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UTILISATION OF INSECTS IN ORNAMENTAL FISH NUTRITION: A REVIEW

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Abstract

Starting from the limitations surrounding fishmeal and the relevance of ornamental fish farming, this paper highlights the possibility of utilizing insects in their diet. Based on the scientific literature, specific nutritional requirements of ornamental fish and the valuable properties of certain insects were identified. Furthermore, experiments using insect protein biomass and artificial feeds formulated with varying percentages of insect meal for feeding ornamental fish were thoroughly analysed. It was demonstrated that insect meal can be included in the diets of goldfish and zebrafish at levels of 60% and 100% without adversely affecting growth or welfare, while for the Siamese fighting fish, the optimal level is 13%. In guppies and swordtails, testing inclusion levels of 50-75-100% yielded results indicating the potential for the complete replacement of fishmeal in their diet. The analysed experiments highlighted that ornamental fish are capable of assimilating nutrients and carotenoids from the composition of certain insects. A positive influence on fish health and coloration was observed, and significant performance was recorded regarding the survival and growth of fry in several freshwater and marine species.

Key words*: food, insects, ornamental fish.*

INTRODUCTION

It is estimated that a significant portion of the pet market revenue is derived from food production and distribution (Kowalska et al., 2021). Fishmeal and fish oil represent the most critical ingredients utilized in the formulation of nutritionally and energetically complete feeds (https://sealineexports.in/the-role-of-fish-meal-in-pet-food-formulations/; https://www.999.dk/en/products-and-segments/segments/pet-food/). The rising costs of fishmeal and fish oil, the depletion of oceanic fish stocks, and the imposed restrictions on their usage (FAO, 2024, 2025; OECD, 2025) are factors driving the identification and investigation of potential substitutes for these feed components (Alfiko et al., 2022; Sales & Janssens, 2003; Shepherd & Jackson, 2013; Turek et al., 2020). Recent studies and research consider insects to be a sustainable source of proteins with high biological value (Cullere et al., 2019; Fantatto et al., 2024; Motte et al., 2019; Surendra et al., 2016). Insect protein biomass is expected to command a market similar to that of fishmeal, with significant potential for use in aquaculture, livestock, and pet feed production (Freccia et al, 2020; Ragozzino-Paulino et al., 2025; Tomberlin et al., 2015; van Huis et al., 2013; Vrij, 2013). In this regard, since 2017, the European Union has approved the Regulation concerning the use of insect meal in aquaculture and pet food (EC 2017/893). Rearing and maintaining aquarium fish is emerging as one of the most popular hobbies (Maia et al., 2025; Miller-Morgan, 2010; Valdez & Mandrekar, 2019). The first public aquariums appeared as early as the 19th century, and it is estimated that there are more than 300 internationally (Karydis, 2011; Penning et al., 2009). Through its complexity and diversity, the aquarium industry has contributed and continues to contribute to the development of scientific research in various fields (Almunia et al., 2024; Safian et al., 2021; Novák et al., 2025).

The international trade in ornamental fish is a substantial industry, which has grown steadily (14%) since 1970 (Arapi & Cable, 2025; Novák et al., 2022; Valdez & Mandrekar, 2019). Its

market value is in the billions of dollars and encompasses over 5,300 freshwater species and 1,800 marine species (Evers et al., 2019; Marchio, 2018; Penning et al., 2009; Raghavan et al., 2013). The field's contribution to the global economy is therefore significant, and the captive breeding and rearing of an increasing number of species is of current interest to many countries (Lafi & Al-Shammari, 2025; Novák et al., 2022, 2025). Nutrition and feeding, along with ensuring water quality and organism welfare, are defining factors for the successful rearing of ornamental fish (Karydis, 2011; Sirimanna & Dissanayake, 2019). Within this general context, the present work highlights the possibility of utilizing insects for feeding ornamental fish.

MATERIALS AND METHODS

A thorough review of the scientific literature was performed to identify studies addressing the use of insects in ornamental fish food. Several major scientific databases were consulted, including PubMed, Google Scholar, Web of Science, Scopus, and ScienceDirect. The search approach relied on combinations of terms relevant to the subject area. Among the main search terms employed were "ornamental", "fish", "insects", "aquafeeds", "requirements", "nutrition" and "protein".

