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# Mahseer in Malaysia: A Review of Feed for Cultured *Tor tambroides* and *Tor tambra*

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*Tor tambroides* and *Tor tambra* or Mahseer that belongs to Cyprinidae family are high value freshwater fish cultivated in captivity in freshwater aquaculture industry in Malaysia today. The population of these popular species usually found at upperstream part of riverines are slowly declining due to continuos fishing activities for the past years. Aquaculture is a measure taken to breed these fish in captivity to allow continuos supply of freshwater food fish as protein source for consumers. Slow growth performances of Masheer while cultured in captivity demands further attention on improvement of breeding techniques including feeds and feeding. This review exploited various research on *Tor tambroides* and *Tor tambra* that encapsulate the fields of morphology, distribution, farming techniques, industry, market status and required nutrition for Mahseer cultured in captivity. It is hoped that this review can serve as a reference tool to aquaculturists and nutritionists who are interested in culturing this species to mass production scale. The review also include recommendations and future perspectives of *Tor tambroides* and *Tor tambra* for aquaculture while accommodating conservation endeavours of wild Mahseer in Malaysia.

**Keywords: Masheer, Empurau, Aquaculture, *Tor tambra* , *Tor tambroides*, nutrition**

## 1 INTRODUCTION

In recent years, freshwater aquaculture has evolved as a source to supply freshwater protein to consumers. Freshwater fisheries has been exploited continuously until many species including Mahseer had slowly depleted in the natural ecosystem. Cultivating fish in captivity requires aquaculturist to be knowledgeable on fish culture techniques especially in fish nutrition. Fish nutrition is the science of a nutrient's interaction with some aspect of a living organism, such as feed composition, intake, energy release, waste disposal, and synthesis for maintenance, growth, and reproduction (Prabu et al., 2017). In addition, choice of feed ingredients used in fish nutrition must be taken into consideration for both farmers and feed producers to ensure that feeds are not costly and must be made affordable to farmers as more than 50% of total cost in aquaculture ventures are on fish feeds.

*Tor* species, generally known as Mahseer, are

widespread and found extensively at famous freshwater ecosystem throughout the Asian region (Redhwan & Komilus., 2021). In Malaysia waters, there were only three identified local species namely *Tor tambroides, Tor duoronensis and Tor tambra*. *Tor tambra* are easily can be found or detected at Kenyir lake (Aqmal-Naser & Ahmad., 2020) while *Tor tambroides* and *Tor duoronensis* (Ambak et al., 2007) are commonly indigenous at East Malaysia Sarawak (Figure 1). Rapid development and urbanization that took place surrounding to watersheds coupled with increased fishing pressure on the natural ecosystem of Mahseer and crucial climate change had eventually impacted the population dynamics of wild *Tor* species.

This review presents an overview of Mahseer aquaculture in Malaysia that includes morphology, distribution, farming techniques, market value of Mahseer and most importantly nutrition aspects of *Tor tambroides* and *Tor tambra*. It is hoped that this information is able to provide a holistic knowledge on feeds and feeding of Mahseer cultured in captivity.

## 2 MASHEER IN MALAYSIA

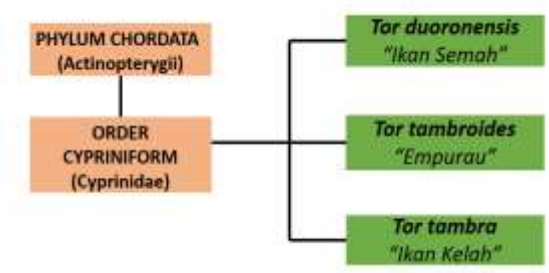


**Figure 1.** Phylogenetic Tree for Tor species reported in Malaysia

*Tor* species, generally known as Mahseer or Empurau, are widespread and famous freshwater throughout Asia country. In 2007, the reported number of species known was approximately 30 (Ambak et al., 2007) but in 2021, Jaafar et al (2021) reported that *Tor* species are widely distributed across Southeast Asia, and 13 *Tor* species have been reported previously which were *Tor ater*, *Tor dongnaiensis*, *Tor douronensis*, *Tor laterivittatus*, *Tor mosal*, *Tor mekongensis*, *Tor putitora*, *Tor sinensis*, *Tor soro*, *Tor tambra*, *Tor tambroides*, *Tor tor* and *Tor yingjiangensis*. However, the exact number of valid *Tor* species remains debatable and thus, this review shall only focus on common species found in Malaysia which are *Tor tambroides, Tor duoronensis and Tor tambra*. *Tor tambroides* can be detected at the headwaters of much of the state's major river systems These Mahseer species are found at some riverine in Peninsular Malaysia and in Borneo Island (Sabah, Sarawak and Kalimantan) according to Kottelat et al (2018) and Sawestri and Marini (2021).

### 2.1.1 Morphology of *Tor tambroides*

The Malayan Mahseer famously known as *Tor tambroides* (Figure 2) is one of the famous freshwater fish targeted in sports fishing. This fish was reportedly able to reach a weight between 30-50kg maximum length of one metre, and the length reported ranges between 61cm until 74.9 cm (Muchlisin et al., 2015). Bleeker 1854 identified that *Tor tambroides* has four dorsal spines, eight dorsal soft rays, three anal spines, five anal soft rays and 39–41 vertebrae. Fingerling of *Tor tambroides* has dark longitudinal stripes but none when it reaches a stage of maturity (adult). Fingerling of *Tor tambroides* also has yellow fin and turn blackish when reach a stage of maturity (adult). Adult *Tor tambroides* possess morphology of 20 gill rakers and nine branched dorsal-fin rays.

