over the last three decades (Kolkovski *et al.*, 2009; Hamre *et al.*, 2013). Kolkovski *et al.* (2009) noted that the failure of most microdiets as total live food replacements is due to the lack of or limited knowledge of fish larval nutrition requirements. Hamre *et al.* (2013) suggested a holistic approach to understand all aspects that are related to larval nutrition which among others include larval mouth and gut development, digestive capacity, feeding behavior and nutrient requirements (Kamarudin, 1999). All these features and requirements differ with species and need to be determined before a specific larval feed can be developed for a particular fish species.

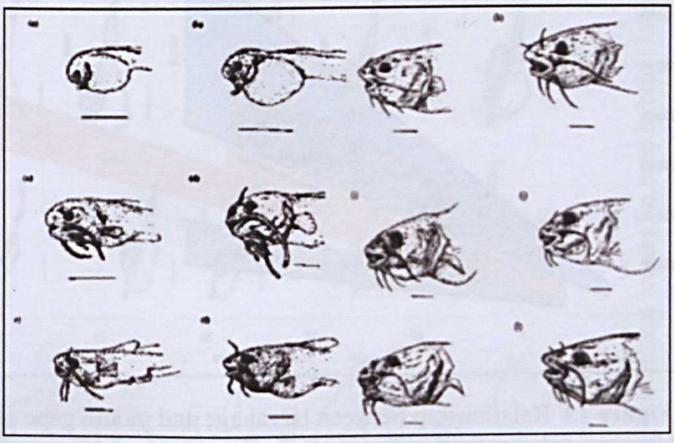
Mouth Development

Fish feeding habit is usually associated with its mouth structure, location and size (Hepher, 1988; Wainwright, 1996). Observing the changes in the larval mouth morphology allows nutritionists to record when the mouth starts to open and move, when the first feeding starts, changes in the mouth position and jaw length, development of sensory organs and others. The larval mouth gape or opening can be estimated from the length of the upper and lower jaws. The nutritionists can thus predict the type of microdiet and feed particle size range that are most suitable for a specific larval stage by studying those changes. The best way to record these changes is by combining the details from both light and scanning electronic microscopy (SEM) images, since each microscopy has its own limitations.

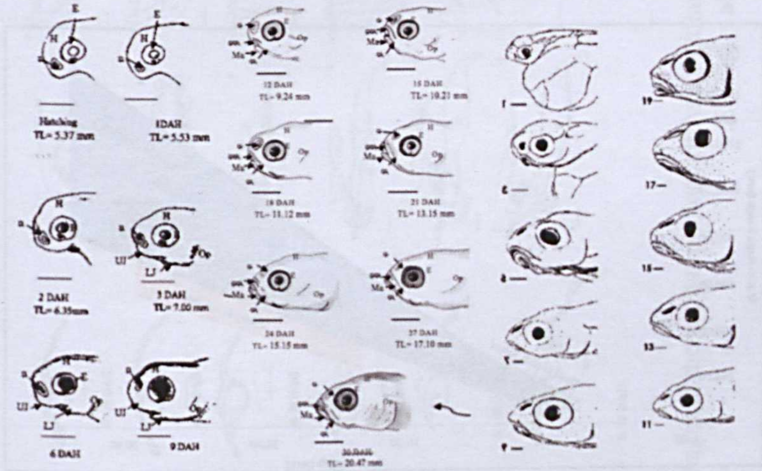
Figure 12 shows the morphological development of larval of several carps and the Asian redtail catfish (Jafari *et al.*, 2009; Ramezani-Fard *et al.*, 2011; El Hag *et al.*, 2012c). Usually a fish larva starts exogenous feeding once the jaws start to move and the eyes are pigmented. Fully developed eyes and sensory organs are important to enable the larva to catch food or prey. Generally, depending on species, the first exogenous feeding starts at 4-10 days after hatching (DAH) upon complete or almost complete yolk sac absorption (Jafari *et al.*, 2009; Ramezani-Fard *et al.*, 2011; El Hag *et al.*, 2012c). As the larva grows, its mouth size enlarges and the food or prey size preference increases. Our work with several fish species clearly indicated that larval age or total length cannot be used to generalize the mouth size and feed particle size for all fish species (Figure 13 and 14). It is therefore very important to determine the ontogenetic changes in the larval mouth morphology and mouth gape size of each aquaculture species for its specific larval feed development.

Digestive Capacity

At hatching, the larval gut is typically made up of a simple tube with a closed mouth and anus (Chen *et al.*, 2006; Ramezani-Fard *et al.*, 2011; El Hag *et al.*, 2012b). Normally the anus of fish larvae opens a day before the mouth opens. As the larvae grow, the morphological changes of the gut seem to vary among fish species (Figure 15). At the start of exogenous feeding, the larval gut of most fish is differentiated into several segments with an underdeveloped stomach although a functional pancreas and liver are present (Verreth *et al.*, 1992; Ramezani-Fard *et al.*, 2011; El Hag *et al.*, 2012b; a).



Asian Redtail Catfish



Kutum Mahseer

Figure 12 Changes in the mouth morphology of Asian redtail catfish, kutum and Malaysian mahseer during larval development (Jafari, 2011; Ramezani-Fard *et al.*, 2011; El Hag *et al.*, 2012c)

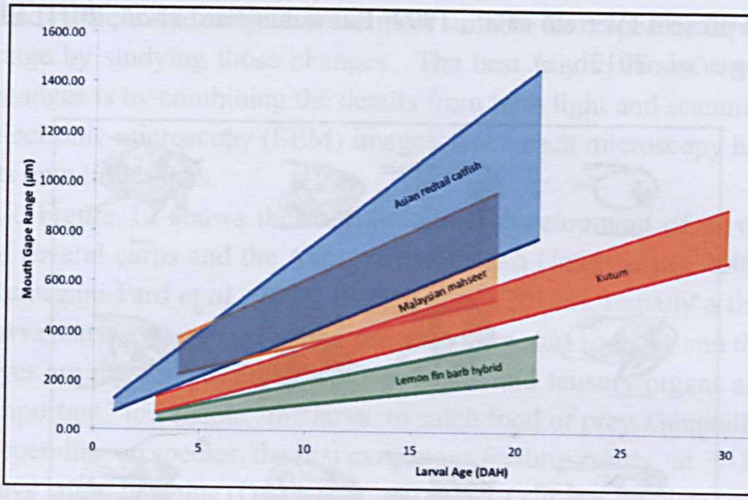


Figure 13 Relationship between larval age and mouth gape of Malaysian mahseer, kutum, lemon fin barb hybrid and Asian redtail catfish (Jafari, 2011; Ramezani-Fard *et al.*, 2011; El Hag *et al.*, 2012c)