RESULTS AND DISCUSSIONS

NUTRITIONAL PARTICULARS OF ORNAMENTAL FISH

To ensure proper nutrient digestibility and support the metabolic requirements of aquarium organisms, a correct dietary intake is essential (Altaff et al., 2015). Both the feed and its ingredients must contain nutrients and energy sources vital for growth and development, depending on the species, life stage, and physiological state of the fish (NRC, 1993). There is limited research regarding the nutritional requirements of ornamental fish, and most information is based on results obtained from the aquaculture of food fish species (Pour et al., 2014; Sales & Janssens, 2003; Sicuro, 2018; Velasco-Santamaría & Corredor-Santamaría, 2011). However, it must be considered that certain differences exist. In ornamental fish farming, the primary objectives are colour enhancement and fish welfare; the feeding behaviour of each species is distinct, the quantitative feed requirement is lower, and the life cycle is longer (Altaff et al., 2015; Karydis, 2011; Sicuro, 2018). Nutritional requirements can be established for energy, proteins and amino acids, lipids, minerals, and vitamins (NRC, 1993). Specific nutritional values for some of the most well-known freshwater ornamental species are presented in Table 1. Protein is considered the most important nutrient for growth and development, and the requirement is dependent on the amino acid profile and digestibility (Miller & Mitchell, 2009; Nogales-Merida et al., 2019; Sirimanna & Dissanayake, 2019). These nutritional exigencies remain unchanged regardless of the source or type of feed. Under natural conditions, most fish rely on a protein-rich diet (Miller & Mitchell, 2009). In contrast to herbivorous and detritivorous species, omnivorous and carnivorous fish require a higher proportion of dietary protein (Henry et al., 2015; Nogales-Merida et al., 2019). Under aquarium conditions, it is crucial that fish utilize dietary proteins efficiently, as the resulting decomposition products have major implications for the living environment and, consequently, for the welfare of the organisms (Altaff et al., 2015; Sales & Janssens, 2003).

Table 1. Proximate composition of diets utilized for feeding aquarium fish*

Specification	Crude protein [%]	Crude fat [%]	Crude fiber [%]	Vitamin and Mineral [%]
Earlier stage	40-45	4-6	-	1-2
Adult	30-40	6-8	-	1-2
C. auratus	40-59	3.5-13.8	1-3	3
P. latipina	30-40	6-10	-	5
P.reticulata	15-52	3-9	6-8	5
P. sphenops	20-59	9.0-9.5	3.0-4.6	3
T.trichopterus	30-40	6-10	-	5
X. helleri	50	16	5	2-5
X. maculatus	18.3-26.3	4.9-5.9	2.2-8.8	-

*Data are compiled from published literature (Abdul Khader & Altaff, 2021; Fernando et al., 1991; Harsha Haridaet al., 2019; Mohanta & Subramanian, 2011; Pour et al., 2014; Sales & Janssens, 2003; Sirimanna & Dissanayake, 2019; Tamaru et al., 2001).

THE PRACTICE OF UTILIZING INSECTS IN FOOD FOR AQUATIC SPECIES

The exceptional properties of insects have been demonstrated through chemical assays. Insects are characterized by a high crude protein content and other nutrients (Table 2), comparable to those of fishmeal and soybean meal - the most

common ingredients used in aquafeed production (Barroso et al., 2014; Irungu et al., 2018). Their nutritional value is further characterized by a well-balanced essential amino acid profile, high lipid content, and also includes vitamins and minerals (Fantatto et al., 2024). The concentration of these nutritional components is strongly influenced by the species, the developmental stage, the nature of the growth substrate, and the extraction and processing methods (Makkar et al., 2014). Similarly, the lipid content and fatty acid profile are diet-dependent and can be adjusted by modifying the substrate (Georgescu et al., 2022). The presence of chitin in the insect exoskeleton may restrict its use in fish feed (Alfiko et al., 2022). On the other hand, positive influences have been reported by adding small amounts of chitin to aquatic feeds; furthermore, it has been proven that certain fish species can effectively utilize feed containing chitin (Georgescu et al., 2025; Tran et al., 2015).