Morphology using the inner part of the Mahseer such as bones, gonads are rarely used for identification due to the high value of this fish and more suitable for aquaculture industry. Information of fish bone morphology is important to understand the relationship between taxonomy and phylogenetic of fish Keivany (2014) as well as to detect of abnormalities on fish bones (Zhang et al., 2012). Zulfahmi et al (2018) clarified that *Tor tambroides* has four bones axial vertebrae included in the Weber bone (Weberian apparatus), 19 abdominal vertebrae, 18 pairs of costal bones, 16 caudal bones vertebrae, and one urostyle bone of the vertebrae, indicating similarities in number of abdominal bones vertebrae with fish that belong to Cyprinidae.

The main morphology for *Tor tambroides* identified based on size and length of long median lobe. *Tor tambroides* (Figure 2) have long median lobe compared to two species identified in Malaysia (A=*Tor duoronensis* and C= *Tor tambra*) as shown in Figure 3 (Jaafar et al., 2021) as described in Table 1.

**Figure 2:** *Tor tambroides* with 1 cm scale (Zulfahmi et al., 2018)

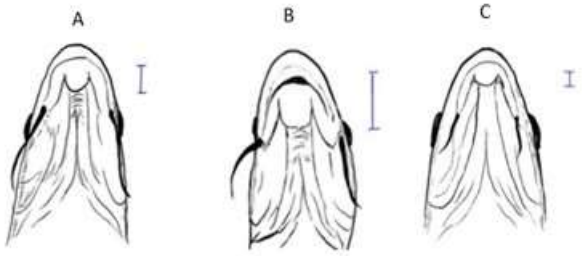


**Figure 3.** Comparisons of Masheer species based on presence of median lobe (Jaafar et al., 2021).

**Table 1.** Description of median lobe for Masheer species (Jaafar et al., 2021; Kottelat., 2013; Haryono & Tjakhrawidjaja., 2006).

| Species | Description |
|---|---|
| A *Tor duoronensis* | Lower lip with median lobe developed square lobe, thick lips, and pointed snout |
| B *Tor tambroides* | Lower lip with long median lobe, thick lips, and pointed snout |
| C *Tor tambra* | Lower lip with short median lobe, thin lips and rounded snout |

### 2.1.2 Morphology of *Tor tambra*

*Tor tambra*, also known as Mahseer, has a huge slightly extended head and mouth (Figure 4). This fish has maxillary slightly longer barbels than the rostral ones and about equal to the length of snout. The distinctive features are color of *Tor tambra* varies depending on where it is found, and it can be reddish, olive, dark, or slightly olive. The morphological features that distinguish *Tor tambra* from *Tor tambroides* include the lower median lobe's varying size and the blunt rostral hood, as well as the lack of an outer median extrapolation and an equal caudal fin as shown in Figure 5.

**Figure 4:** *Tor tambra* (Zulfahmi et al., 2020)

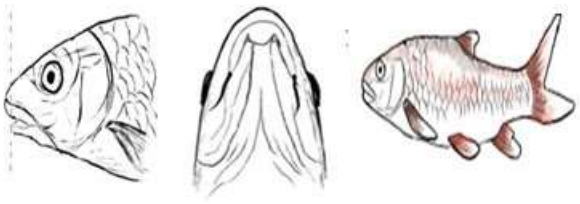


**Figure 5.** A: mouth position, B: lower median lobe, and C: Feature (Jaafar et al., 2021)

### 2.2.1 Habitat Distribution of *Tor tambroides*

*Tor tambroides* is generally found in upper stream of rivers mostly at Sarawak rivers. Continuos exploitation of this species has caused overfishing. Sportfishing activity too became another cause of the decline of this fish. Illegal, unregulated and unreported fishing (IUU) techniques such as the use of poison has disturbed breeding ground and deteriorated the population. However, impacts of IUU fishing on population dynamics of this species in the wild is less studied and although the Malayan Mahseer is not listed as a protected or endangered species by The International Union for Conservation of Nature (IUCN), the rapid decline of natural populations of *Tor tambroides* has raised awareness of the importance to prevent the extinction and reduction of *Tor tambroides* in Malaysia. A catch-and-release policy was also impost for sportfishing anglers as a prevention strategy to sustain the population of Mahseer in its natural ecosystem (Leong et al., 2020).

**Table 2.** Distribution of *Tor tambroides* in Southest Asian Country (Jaafar et al., 2021)

| Southeast Asian Country | Distribution of *Tor tambroides* |
|---|---|
| Malaysia | Peninsular Malaysia, Sabah, Sarawak |
| Indonesia | Jawa, Kalimantan, Sumatera |
| Thailand | Chou Praya, Mekong River |
| Vietnam | Nam Theun watershed (belong to the Mekong River) |
| China | Dong Nai River, Yunan |
| Brunei | Brunei-Muara, Tutong, Belait, and Temburong |

*Tor tambroides* adult is a slow moving and prefers murky turbid water. Residence of long houses located at Sungai Kapit Sarawak communicated personally that this fish prefers to swim upstream of Sungai Kapit to breed. Similar observation was reported by Aryanti et al (2021) that *Tor tambroides* is predicted to spawn uphill of streams during the months of July until September.