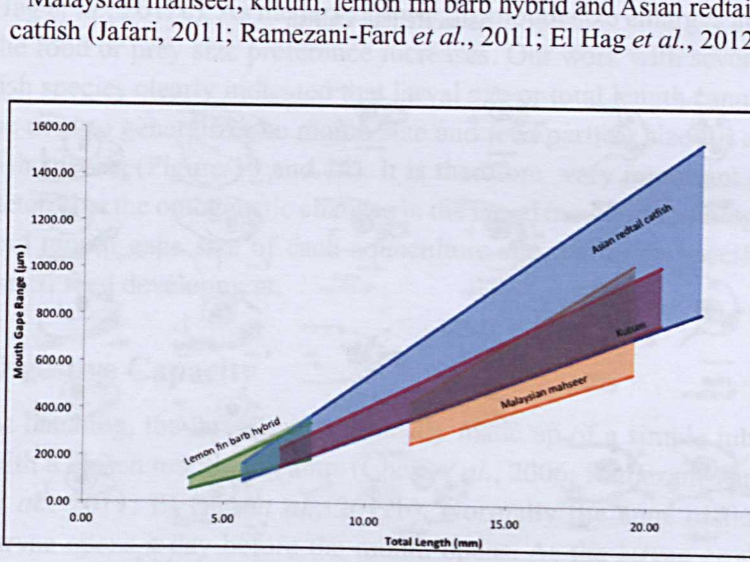


Figure 14 Relationship between larval age and mouth gape of Malaysian mahseer, kutum, lemon fin barb hybrid and Asian redtail catfish (Jafari, 2011; Ramezani-Fard *et al.*, 2011; El Hag *et al.*, 2012c)

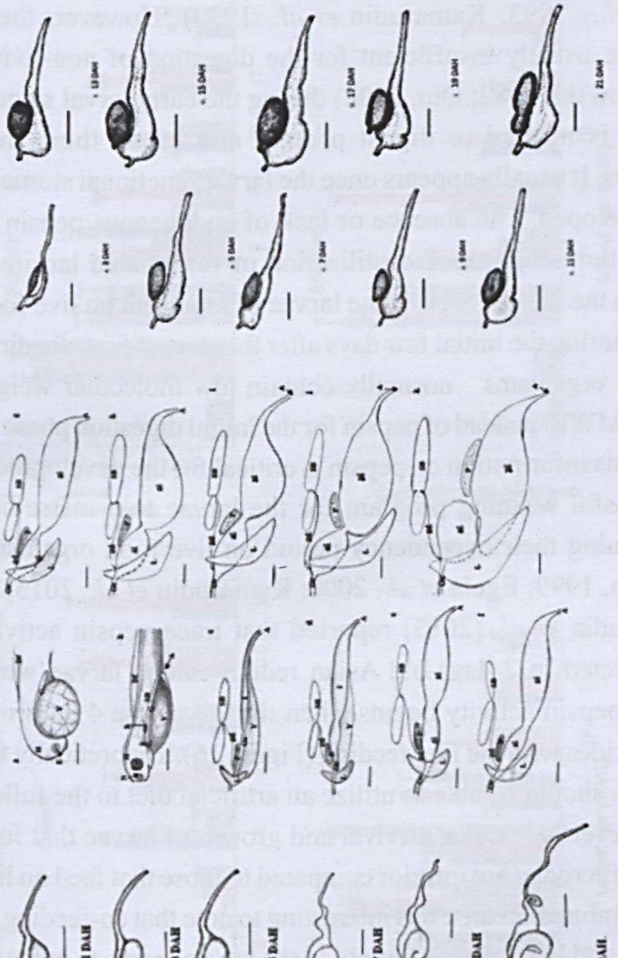


Figure 15 Changes in the gut morphology of Asian redtail catfish, kutum and lemon fin barb hybrid (Jafari, 2011; El Hag et al., 2012b)

At this stage, all major digestive enzymes are present in the digestive tract of most fish, except for pepsin (Verreth *et al.,* 1992; Verreth*et al.,* 1993; Kamarudin *et al.,* 1999). However, these enzymes are usually insufficient for the digestion of non-living food (Dabrowski, 1982; Qin, 2008) during the early larval stages.

Pepsin is needed to digest protein and break them into polypeptides. It usually appears once the larval functional stomach is fully developed. The absence or lack of endogenous pepsin in fish larvae limits the use and utilization of formulated larvifeed and leads to the dependence of the larvae of most fish on live food organisms during the initial few days after the start of first feeding. Live food organisms normally contain low molecular weight protease (LMWP) instead of pepsin for the initial digestion phase of proteins. This information on pepsin is critical for the development of a successful weaning program for the larvae to a microdiet, thus shortening their dependency period on live food organisms (Kamarudin, 1999; Eguia *et al.*, 2000; Kamarudin *et al.*, 2013).

Kamarudin *et al.* (2013) reported that trace pepsin activity can be detected in 2 days old Asian redtail catfish larvae while significant pepsin activity begins when the larvae are 4 days old, which coincides with the first feeding (Figure 16). Theoretically the catfish larva should be able to utilize an artificial diet to the fullest capacity. Nevertheless the survival and growth of larvae that feed solely on a microdiet are inferior compared to those that feed on live food or a combination diet. It is interesting to note that co-feeding of a microdiet and live *Artemia* nauplii to the larvae seems to enhance its pepsin production, survival and growth. This seems to support the idea that a live food organism may stimulate an increase in the secretion of larval endogenous enzymes (Pedersen and Hjelmeland, 1988) or activate zymogen (Petkam and Moodie, 2001).