### 2.2.2 Habitat Distribution of *Tor tambra*

*Tor tambra* is known as one of the two recognised species of the native Tor mahseer (Chew et al., 2021). The *Tor tambra* species could be found across the trans-Himalayan area, including rivers in Pakistan, India, Sri Lanka, Bangladesh, and Myanmar while habitats of other *Tor* species also extend to most Southeast Asian countries, including Thailand, Laos, Vietnam, Malaysia, and Indonesia (Figure 6). *Tor tambra* has indeed been discovered to be biologically compatible with Mahseer populations found across mainland Southeast Asia, particularly those in Malaysia (Pinder et al., 2019). This species can be found in China's Yunnan region, Lao PDR, Thailand, Cambodia, and Vietnam, as well as in Java, Borneo (excluding western Sabah), Sumatra, and possibly the Malay Peninsula regions; the remote populations are separate species, and more investigation is needed (Kottelat 2018). *Tor tambroides* is a Cyprinidae family member that shares a biogeographical habitat with *Tor douronensis* and *Tor tambra* in Indonesian and Malaysian natural waters (Pinder et al., 2019; Lim et al., 2021). This relative species of fish is known to be a type of freshwater fish with great economic worth, thus making it a favourite fish among anglers. Rivers in tropical woods, particularly in steep locations, are home to *Tambra* fish groups and can be found in the Sumatra, Java, Malaya, Burma, Thailand, and Indochina regions (Atifah et al., 2021).


**Figure 6.** Geographical distribution of *Tor* species in the South East Asian region (Jaafar et al., 2021)

### 2.3 Farming technique of *Tor* spp.

Production of *Tor* spp can be still regarded at infancy especially for *Tor tambroides*. Several production hatcheries are currently in operation in Sarawak and also some in Peninsular Malaysia. Hatcheries are focussed in breeding broodstock in either cement or high density polyethelene (HDPE) tanks for fingerling production. Fisheries Research and Production Centre (IFRPC) Serian Sarawak, Department of Agriculture Sarawak has been among the pioneers involved in *Tor tambroides* research. Borneo Empurau Farm (BEF) is another new private fish farm in Kuching that focuses on research and development (R&D) of *Tor tambroides*, specifically on broodstock and fingerling management, nutrition, disease management and others. Another crucial success factor of culturing fish in captivity is ensuring water quality is similar to water quality in the natural ecosystem as indicated in Table 3.

**Table 3** Natural environment physiochemical characteristic at Seturan, Langap and Loreh, Indonesia (Rachmatika, et al.2005).

| Water quality parameters | Range |
|---|---|
| Temperature (ºC) | 25.26-27.30 |
| pH | 6.81-7.09 |
| Dissolved oxygen (mg/L) | 6.30-8.34 |
| Conductivity (2mS/cm) | 0.051-0.118 |
| Velocity (m/sec) | 0.27-0.86 |
| Water colour | Clear to turbid |

## 3 INDUSTRY AND MARKET STATUS OF MAHSEER IN MALAYSIA

*Tor tambroides*, which is known as the "King of the River" in Sarawak, has a high commercial value and can fetch anything from RM800 to RM1,000 per kg (Bernama 2021). Joseph (2018) has reported that the price for juvenile can reach to RM24 per tail with a total length of less than 3 inches. In comparison, price of *Tor tambra* is lower ranging from RM10 per tail (1-2 inches) to RM450 per tail (15-16 inches) depending on market supply and demand. Demand for Mahseer has expanded to outside of Malaysia, particularly in Singapore, China, Hong Kong, Macau, Taiwan and Brunei (Jackson, 2018). The present scenario indicates that the market for this lucrative fish will continue to expand as recovery for post-Covid 19 agriculture industry takes place.

## 4 BREEDING PERFORMANCE *TOR* SPP.

Although Mahseer is known for its premium market price, there is still limited research done on breeding performance of Broodstock mahseer. A successful breeding in captivity is usually dependent on hormones and nutrition. Hormone injections are usually applied in the artificial breeding of cyprinid fish broodstock in captivity (Podhorec et al., 2016; Xu et al., 2017). Similar technique was also used to stimulate breeding in *Tor* tambroides and *Tor douronensis*. Change in temperature and surroundings also play role for the spawning season. However, there are no data available for breeding performance *Tor tambra*.

## 5 FEED IN AQUACULTURE

Aquaculture in Malaysia is a fast-growing aquatic food industry in line with continuous global aquaculture production amid the worldwide spread of the COVID-19 pandemic (FAO, 2022a). Human population is expected to increase dramatically from nearly 8 billion to more than 10 billion in 2100 (Figure 7). The incremental population pattern is also putting extreme pressure on providing food security for the nation. Agricultural production is expected to increase at a slightly faster rate than population growth, from around 3000 million metric tonnes in 1961 to nearly 7000 million metric tonnes in 2010 (Boyd 2015). Fisheries accounts to approximately 20% of consumers' protein intake today is being exploited continuously is currently facing natural stock deterioration due to overfishing. The declining state of capture fisheries has resulted incremental emergence of aquaculture (Figure 8). As aquaculture is expected to rise steadily in coming years, aquaculturists and fish nutritionists are highly challenged in producing affordable feeds without jeopardizing feed quality.

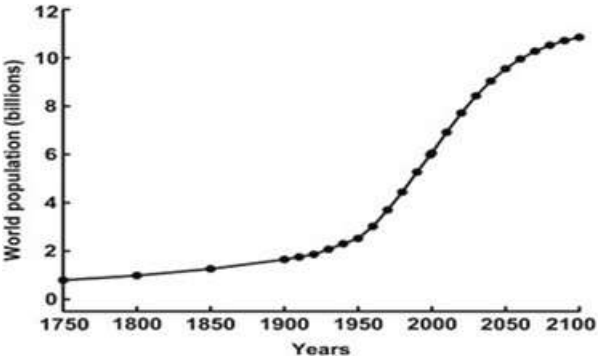


**Figure 7.** Global population estimate (Boyd 2015)

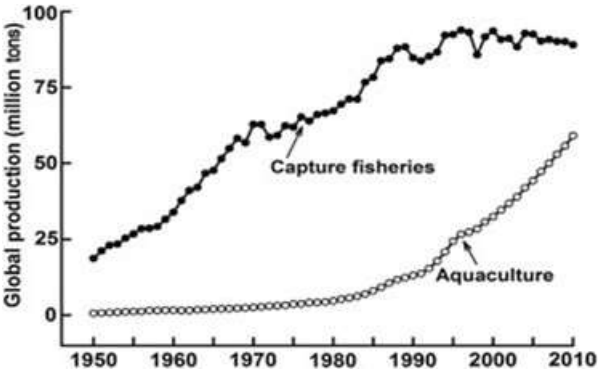


**Figure 8.** Global fisheries production by capture and aquaculture (Boyd 2015)

### 5.1 Fish Feed Ingredients

Aquaculture feed is generally rich in protein with acceptable amount of lipid, vitamins and minerals that could nourish fish requirements for good growth and high productivity. Ingredients conventionally used in fish diets are fish meal, grains, plant meal, fish oil and plant oil among others. However, pressing issues like availability of raw sources, anti-nutritional properties, sanitation and high price among others hinder production of feed.

Manufactured feeds are designed to meet dietary requirements of freshwater fish based on their growth stages and type of species. Several leading countries in freshwater aquaculture like China, Bangladesh, Vietnam, Thailand, India as well as European had established quality standards for feeds in FAO's aquaculture feed and fertilizer resources information system (FAO 2022a). The quality standards intensively prescribed feed type, shape of feed, durability of feed, crude energy based on feed type and proximate composition

properties in each respective feed (FAO 2022b). Up to today, various ingredients in Table 4 (Bélanger et al., 2021 (Trout); De Souza et al., 2019 (Tilapia); Nethaji et al., 2022 (Shrimp); Yildirim-Aksoy et al., 2020 (Chanel Catfish)) were recognised as good protein sources in fish formulated diets.

**Table 4.** Main Ingredient for some aquaculture specie (Bélanger et al., 2021; De Souza et al., 2019; Nethaji et al., 2022; Yildirim-Aksoy et al., 2020)

| | Ingredient content (%) | | | |
|---|---|---|---|---|
| | **Trout** | **Tila-pia** | **Shri-mp** | **Channel catfish** |
| **Soybean meal** | 23.0 | 52.0 | 12.0 | 45.0 |
| **Corn meal** | 17.0 | 25.5 | - | 14.0 |
| **Wheat middlings** | 16.3 | 10.0 | 4.0 | 24.0 |
| **Fish meal** | 30.0 | 9.7 | 50.0 | 8.0 |
| **Fish Oil** | 11.2 | 0.8 | - | 4.0 |

## 5.2 Farmer feed input

Good nutrition intake is crucial in producing better and healthier, convenient and economical product. Nutrition is critical issues in fish farming (aquaculture) because feed leads to increased half of the variable production cost (Eriegha & Ekokotu., 2017). In normal practice, aquaculturist would rather consider to choose feed ingredients that are easily obtained, cheaper and available at all time. In addition to that, they should also be knowledgeable on fish feeding habits for herbivorous, omnivorous, or carnivorous species, farming techniques and culture systems (Tacon & Metian., 2015). All these inputs are important factors that need to be considered in choosing feed ingredients and designing feed formulation for the chosen fish species. Good judgement and ability to comprehend these inputs would benefit feed producers in designing a good and affordable feed that can match fish farmers' buying capacity on feed. Farmer's basic knowledge on management of fish culture namely feed conversion ratio (FCR), specific growth rate (SGR), protein efficiency ratio (PER). Feed efficiency (FE) and net protein utilization (NPU) is crucial too as observation is part of feeding management. All these calculations (Table 5) are basic indicators in fish nutrition that could determine the condition of the fish as well as efficiency of fish management.

**Table 5**. Aquaculture formulation (Rahman et al., 2020)

| **Parameter** | **Formula** |
|---|---|
| Feed conversion ratio(FCR) | total dry feed fed (g) /wet weight gain (g) |
| Specific growth rate(SGR) | (ln final mean weight−ln initial mean weight/days of feeding trial) × 100 |
| Survival rate (SR) | Final count/initial count × 100 |
| Feed efficiency(FE) | Biomass gain(kg)/feed used (kg) × 100 |
| Net protein utilization(NPU) | 100 × (final−initial fish body protein)/total protein intake) |

## 5.3 Feeds suitable of *Tor tambroides* and *Tor tambra*

*Tor tambroides* and *Tor tambra* are both omnivorous feeders. They scavenge on molluscs, small fish, freshwater crustracians and plant. Natives residing near to Sungai Kapit area in Sarawak described *Tor tambroides* as fish that are able consume wild fruits that grow along the river banks of Sungai Kapit. Interestingly, it is also observed that besides consuming *Shorea macrophylla* or known as *buah engkabang* by locals of Sarawak, this fish seems to eat other fruits like ensurai (*Dipterocarpus oblongifolius)*, kelampok or jambu air (*Syzygium aqueum*), buah ara (*Ficus* sp) and even oil palm fruit (*Elaeis guineensis*). Nevertheless, little information on the contribution of these wild fruit phytochemical properties to the savoury taste of *Tor tambroides*. *Tor tambra* natural feeding habit has been studied by Muchlisin et al (2015) on Nagan and Sikundo Rivers, Aceh Province, Indonesia. The study found that *Tor tambra* diet in natural habitat consist of green algae (27.8 – 77.6%), earth worm (22.4-69.6%) and leafage (2.1%). Information on other natural diets from natural habitat are still unknown.