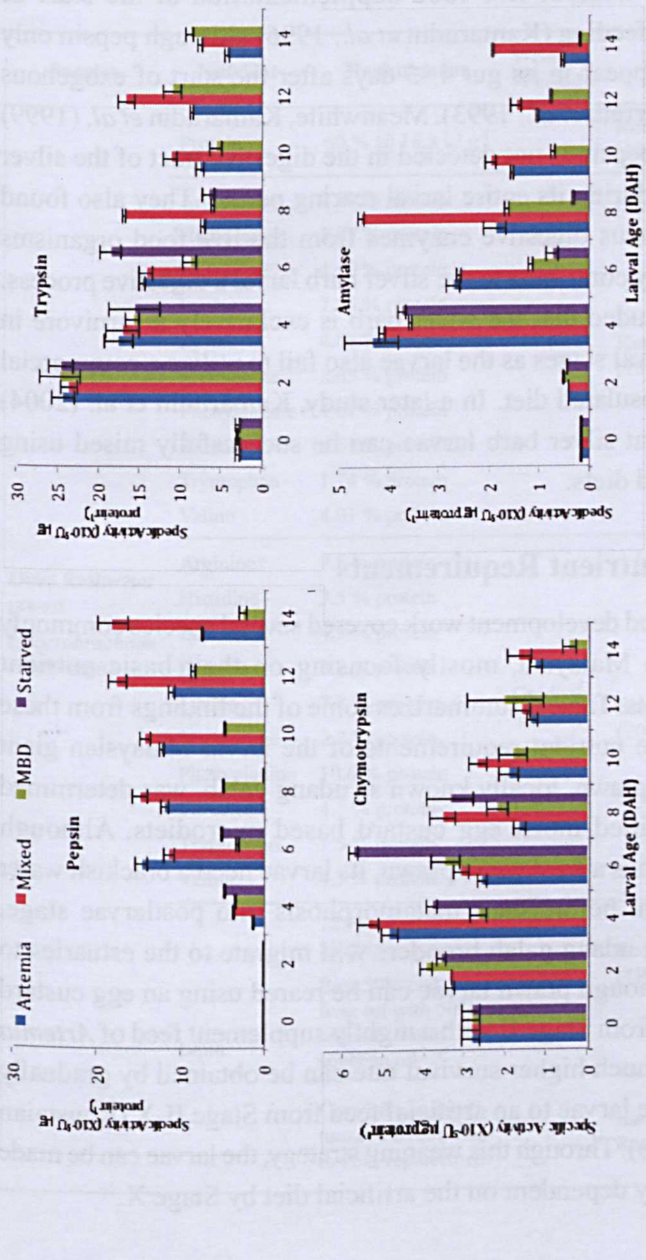


Figure 16 Changes in the digestive enzyme activities of larval Asian redtail catfish (Kamarudin *et al.*, 2013)

In contrast, the African catfish is able to efficiently utilize microdiets without live food supplementation at the start of exogenous feeding (Kamarudin *et al.,* 1996) although pepsin only begins to appear in its gut 4 -5 days after the start of exogenous feeding (Verreth *et al.,* 1993). Meanwhile, Kamarudin *et al.* (1999) noted that pepsin is not detected in the digestive tract of the silver barb larva during its entire larval rearing period. They also found that exogenous digestive enzymes from the live food organisms significantly contribute to the silver barb larval's digestive process. They concluded that the silver barb is exclusively a carnivore in its early larval stages as the larvae also fail to utilize a commercial microencapsulated diet. In a later study, Kamarudin et al. (2004) reported that silver barb larvae can be successfully raised using microbound diets.

Larval Nutrient Requirements

Our larvifeed development work covered several species commonly cultured in Malaysia, mostly focusing on their basic nutrient requirements. Table 6 summarizes some of the findings from these studies. The nutrient requirements of the larval Malaysian giant freshwater prawn, locally known as udang galah, was determined using modified moist egg custard based microdiets. Although udang galah is a freshwater prawn, its larvae need a brackish water environment before their metamorphosis into postlarvae stage. In the wild, udang galah brooders will migrate to the estuaries to spawn. Although prawn larvae can be reared using an egg custard based diet from Stage II with a nightly supplement feed of *Artemia* nauplii, a much higher survival rate can be obtained by gradually weaning the larvae to an artificial feed from Stage II-X (Roustaian *et al.*, 1999b). Through this weaning strategy, the larvae can be made to be solely dependent on the artificial diet by Stage X.

Table 6 Larval nutrient requirements of some aquaculture species in Malaysia

Species	Nutrient	Requirement	Weaning Period	References
	Protein	60 % @ 18.8 kJ g^{-1}		Roustaian *et al.* (1999b)
	Arginine*	2.38 % protein		Kamarudin *et al.* (1990)
	Histidine	3.27 % protein		
	Isoleucine	4.52 % protein		
	Leucine	7.05 % protein		
	Lysine	4.88 % protein		
	Methionine	2.65 % protein		
	Phenyalanine	4.61 % protein		
	Threonine	6.61 % protein		
	Tryptophan	1.74 % protein		
	Valine	4.01 % protein		
Giant freshwater prawn (*Macrobrachium rosenbergii*)	Arginine*	7.5 % protein	Gradual: stage II to X	Roustaian *et al.* (2000)
	Histidine	3.5 % protein		
	Isoleucine	4.9 % protein		
	Leucine	8.7 % protein		
	Lysine	7.8 % protein		
	Methionine	2.2 % protein		
	Phenyalanine	10.6 % protein		
	Threonine	4.7 % protein		
	Tryptophan	1.5 % protein		
	Valine	4.7 % protein		
	Lipid	12 % with 1% lecithin		Roustaian *et al.* *(1999b; 2001a),*
		Best 50% cod liver oil with 50% refined corn or soybean oil		
		Corn oil can substitute cod liver oil up to 75% replacement		Kamarudin and Roustaian (2002)