## 5.4 Fingerling Feed

Several feeds and feeding trials were conducted to further understand feed requirements of fingerling reared in captivity. Ng et al (2008) provided the first reported data on nutrient requirement and body composition of *Tor tambroides* through a feeding trial using five dietary protein levels from 30 to 50%. Results show that higher inclusion of protein improved

growth performance and feed conversion ratio without affecting haematocrit and body-organ indices. A similar study on dietary protein by Misieng et al (2011) reported that 40% dietary protein has significantly increased body weight gain and specific growth rate of fingerling with the lowest feed conversion ratio. Both studies clarify that protein requirement for fingerling is much higher than the requirements by other freshwater fish like tilapia (40-45%), catfish (25-36%) and freshwater giant prawn (30%).

Ng et al (2008) found that 15% dietary lipid in diet has no effect on growth performance and feed utilization efficiency. Ramezani-Fard et al (2012) observed that incremental dietary lipid from 5% to 20% significantly decreased growth performance, survival rate, and daily feed intake of Malaysian Mahseer**,** thus recommended 5% too as the suitable lipid intake for this fish. Both recommendations indicate that the optimum dietary lipid for Mahseer should not exceed 5% as excess lipid would increase dietary gross energy which is regarded as extra unutilized energy by fish. In addition, some lipid used may not be acceptable to fish such as canarium fruit oil. Fish fed with Canarium oil free diet gave significant higher growth performance with better protein efficiency ratio (Bami et al., 2017). Lipid provides fatty acids to fish muscle and other parts of fish organs. Jaya-Ram et al (2018) explained that deposition of fatty acids such as omega-3 long-chain polyunsaturated fatty acids (LC-PUFA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in fish muscle varies depending on feeding habits. Lipid can also be sourced from oil palm, which is rich in Vitamin E (Alpha tocopherol) can be regarded as a good source of vitamin E for fingerling. Muchlisin et al (2016) suggested that vitamin E from oil palm can be supplemented at 150mg $kg^{-1}$ feed.

Carbohydrate requirements for freshwater fish including Masheer is still under studied. Inclusion of different levels of carbohydrates revealed that *Tor tambroides* fingerlings suffered from hypertrophy and mild hepatic steatosis (Ishak et al., 2020). This condition suggested that lower levels at 20% to 25% could be the best concentration for optimal dietary carbohydrate for this fish without detrimental effects on liver, body weight and feed efficiency levels. The study also recommended an optimal level at 23.4% carbohydrate for fingerling stage. Ishak et al (2021) also recommended corn starch, tapioca starch, sago and taro as suitable carbohydrate sources for *Tor tambroides* fingerling.

### 5.5 Broodstock Feed

Mahseer are considered as the omnivore species where it consumes small fish, insects and mollusks (Entri 2013). Each captive rearing life stage of Mahseer fish is different as the amount and percentage of commercial feed depend on the captive phases of fish. The first 8 months of Mahseer fish (<300 g) in captivity required 32% crude protein; the eight months to 2 years (300 g to 1kg) in captivity needed floating pellet which about 40% crude protein and 5% crude fat and two till five years (> 1 kg) in captivity required 43% min crude protein and 8% crude fat (Abduh et al., 2021). Duangjai & Punroob (2018) also suggested that the optimal crude protein in commercial diet for *Tor tambroides* should be more than 32 percent crude protein because the fish may ingest it directly. Nevertheless, little information on nutrition standards for broodstock management are published. Most references on broodstock are focused mainly in improvement of spawning performance. Ingram et al. (2007) discovered 79% hatching rate for *Tor tambroides* were attained when fish are fed with seabass diet (45% crude protein,10% fat) which is considerably good for production. In comparison, fish fed with fruit and vegetable (banana, rambutan, kelampu and kelempai) as supplements to seabass diet showed lower hatching rate at 34%. As this review is focused on natural feeds and feeding of *Tor tamborides* in the natural ecosystem, further research need to be undertaken to determine effects of natural fruits consumption on Mahseer broodstock development.

### 5.6 Probiotic Feed

Probiotics are live microorganism that, when swallowed in adequate quantities through the oral cavity, confers a positive impact on the host owing to an improvement in the intestinal microbial balance and is often characterised as "a live microbial feed additive that improves the microbial balance of the host animals." (Abareethan & Amsath., 2015). This concept of probiotics has changed over time, particularly in terms of its usefulness in aquaculture. In aquaculture, the use of microbial supplement has proved critical in increasing production output by boosting the nutritional qualities of the targeted fish (Chowdhury et al., 2016). *Lactobacillus casei* is a probiotic often used in fish diets to boost growth performance and feed efficiency. Growth

performance and feed efficiency increased with increasing probiotic dosage (*Lactobacillus casei*) in the diet from control (no probiotic) to 10 ml $kg^{-1}$ of probiotic dosage and then decreased when the dosage was increased up to 15 ml $kg^{-1}$ (Muchlisin et al., 2017). This study revealed that increasing probiotic dosage in the diet from control (no probiotic) to 10 ml kg of probiotic dosage boosted growth performance and feed efficiency, but reduced when the dose was raised up to 15 ml kg. 10ml kg inclusion gave the highest weight gain (1.48 g), Specific growth rate (2.04%), Feed efficiency (42.21%), Survival rate (95.56%) and the lowest Feed conversion ratio (2.37). These are signals of good feeding using probiotic supplement. The supplementation of probiotics in diet of *Tor tambra* larvae may improve growth performance, feed efficiency, feed conversion, protein uptake, and protein digestibility.Probiotic increased villus area, villus length, and villus breadth according to Asaduzzaman et al (2018a) while Asaduzzaman et al (2018b) also who investigated hypertrophic muscle development and growth-associated gene expressions in the same *Tor tambroides* juvenile samples stated above suggest that muscle fibre hypertrophy was the primary driver of *Tor tambroides* increased growth rate.

### 5.7 Food Waste as Feed

Besides feeding on wild fruit, *Tor tambroides* also feed on pineapple crown and rind, jackfruit rind, and pulp, and dried coconut. The high ability of this fish to consume natural resources suggest promising advantages of this fish to take other food like fruit debris, dried coconut and jackfruit. as promising advantages because these materials are significantly higher in fat and contain much less ash than other fruit debris as in fact the pineapple scraps and jackfruit were high in protein and carbohydrates (Kawata et al., 2021).There are some research that studied the replacement of alternative ingredients for the fish meal feed formulation for *Tor tambroides* using a variety of food waste products from animal protein sources such as krill waste, anchovy waste head, and chicken offal (CO) to plant protein sources, soy waste and palm kernel cake (PKC). Wan (2015) assured that CO could intensively replaces the usual fishmeal of *Tor tambroides* fingerlings without any further disturbances on various factors including survival rate, the growth performances and the whole region body proximate components.

## CONCLUSION

In conclusion, this review has provided an insight on some latest information on feeds and feeding of Mahseer. As there are many unexploited and unknown prospective feeds that are available in the wild Mahseer natural ecosystem, it is timely to obtain and continue to investigate properties of these items before a feed and feeding trial is conducted. In addition, it is also crucial to understand efficacy of feeds on the gastrointestinal tract of fish so that digestibility mechanism can be understood before formulation of fish diet. This approach is suggested to minimize incorrect fish feed formulation. It is also hoped that this review may benefit in infusing more resources, both environmental and economic, into *Tor* spp research to facilitate conservation measures and propel the growing market for *Tor tambroides* and *Tor tambra* aquaculture.

## CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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## AUTHOR CONTRIBUTIONS

AIR, SNR and NAMZ: Research framework, research protocol, analyzed & interpreted the data, wrote & revised the manuscript; CFK and AK: Conceived & designed the framework; SIN, HCH WSY and FHY: provided scientific informations and insights from industry; CFK, HCH, NI, ASK and FHY: Revised and finalized the manuscript. All authors read and approved the final version.

## REFERENCES


Abareethan M, Amsath A, 2015. Characterization and evaluation of probiotic fish feed. International Journal of Pure and Applied Zoology, 3(2):148-153.

Abduh MY, Koh ICC, Abol-Munafi AB, Norazmi-Lokman, NH, Mat NN, 2021. Effects of dietary fish oil and corn oil on gonadosomatic and hepatosomatic index, gonadal histology, 17β-oestradiol level and fatty acids profile of Mahseer (*Tor tambroides*) broodstock in captivity. Aquaculture Nutrition, *27*(5):1448-1459.

Ambak MA, Ashraf AH, Budin S, 2007. Conservation of the Malaysian Mahseer in Nenggiri basin through community action. In: Siti Shapor, S., Christianus, A., Ng, C.K., De Silva, S.S. (Eds.), Mahseer: The Biology, Culture and Conservation, vol. 14. Malaysian Fisheries Society Occasional Publication, Kuala Lumpur, Malaysia, pp. 217–228.

Aqmal-Naser M, Ahmad AB, 2020 In: Kenyir Lake Fisheries Resources: Will It Last? Fishmail, 29: 20-26. Publication of the Malaysian Fisheries Society.

Aryanti NA, Susilo TSSD, Ningtyas AN, Rahmadana M, 2021. Pemodelan Spasial Kesesuaian Habitat Elang Jawa (Nisaetus bartelsi) di Taman Nasional Bromo Tengger Semeru (Spatial Modeling of Javan Hawk-Eagle (*Nisaetus bartelsi*) Habitat Suitability in Bromo Tengger Semeru National Park). Jurnal Sylva Lestari, 9(1): 179-189.

Asaduzzaman MD, Lehata S, Akter S, Kader MA, Ghosh SK, Khan MNA, Abol-Munafi AB, 2018a. Effects of host gut-derived probiotic bacteria on gut morphology, microbiota composition and volatile short chain fatty acids production of Malaysian Mahseer *Tor tambroides.* Aquaculture Reports, 9: 53-61.

Asaduzzaman MD, Sofia E, Shakil A, Haque NF, Khan MNA, Ikeda D, Abol-Munafi AB, 2018b. Host gut-derived probiotic bacteria promote hypertrophic muscle progression and upregulate growth-related gene expression of slow-growing Malaysian Mahseer *Tor tambroides*. Aquaculture Reports, 9: 37-45.

Atifah Y, Achyar A, Sumarmin R, 2021. Population of *Tambra* Fish (*Tor tambra*) in Batang Gadis River Mandailing Natal North Sumatra. In Journal of Physics: Conference Series, 1940 (1): 012067. IOP Publishing.

Bami ML, Kamarudin MS, Saad CR, Arshad A, Ebrahimi M. (2017). Effects Of Canarium Fruit (*Canarium Odontophyllum)* Oil As A Dietary Lipid Source For Juvenile Mahseer (*Tor Tambroides*). Aquaculture Reports 6: 8-20

Bélanger A, Sarker PK, Bureau D.P, Chouinard Y, Vandenberg G.W, 2021. Apparent digestibility of macronutrients and fatty Acids from microalgae (*Schizochytrium* sp.) fed to rainbow trout (*Oncorhynchus mykiss*): A potential candidate for fish oil substitution. Animals, 11(2): 456.