Species	Nutrient	Requirement	Weaning Period	References
African catfish (*Clarias gariepinus*)	Protein	60% @ 18.8 kJ g^{-1}	No requirement	Kamarudin *et al.* (1995)
Asian redtail catfish (*Hemibagrus nemurus*)	Protein	60 % @ 17.6 kJ g^{-1}	Gradual: 4-10 days after first feeding Direct: 6 days after first feeding	Kamarudin (1999), Eguia (1998), Eguia *et al.* (2000)
	Protein-Energy	55 % @ 18.4 kJ g^{-1}		
	Arginine*	4.77 % EAA		
	Histidine	10.73 % EAA		
	Isoleucine	9.94 % EAA		
	Leucine	5.11 % EAA		
	Lysine	11.12 % EAA		
	Methionine	12.14 % EAA		
	Phenyalanine	5.85 % EAA		
	Threonine	9.31 % EAA		
	Tryptophan	17.41 % EAA		
	Valine	13.60 % EAA		
Walking catfish (*Clarias batrachus*)	Arginine*	7.34 % protein	No requirement	Kamarudin *et al.* (1990)
	Histidine	3.79 % protein		
	Isoleucine	4.55 % protein		
	Leucine	7.63 % protein		
	Lysine	6.50 % protein		
	Methionine	3.85 % protein		
	Phenyalanine	5.56 % protein		
	Threonine	3.47 % protein		
	Tryptophan	5.70 % protein		
	Valine	5.09 % protein		

Species	Nutrient	Requirement	Weaning Period	References
Silver barb (*Barbynomous gonionotus*)	Protein	55 % @ 18.8 kJ g-1		Tayag (2004). Tayag *et al.* (2008)
	Protein-energy	50 % @ 19.7 kJ g-1		
	Arginine*	7.43 % protein		
	Histidine	3.28 % protein		
	Isoleucine	4.49 % protein		
	Leucine	8.98 % protein		
	Lysine	8.46 % protein		
	Methionine	2.76 % protein		
	Phenyalanine	4.84 % protein		
	Threonine	4.66 % protein		
	Tryptophan	0.86 % protein		
	Valine	5.35 % protein		
Lemon fin barb hybrid	Protein	50 % @ 19.7 kJ g-1	No requirement	Mi'ad (2015)
	Protein-energy	50 % @ 20.5 kJ g-1		Suharmili (pers. comm)
	Arginine*	2.05 % protein		
	Histidine	0.59 % protein		
	Isoleucine	0.68 % protein		
	Leucine	2.60 % protein		
	Lysine	3.09 % protein		
	Methionine	0.02 % protein		
	Phenyalanine	0.01 % protein		
	Threonine	1.16 % protein		
	Tryptophan	0.003 % protein		
	Valine	0.75 % protein		

Species	Nutrient	Requirement	Weaning Period	References
Asian seabass (*Lates calca-rifer*)	Arginine*	7.95 % protein		Kamarudin *et al.* (1990)
	Histidine	3.68 % protein		
	Isoleucine	4.38 % protein		
	Leucine	6.93 % protein		
	Lysine	7.59 % protein		
	Methionine	3.89 % protein		
	Phenyalanine	4.44 % protein		
	Threonine	6.21 % protein		
	Tryptophan	3.12 % protein		
	Valine	5.62 % protein		

* Estimated from the amino acid profile of newly hatched larvae

A microdiet containing 60% protein, 12% lipid, 1% lecithin and 18.8 kJ g^{-1} gross energy (dry weight basis) can give high survival, growth rates and postlarval production of the prawn (Roustaian *et al.*, 1999b; Roustaian *et al.*, 1999a; Roustaian *et al.*, 2001a; Roustaian *et al.*, 2001b; Kamarudin and Roustaian, 2002). Omega-3 fatty acids seem to be a very important dietary requirement in the early larval stages of the prawn, which is similar to that of other marine shrimp and fish larvae. This requirement seems to decrease towards the later stages as the larvae prepare themselves for the freshwater environment where omega-6 fatty acids become more important in the prawn's diet. The combination of 5 -7.5% corn or soybean oil and 2.5 -5% fish oil is ideal to fulfill the larval lipid requirement in the brackish water environment.

Larval Asian redtail catfish, locally known as baung, requires live food organisms in the early feeding stages, although all the major digestive enzymes, including pepsin, are present at the first feeding stage (Kamarudin, 1999; Kamarudin *et al.*, 2013). They can only be gradually or directly weaned to a microbound diet from 4 days or at 6-8 days after the first feeding (Eguia, 1998; Eguia *et al.*, 2000). The dietary protein and energy requirements of baung larvae are 55% and 18.4 kJ g^{-1} gross energy (as fed basis), respectively. In contrast, with the absence of pepsin at the first feeding, the African catfish larvae can do extremely well when solely fed an optimally complete microbound diet. Their larval dietary protein and energy requirements (60% and 18.8 kJ g^{-1} gross energy, respectively) are higher than that of the baung larvae (Kamarudin *et al.*, 1995).

Carp larvae seem to have a lower optimal dietary protein requirement than the prawn and catfish larvae. Both the silver barb and lemon fin barb hybrid larval require an optimal 50% protein in their diet (Tayag, 2004; Tayag *et al.*, 2008; Mi'ad, 2015). However, the optimal energy requirement of the lemon fin bard hybrid is higher, at 20.5 kJ g^{-1} gross energy, compared to the silver barb, at 19.7 kJ g^{-1} gross energy.

In general, the larval dietary protein and energy requirements of the commonly cultured fish vary with species and range between 50-60% protein and 18.4-20.5 kJ g^{-1} gross energy. The protein requirement appears to be close to the protein content of most live food organisms. Our work on larval nutrition is however far from complete. The main constraint in larval nutrition research is the availability of a constant supply of fertilized eggs or newly hatched larvae.

Feeding Frequency

It is important that a suitable feed is made available to the fish larvae. Filter feeding larvae such as the shrimp larvae feed all the time and thus feed must be made available, suspended in the water column, for 24hrs a day. However suspending microdiets for a long time will lead to severe nutrient leaching and possible fungal infestation, especially in tropical conditions (Velasco *et al.,* 1999). Increasing feeding frequency to an optimum for the specific fish will solve this problem and is of utmost importance for larval survival and growth (Mollah and Tan, 1982). Tayag *et al*. (2005) reported that the optimal feeding frequency for silver barb larval is four times d^{-1} under daylight. Night feeding is not beneficial indicating that barb larvae are visual feeders. In contrast, rohu and singhi larvae feed continuously, even in the dark (Mookerji and Rao, 1995). The optimal feeding frequency for African catfish larvae, on the other hand, is lower at three times d^{-1} (Mollah and Tan, 1982)while a higher optimal feeding frequency of 8 times d^{-1} is needed for the large yellow croaker (Xie *et al*., 2011).

Postlarval Fish

Similar to the larval stage, the nutrition requirements of postlarval fish vary with species. Our postlarval nutrition work has been focused on two indigenous carps, the Malaysian mahseer (*Tor tambroides*) and the lemon fin barb hybrid. To keep up with the industry practices which favour the use of floating pellets for fish feeding, extruded practical test diets are now routinely used in our studies. Some of our recent findings are presented in this section.

Malaysian Mahseer

The mahseers *Tor* spp. are large, riverine cyprinids found in southern Asia and sought after mainly as food and recreational fish. There are three mahseer species in Malaysia, i.e. *Tor tambroides, T. tambra* and *T. douronensis*. *T. tambroides* is known as the Malaysian mahseer, kelah or empurau and is the most sought after among the three species. Similar to other mahseers in other parts of South Asia, these slow growing carps have been overexploited and are classified as moderately threatened or endangered (Chong *et al*., 2010). Figure 17 shows the declining annual catch of mahseer fisheries in Malaysia and Indonesia.

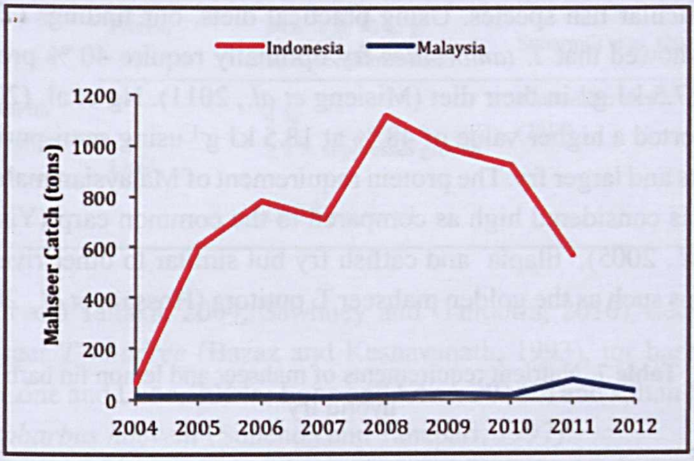


Figure 17 Mahseer fisheries in Malaysia and Indonesia

Since the initial success in its induced breeding (Ingram *et al.*, 2005; Ingram *et al.*, 2007), the interest in mahseer culture has increased in Malaysia. Mahseers are now being cultured in ponds, mainly in Sarawak and Pahang. The Department of Fisheries recently reported that mahseer aquaculture production in 2012 and 2013 were 15 tons (RM360,000) and 19.66 tons (RM 1.56 million), respectively (DOF, 2013; 2014). Most of the fry used by the farmers are wild caught and this practice must be regulated or totally stopped as it will certainly affect the already alarmingly low natural mahseer population. The supply of hatchery-bred fry is still very low and far from meeting industry demand as Malaysian mahseers are partial spawners. Abnormality among hatchlings is also common and significant which is believed to be due to the poor nutritional conditions of the broodstocks as a result of the absence of a commercial specific maturation diet.

Protein is the main and costliest component in an aquafeed, from the postlarval stage to harvest. The higher the dietary protein requirement the higher the feed and operational costs in raising a particular fish species. Using practical diets, our findings (Table 7) showed that *T. tambroides* fry optimally require 40 % protein at 17.5 kJ g^{-1} in their diet (Misieng *et al.*, 2011). Ng et al. (2008) reported a higher value of 48 % at 18.5 kJ g^{-1} using semi-purified diets and larger fry. The protein requirement of Malaysian mahseer fry is considered high as compared to the common carp (Yilmaz *et al.*, 2005), tilapia and catfish fry but similar to other riverine carps such as the golden mahseer T. putitora (Hossain *et al.*, 2002;

Table 7 Nutrient requirements of mahseer and lemon fin barb hybrid fry

Species	Nutrient	Requirement	Reference
Malaysian mahseer (*Tor tambroides*)	Protein	40 % @ 17.5 kJ g^{-1}	Misieng et al. (2011)
	Lipid	5 % >10% depresses growth	Ramezani-Fard *et al.* (2012a)
		Refined bleached deodorized palm oil (RBDPO) improves growth	Kamarudin *et al.* (2012)
		Low n-3 PUFA (2.5% lipid) and high SFA gives best growth	Ramezani-Fard *et al.* (2012b)
		Crude palm oil (CPO) at par RBDPO	Kamarudin *et al.* (2014)
		Shorea oil < CPO	Kamarudin *et al.* (2014)
	Carbohydrate	25 % >25 % suppresses growth	Kamarudin *et al.* (2014)
		Corn starch > taro > sago > tapioca	Kamarudin *et al.* (2014)

	Protein	34.6 % @ 16 kJ g^{-1} 30 % recommended	Suharmili et al. (2015)
Lemon fin barb hybrid	Lipid	4 % ≥ 8 % suppresses growth CPO > canola oil	Kamarudin *et al.* (2014)

Islam and Tanaka, 2004; Sawhney and Gandotra, 2010), deccan mahseer *T. khudree* (Bazaz and Keshavanath, 1993), tor barb *T. tor* (Lone and Lone, 2014a; Lone and Lone, 2014b) and sultan fish *Leptobarbus hoeveni* (Suhenda and Tahapari, 1997).