Bernama, 2021. Siakap vs Empurau, which is more expensive? New Straits Times. https://www.nst.com.my/news/nation/2021/11/745285/siakap-vs-empurau-which-more-expensive

Boyd CE, 2015. Overview of aquaculture feeds: Global impacts of ingredient use. In Feed and feeding practices in aquaculture. p3-25. Woodhead Publishing.

Chew PC, Christianus A, Zudaidy, JM, Ina-Salwany MY, Chong CM, Tan SG, 2021. Microsatellite Characterization of Malaysian Mahseer (*Tor* spp.) for Improvement of Broodstock Management and Utilization. Animals, 11(9): 2633.

Chowdhury AJK, Zakaria NH, Abidin ZAZ, Rahman MM, 2016. Phototrophic purple bacteria as feed supplement on the growth, feed utilization and body compositions of Malaysian Mahseer, *Tor tambroides* juveniles. Sains Malays, 45(1):135-140.

De Souza EM, De Souza RC, Melo JF, Da Costa MM, De Souza AM, Copatti CE, 2019. Evaluation of the effects of *Ocimum basilicum* essential oil in Nile tilapia diet: Growth, biochemical, intestinal enzymes, haematology, lysozyme and antimicrobial challenges. Aquaculture, 504:7-12.

Duangjai E, Punroob J, 2018. Growth performance of Mahseer fish (*Tor tambroides*) in different types of cultured environments. Eau Heritage Journal Science and Technology, 12(3): 225-235.

Ramezani-Fard E, Kamarudin MS, Saad CR, Harmin SA, Meng GY, 2012. Dietary lipid levels affect growth and fatty acid profiles of Malaysian Mahseer *Tor tambroides*. North American Journal of Aquaculture, 74(4): 530-536.

Entri DA, 2013. Determination of *Tor Tambroides* (empurau) Growth Rate Using Different Feed System (Doctoral dissertation, Universiti Malaysia Sarawak).

Eriegha OJ, Ekokotu PA, 2017. Factors affecting feed intake in cultured fish species: A review. Animal Research International, 14(2): 2697-2709.

FAO, 2022a. The State of World Fisheries and Aquaculture 2022, Towards Blue Transformation, 266p.

FAO, 2022b. Feed and feed ingredient standards. *In:* https://www.fao.org/fishery/affris/feed-and-feed-ingredient-standards/en/

Haryono H, TJAKRAWIDJAJA AH, 2006. Morphological study for identification improvement of Tambra fish (Tor spp.: Cyprinidae) from Indonesia. *Biodiversitas Journal of Biological Diversity*, *7*(1).

Ingram B, Sungan S, Tinggi D, Sim SY, De Silva SS, 2007. Breeding performance of Malaysian Mahseer, *Tor tambroides* and *T. douronensis* broodfish in captivity. Aquaculture Research, 38(8): 809-818.

Ishak SD, Razali SA, Kamarudin MS, Abol-Munafi AB, 2020. Data on PCR primer design for glucose 6-phosphate dehydrogenase gene and the effects of dietary carbohydrate levels on its expression in the liver of Malaysian Mahseer (*Tor tambroides*). Data in brief, 31:105916

Ishak SD, Yusof YA, Abol-Munafi AB, Kamarudin MS, 2021. Different starch sources in extruded diets for the Malaysian Mahseer (*Tor tambroides*) effects on growth, feed utilisation and tissue histology. J Sustain Sci Manag, 16: 94-108.

Jaafar F, Na-Nakorn U, Srisapoome P, Amornsakun T, Duong TY, Gonzales-Plasus, MM, Parhar IS, 2021. A Current Update on the Distribution, Morphological Features, and Genetic Identity of the Southeast Asian Mahseers, *Tor* species. Biology, 10(4): 286.

Jackson CA, (2018). Empurau fish farmers venture overseas. Borneo Post. https://www.pressreader.com/malaysia/the-borneo-post/20181025/281496457270438

Jaya-Ram A, Fuad F, Zakeyuddin MS, Sah ASRM, 2018. Muscle Fatty Acid Content In Selected Freshwater Fish From Bukit Merah Reservoir, Perak, Malaysia. Trop Life Sci Res. 29(2): 103–117.

Joseph M, 2018. Ternak Ikan Empurau, Termahal DI Malaysia. Berita Harian. https://www.bharian.com.my/wanita/lain-lain/2018/09/471239/ternak-ikan-empurau-termahal-di-malaysia.

Kawata Y, Yusoff FM, Khong NM, Umi DW, 2021. The economic feasibility assessment of using tropical fruit wastes in production of fish feed for the Malaysian Mahseer, *Tor tambroides* (Bleeker, 1854). Journal of Material Cycles and Waste Management, 23(3):1026-1036.

Keivany Y, 2014. Comparative osteology of the jaws in representatives of the eurypterygian fishes. Research in Zoology, 4(2): 29-42.

Kottelat M, Pinder A, Harrison A, 2018. *Tor tambroides*. The IUCN Red List of Threatened Species 2018: e.T187939A91076554. http://dx.doi.org/10.2305/IUCN.UK.20182.RLTS.T187939A91076554.en

Kottelat M, 2013. The fishes of the inland waters of Southeast Asia: A catalogue and core bibliography of the fishes known to occur in freshwaters, mangroves and estuaries. The Raffles Bulletin of Zoology 27: 1–663.