The optimal dietary lipid requirement of *T. tambroides* fry is low at 5% (Ng and Andin, 2011; Ramezani-Fard *et al.*, 2012c) while a diet containing more than 10% lipid will suppress fish growth (Ramezani-Fard *et al.*, 2012c). Kamarudin *et al.* (2012) reported that vegetable oils are superior to fish oil as the dietary lipid source for mahseer fry, with refined bleached deodorized palm oil (RBDPO) as the best oil. Vegetable oils are better because the fry require high saturated fatty acids (SFA) and low n-3 fatty acids (2.5 % lipid) in their diet (Ramezani-Fard *et al.*, 2012b). In the following studies, crude palm oil (CPO), which is cheaper than RBDPO, was found to perform as well as RBBPO and better than *Shorea* and *Canarium* oil as a dietary lipid source for the mahseer. *Shorea* and *Canarium* are riverine fruits that are commonly eaten by the wild mahseers where mahseer consumers and farmers believe that these fruits are responsible for the unique taste of the Malaysian mahseers.

T. tambroides fry require an optimal dietary carbohydrate level of 23.4% (Kamarudin *et al.,* 2014). Fry growth is suppressed when the dietary carbohydrate level exceeds 25%. Our work also revealed that corn starch is the best carbohydrate source for mahseer fry, followed by taro, sago and tapioca starch. The preference for corn starch can spell a problem, which will be discussed in a later section.

Lemon Fin Barb Hybrid

The Department of Fisheries Malaysia introduced the lemon fin barb hybrid, named "kerai lampam", in 2004 for the production of an affordable "people's fish". The hybrid carp, a cross between the male lemon fin barb (kerai kunyit), *Hypsibarbus wetmorei,* and the female silver barb (lampam Jawa) *Barbodes gonionotus*, can reproduce in captivity. The hybrid has the external features of the lemon fin barb with the fast growing feature of the silver barb. Since its introduction, the fish has become popular, especially in Pahang, and fetches a high market price of up to RM 35 kg^{-1} (DOF, 2014) due to its fine meat quality and the external features of the lemon fin barb (Suharmili *et al.*, 2015). This hybrid is mainly pond cultured in Pahang. Its production has tripled from 29.9 tons (RM 198,760) in 2012 to 99.6 tons (RM 3.16 million) in 2013 (DOF, 2013; 2014).

Suharmili *et al.* (2015) reported that the hybrid has an optimal dietary protein requirement of 34.6 % at 16 kJ g^{-1}. However, a diet containing 30% protein is recommended for the hybrid as it gives a similar growth and survival rate as the 35% protein diet. The dietary protein requirement of the hybrid fry is very much similar to that of its maternal herbivorous silver barb (Mohanta *et al.*, 2008) and lower than that of the omnivorous mahseer. The dietary protein requirement of the lemon barb has not been reported but could be closer to that of mahseers or sultan fish.

It is interesting to note that lemon fin barb hybrid fry, a fatty fish, requires only 4% lipid in its diet (Ismail *et al.*, 2014). Its growth is significantly suppressed when fed a diet containing 8% lipid or more. Its growth is also suppressed if its diet contains 0% lipid indicating that lipid is an essential nutrient for the fish. Its low dietary lipid requirement is similar to that of the mahseer. CPO is found to perform better than canola oil as the lipid source for the hybrid fry in terms of fish growth and lipid retention. The fry seems to be able to convert carbohydrates into most of its body lipid. Given the low dietary protein and lipid requirements, the feed cost for this hybrid should be competitively low.

Alternative Ingredients

Fishmeal Replacement

Fishmeal is an essential protein source in almost all aquafeeds as its amino acid profile usually meets the fish amino acid requirements. The supply of global fishmeal is not limited but is also decreasing while its price has more than tripled in the last decade (Olsen and Hasan, 2012). Although Malaysia has significantly reduced its dependency on imported fishmeal since 1989 (Figure 18), the local fishmeal production (Figure 19), which relies on trash fish, appears to have reached its maximum in the last 3 years (IndexMundi, 2015) and its price too continues to soar. The need to find "halal" fishmeal replacement alternatives has been discussed in an earlier section.

The capability of fish to utilize potential fishmeal alternatives seems to vary with species (Table 8). Mahseer fry seem to be more versatile in its feeding as it can fully utilize commercial poultry offal meal (POM) and black soldier fly prepupae meal (BSFPM) as a total fishmeal replacement in its diet. In the wild, aquatic insects and larvae are the main protein sources for the riverine mahseers (FishBase, 2014). The weight gain of red tilapia fry is reported to be 80% higher when blowfly maggot meal is included in their diet to totally replace fishmeal (Sing *et al.*, 2014). In contrast, only 50 and 75 % of fishmeal, respectively, can be replaced by POM and BSFPM in the diet of the lemon fin barb hybrid fry. Soybean meal too can only substitute half of the fishmeal in the hybrid's diet.

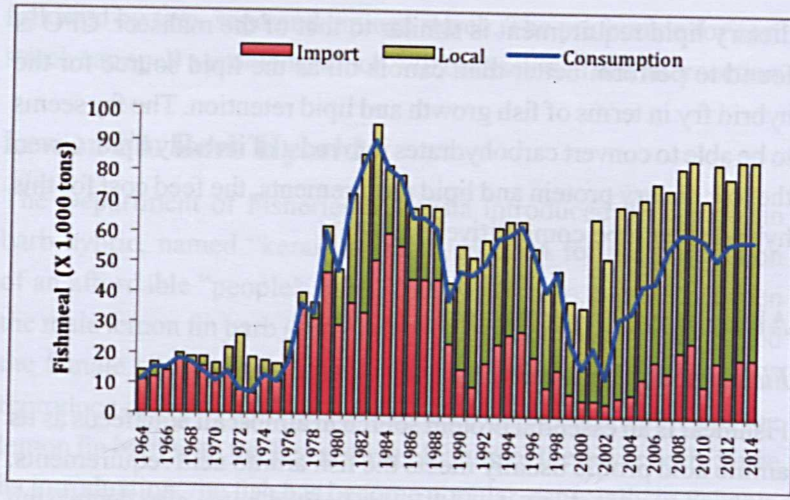


Figure 18 Local production, import and consumption of fishmeal in Malaysia (IndexMundi, 2015)