Leong KM, Torres A, Wise S, Hospital J, 2020. Beyond recreation: when fishing motivations are more than sport or pleasure. National Oceanic and Atmospheric Administration Admin Rep. H-20-05, 57p. doi:10.25923/k5hk-x319

Lim LWK, Chung HH, Lau MML, Aziz F, Gan HM, 2021. Improving the phylogenetic resolution of Malaysian and Javan Mahseer (Cyprinidae), *Tor tambroides* and *Tor tambra*: Whole mitogenomes sequencing, phylogeny and potential mitogenome markers. Gene, 791:145708.

Misieng JD, Kamarudin MS, Musa M, 2011. Optimum Dietary Protein Requirement of Malaysian Mahseer (*Tor tambroides*) Fingerling. Pakistan Journal of Biological Sciences 14(3):232-5

Muchlisin ZA, Murda T, Yulvizar C, Dewiyanti I, Fadli N, Afrido F, Muhammadar AA, 2017. Growth performance and feed utilization of keureling fish *Tor tambra* (Cyprinidae) fed formulated diet supplemented with enhanced probiotic. F1000Research, 6.

Muchlisin ZA, Arisa AA, Muhammadar AA, Fadli N, Arisa II, Siti-Azizah MN, 2016. Growth performance and feed utilization of keureling (*Tor tambra*) fingerlings fed a formulated diet with different doses of vitamin E (alpha-tocopherol). Archives of Polish Fisheries, 24*:* 47 - 52.

Muchlisin ZA, Batubara AS, Azizah MNS, Adlim M, Hendri A, Fadli NUR, Sugianto S, 2015. Feeding habit and length weight relationship

of keureling fish, Tor tambra Valenciennes, 1842 (Cyprinidae) from the western region of Aceh Province, Indonesia. Biodiversitas Journal of Biological Diversity, 16(1)

Nethaji M, Ahilan B, Kathirvelpandiyan A, Felix N, Uma A, Mosses TLS, Lingam R, 2022. Biofloc meal incorporated diet improves the growth and physiological responses of *Penaeus vannamei*. Aquaculture International, 1-20.

Ng WK, Abdullah N, De Silva SS, 2008. The dietary protein requirement of the Malaysian mahseer, *Tor Tambroides* (Bleeker), and the lack of protein-sparing action by dietary lipid. Aquaculture, 284(1-4): 201–206.

Pinder AC, Britton JR, Harrison AJ, Nautiyal P, Bower SD, Cooke SJ, Raghavan R, 2019. Mahseer (*Tor* spp.) fishes of the world: status, challenges and opportunities for conservation. Reviews in Fish Biology and Fisheries, 29(2): 417-452

Podhorec P, Socha M, Ammar IB, Sokolowska-Mikolajczyk M, Brzuska, E, Milla S, Gosiewski, G, Stejskal V, Simko M, Kouril J, 2016. The effects of GnRHa with and without dopamine antagonist on reproductive hormone levels and ovum viability in tench *Tinca tinca.* Aquaculture, 465:158–163.

Prabu E, Felix S, Felix N, Ahilan B, Ruby P, 2017. An overview on significance of fish nutrition in aquaculture industry. International Journal of Fisheries and Aquatic Studies, 5(6): 349-355.

Rachmatika I, Nasi R, Sheil D, Wan M, 2005. A First Look at the Fish Species of the Middle Malinau. Center for International Forestry Research (CIFOR), Bogor, Indonesia, 34-35. & Technology Research, 3(6): 285-292

Rahman F, Ghosh AK, Islam SS, 2020. Effect of time-restricted feeding and refeeding regimes on compensatory growth, body composition, and feed utilization in prawn (*Macrobrachium rosenbergii)* culture system. Journal of Applied Aquaculture, 32(3): 236-249.

Redhwan AI, Komilus CF, 2021. Mahsheers in Malaysia: A Review on Feed for *Tor tambroides* (Empurau) Cultured in Captivity. Campus Director's Foreword, 64.

Sawestri S, Marini M, 2021. Diversity of fish fauna in the Sembakung river, North Kalimantan, Indonesia. IOP Conf. Ser.: Earth Environ. Sci. 919: 012021

Tacon AG, Metian M, 2015. Feed matters: satisfying the feed demand of aquaculture. Reviews in Fisheries Science & Aquaculture, 23(1): 1-10.

Wan MS, 2015. Investigation of alternative ingredients for the replacement of fish meal in formulation of feed for Malaysian mahseer fingerlings, Tor Tambroides (Doctoral dissertation, UTAR).

Xu Y, Li W, Ding Z, 2017. Polyunsaturated fatty acid supplements could considerably promote the breeding performance of carp. European Journal of Lipid Science and Technology, 119(5):1600183. https://doi.org/10.1002/ejlt.201600183

Yildirim-Aksoy M, Eljack R, Beck BH, 2020. Nutritional value of frass from black soldier fly larvae, *Hermetia illucens*, in a channel catfish, *Ictalurus punctatus*, diet. Aquaculture nutrition, 26(3): 812-819.

Zhang J, Zuo Z, Sun P, Wang H, Yu A, Wang C, 2012. Tributyltin exposure results in craniofacial cartilage defects in rockfish (*Sebastiscus marmoratus*) embryos. Marine environmental research, *77*: 6-11.

Zulfahmi I, Akmal Y, Batubara AS, 2018. The morphology of Thai Mahseer's *Tor tambroides* (Bleeker, 1854) axial skeleton (ossa vertebrae). Jurnal Iktiologi Indonesia, 18(2): 139-149.

Zulfahmi I, Akmal Y, Radhi M, Hidayat M, Muliari M, 2020. Comparative osteology of Tor tambroides (Bleeker, 1854) and Tor tambra (Valenciennes 1842) vertebral column (ossa vertebrae). *Jurnal Iktiologi Indonesia*, *20*(3), 235-249.