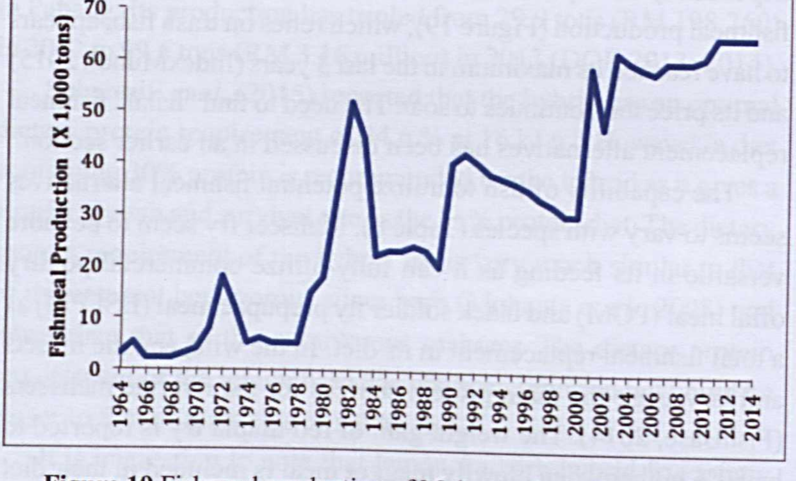


Figure 19 Fishmeal production of Malaysia (IndexMundi, 2015)

It is also interesting to note that the cannibalistic giant freshwater prawn is poor in utilizing an insect meal. BSFPM inclusion of more than 25% fishmeal replacement severely reduces the prawn's growth. Cheng (2012) also found that insect meal can only partially replace fishmeal in the diet of crayfish *Procambarus clarkii* as a higher insect meal inclusion reduces the survival rate of the crayfish. Makkar *et al.* (2014) reported that frass of BSF larvae reared on dried distiller grains has been successfully used in commercial prawn farms in Ohio, USA.

Table 8 Performance of alternative protein sources as fishmeal replacement

Feedstuff	Species	% Replacement	Reference
Poultry offal meal	Malaysian mahseer (*Tor tambroides*)	100 % and no adverse effects	Ismail *et al.* (2013)
	Lemon fin barb hybrid	Up to 75% 50% recommended	
Defatted black soldier fly prepupae meal (BSFP)	Malaysian mahseer (*Tor tambroides*)	100 % 75 % recommended	
	Lemon fin barb hybrid	75% and no adverse effects	
	Giant freshwater prawn (*Macrobrachium rosenbergii)*	25%	
Blowfly maggot meal	Red tilapia	100 % and 80% higher weight gain	Sing *et al.* (2014)
Soybean meal	Lemon fin barb hybrid	50% and no adverse effect	

Corn Starch Alternative

Most aquafeed millers use at least 20% corn starch in their feed formulation as the starch source in the manufacture of floating and slow sinking fish pellets. The supply of corn starch is expected to be low in the near future as more and more corn is now used for the production of ethanol, an important component of biodiesel, instead for livestock feed ingredient. Malaysian aquafeed millers are thus now turning to tapioca and broken rice as alternative starch sources. It has also been observed recently that locally grown and produced sago and tapioca starch perform equally well as starch for the production of extruded mahseer fry feed (Umar *et al.*, 2013). In another study, taro and broken rice are also found to be excellent starch alternatives once the optimization conditions of the specific starch are determined (De Cruz *et al.*, 2015). The starch requirement in the production of extruded aquafeed can be lowered to 15% if modified taro and broken rice are used. This reduction will give more room for a fish nutritionist to formulate an aquafeed at a lower cost.

SUMMARY

Fish fry production is a crucial factor in providing sufficient seed for the development and expansion of the aquaculture industry. Aside from high quality broodstock and good induced breeding technology, the hatched larvae must be given the right feed at the start of the exogenous feeding or when the larvae has gained the ability to digest an artificial diet to ensure high survival and growth rates, while eliminating deformities. The feed must be of the right type and particle size for the larvae to catch and ingest and contains all the nutrients required by the larvae. The feed must also be delivered in the right amount, frequency and time. Our findings have reconfirmed earlier notions that different larval species have different specific feeding and nutritional requirements. It is therefore of prime importance that the specific requirements for all important and potentially important aquaculture fish species in Malaysia be scientifically and holistically determined to ensure the success of their larviculture.

A similar but less extensive approach must be applied to postlarval rearing. At this stage, postlarvae of most fish have a fully functional stomach and digestive capability to utilize artificial diets. Extruded micropellets or crumbles are excellent as postlarval fish feed. Our work with local carps reaffirmed that the specific nutrient requirements of each species must be determined before specific postlarval feed can be developed.

Feed is a major operational cost for fish culture from the postlarval stage and beyond, where fishmeal is the main and most expensive protein source. Partial or full replacement of fishmeal with cheaper and suitable proteins can reduce feed cost. Insect meals can be cheaply produced by utilizing food and agriculture waste, and this has shown good potential as a major or full fishmeal replacement for fish postlarvae but not crustacean postlarvae. More study is needed to determine the potential of alternative proteins and starch, and the requirements of other important local young fish. However, the importance of these local species in meeting "the international interest" has to be carefully considered to ensure that our publication obligations can also be met.

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BIOGRAPHY

Dr. Mohd Salleh Kamarudin was born in Jalan Bakariah, Bandar Maharani, Johor in 1959, and grew up in Parit Nipah, Muar. He began his education at the Parit Jamil Primary English School in Muar (1969-1971) before continuing his lower secondary education at the Muar High School (1972-74). He was selected to complete his upper secondary education at Sekolah Menengah Sains Johor, Kluang, Johor. In 1977, he entered Universiti Pertanian Malaysia (now Universiti Putra Malaysia) to pursue a Diploma in Fisheries before transferring to the University of Washington in 1980. There, he had the opportunity to take a course on fish nutrition taught by Professor John E. Halver, the Father of Fish Nutrition. He completed his Bachelor of Fisheries Science with double majors in Fish Culture and Invertebrate Culture by Spring 1982. In Fall 1982, he joined the (now defunct) Faculty of Fisheries and Marine Science in UPM as a tutor and enrolled at the Auburn University as a Master's student. He completed his Master of Science under the supervision of Professor Richard T. Lovell, a prominent warmwater fish nutritionist in 1984.

He was accepted by the Auburn University to continue his studies for a PhD under a Public Service Department scholarship but was denied a study leave. He returned to Malaysia in October 1984 and began his academic career at UPM where he taught fish nutrition, fish anatomy, invertebrate biology, aquaculture engineering, fish genetics and biostatistics, mostly at the undergraduate levels (diploma and bachelor). In 1986, he had the opportunity to attend a 3-months training course under Professor Shinichi Teshima at the Kagoshima University, sponsored by JICA. By fall 1989, he won an Association of Commonwealth Universities Scholarship to further his studies at the University of Wales, under the supervision of Professor David A. Jones, the inventor of microencapsulated larvifeed. He completed his PhD by the end of 1992.

In 1996, the Faculty of Fisheries and Marine Science was moved to Terengganu. Dr. Mohd Salleh and 19 others were thus relocated to several other faculties within UPM. Dr. Mohd Salleh was transferred to the Faculty of Agriculture, beginning in the Department of Agronomy (now Department of Crop Science) and later moving to the Department of Agriculture Technology and then the Department of Aquaculture that was established in 2007. At his new faculty, he continues his research and teaching in aquaculture nutrition and aquaculture technology. He has also been involved in other affiliated research fields such thermal conditions and design of aquaculture buildings. He has secured many research grants from local and international sponsors including the European Union and International Foundation for Science. He was promoted to associate professor in 2001 and won an Australian Asia Fellowship the following year. He spent his fellowship at the Queensland University of Technology from Feb 2002 to Feb 2003. In 2012, he was promoted to full professor in Aquaculture Nutrition. He served as a Deputy Dean between 2006 and 2009 and since 2010 until now Dr. Mohd Salleh is heading the Department of Aquaculture.

Dr. Mohd Salleh has more than 160 publications, mostly in international journals, and is the main supervisor for 36 PhD and M.Sc. students. He sits on the Editorial Boards of three fisheries and aquaculture international journals and has been a regular reviewer for several international journals. He has also been appointed as external thesis examiner for several local and international universities, including the University of Tasmania and the Deakin University. He is a life member of the Malaysian Fisheries Society and has served as its Treasurer from 1996 to 1998 and as a Council Member from 1998 to 2000. He is also a life member of the Malaysian Applied Biology Society. Very recently, he was nominated to represent Malaysia at the 12th Meeting of the NACA Technical Advisory Committee, held on 10-12 March 2015 in Cha Am, Thailand.

ACKNOWLEDGEMENTS

The author would like to acknowledge and thank the following persons and institutions:

- All his co-researchers including his former and present graduate and final year project undergraduate students who are too many to be listed here. Without their contributions and dedication, none of the work presented here and elsewhere would have been possible.
- All his present and former colleagues at the Faculty of Agriculture and Institute of Halal Product Research, and all his former colleagues at the now defunct Faculty of Fisheries and Marine Science, UPM
- The Ministry of Science, Technology and Innovation, Ministry of Education, International Foundation for Science, European Union and UPM for providing research grants.
- The Department of Fisheries Malaysia, Forest Research Institute Malaysia (FRIM), Universiti Teknologi Mara (UiTM), Sarawak Department of Agriculture, Malaysia Agriculture Research and Development Institute (MARDI) and other institutions that have provided various types of assistance, support and cooperation.

And last but not least

- His wife Dr. Sabarinah Sheikh Ahmad Al Jabri and daughters Sofia Amira and Safra Marsya who have brought joy and colors to his life and have always been supportive of his career.
- His late parents Haji Kamarudin Haji Salleh and Hajah Rodziah Haji Ibrahim, who had raised him well and had been very supportive throughout his schooling and career, and my siblings Latifah, Adibah and Ahmad who took our parents while I was away from home.

LIST OF INAUGURAL LECTURES

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The Challenge to Communication Research in Extension
22 July 1989

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Indigenous Materials and Technology for Low Cost Housing
30 August 1990

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Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops
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Numerical Solution of Ordinary Differential Equations: A Historical Perspective
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Changing Roles of Agricultural Economics
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The Changing Demand for Livestock Products
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Plant Taxonomy, Biodiversity and Conservation
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Engineering Technological Developments Propelling Agriculture into the 21st Century
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Rock, Mineral and Soil
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Pest Control: A Challenge in Applied Ecology
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Chromosome Distribution and Production Performance of Water Buffaloes
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192. Prof. Datin Dr. Faridah Hanum Ibrahim
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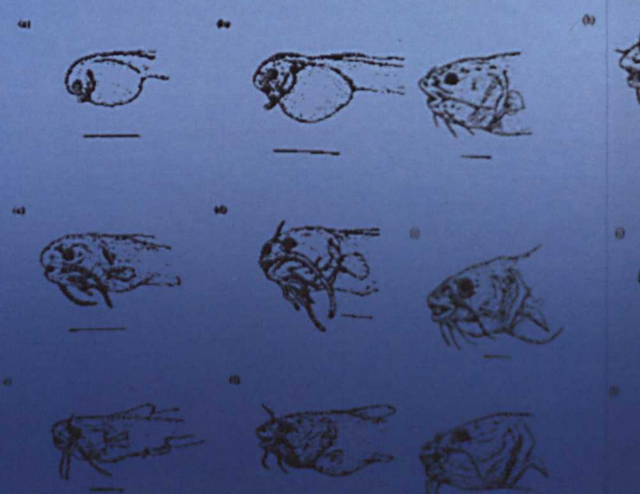
27 March 2015

Feeding & Nutritional
Requirements
of YOUNG FISH

THE INAUGURAL LECTURES are given by honored faculty members within the University who have obtained the rank of full professor. This event gives the honoree the opportunity to deliver a lecture to fellow faculty and other university guests concerning their work and research interests.

The context of the lecture itself typically includes a summary of the evolution and nature of the honoree's specialized field, highlights of some of the general issues of that particular field, and a description of how the honoree situates his/her work within their field.

UPM conducts this event to highlight and bring attention to the scholarly work that is being done by its distinguished faculty and to illustrate how the work contributes to mankind as a whole.



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