Table 2. Nutritional value of some insect species

Specification	Crude protein [%]	Crude fat [%]	Crude fiber [%]	Ash [%]	Gross energy [MJ/ kg]
Fish meal Soy meal	70.6 51.8-55.2	9.9 1.7-2.0	- 4.4	- 7.3	- 20.0
Tenebrio molitor	52.8	36.1	2-5	3.1	26.8
Zophobas morio meal	49.3	33.6	5.7	2.9	26.8
Musca domestica maggot meal pupae meal larvae	 50.4 70.8 49.2	 18.9 15.5 17.5	 5.7 15.7 5.1	 10.1 7.7 10.2	 22.9 24.3 -
Hermetia illucens larvae meal	 42.1 41.8	 26.0 24.9	 7.0 8.8	 20.6 10.8	 22.1 -
Bombyx mori meal	 23.1-75.6	 4.7-14.2	 3.9-6.6	 1.2-6.8	 9.6
Galleria mellonella	38.8	51.4-58.6	8.9	2.2-3.3	-
Acheta domestica imago meal	 66.6 62.3	 22.1 13.3	 3.2 8.6	 3.6 8.4	 - -
Gryllodes sigillatus	45.0-70.0	16.8-18.2	3.6-11.8	4.7	19.0
Schidtocerca gregaria	76.0	13.0	2.5	3.3	18.0

*Data are compiled from published literature (Hawkey et al., 2021; Irungu et al., 2018; Kowalska et al., 2021; Makkar et al., 2014; Tran et al., 2015).

In accordance with EU legislation, eight insect species have been approved for use in aquaculture (Alfiko et al., 2022; EC 2017/893); among these, the black soldier fly (*H. illucens*), the housefly (*M. domestica*), the yellow mealworm (*T. molitor*), and crickets (*A. domestica, G. sigillatus*) are among the most extensively tested and utilized.

Preliminary studies and research on replacing fishmeal with insect meal have been conducted on various aquaculture species (Alfiko et al., 2022; Bake et al., 2021; Irungu et al., 2018; Magalhães et al., 2017; Motte et al., 2019; Oteri et al., 2021; Renna et al., 2017; Stamer et al., 2014; Tilami et al., 2020). According to these, it has been proven that many species efficiently utilize feed containing insects (Kowalska et al., 2021), and some experiments conducted on ornamental fish have reported that their diets can consist of insect protein biomass; furthermore, fishmeal in artificial feeds can be replaced with insect meal. In an attempt to determine the potential of insects as feed for ornamental fish, Das (2023) evaluates the growth, survival, and coloration of platy (*X. maculatus*) fed with three types of insects (grasshoppers, crickets, and mealworms) that were dried and crushed. At the end of the experiment, the results showed differences in favor of the groups fed with insects compared to the control group, which was fed with commercial feed. Some conclusions have also emerged indicating that a diet consisting of insects can be successfully administered, as the species is capable of assimilating the nutrients and carotenoids within their composition. The use of fishmeal has been tested on highly valued ornamental fish species (Table 3).

Table 3. Substitution of fishmeal with insect meal in the diet of some ornamental fish species

Insect species	Fish species	Replacement %	References
HI	*Amphiprion ocellaris*	25-50-75	Vargas-Abúndez et al., 2019
HI	*Betta splendens*	6.5-13-19.5-24.5	Kari et al., 2023
ZM	*Carassius auratus*	25-50-75-100	Das et al., 2024
HI	*Carassius auratus*	20-40-60-80-100	Kamalii et al., 2023
HI	*Cyprinus carpio* var. *koi*	25-50-75-100	Linh et al., 2024
HI	*Danio rerio*	25-50-75-100	Zarantoniello et al., 2021
AD GB	*Poecilia reticulate*	50-75-100	Perera & Bhujel, 2022
AD GB TM	*Xiphophorus helleri*	100	Perera et al., 2025.

AD - *Acheta domesticus*; GB - *Gryllus bimaculatus;* HI - *Hermetia illucens*; TM - *Teleogryllus mitratus*; ZM - *Zoophobas morio*.

In the Siamese fighting fish (*B. splendens*), in an experiment conducted by Kari et al. (2023), different inclusion percentages of insect meal in the feed were tested, and the results showed that at a level of 13%, growth and health status are improved. Research conducted by Das et al. (2024) highlights that in goldfish (*C. auratus*), it is possible to completely replace fishmeal with superworm meal (*Z. morio*). The research results indicate improved performance in terms of growth and survival, as well as fish coloration. The study by Kamalii et al. (2023) also focuses on the use of insect meal in goldfish. In an attempt to include different levels of black soldier fly larvae meal (*H. illucens*) in the diet of juveniles, the findings demonstrate better growth and feed utilization and specifically recommend 60% to ensure fish welfare. In another study conducted by Linh et al. (2024) on ornamental carp (*C. carpio* var. *koi*), results were obtained indicating the ability of *H. illucens* larvae meal to replace fishmeal and fish oil; furthermore, it is recommended as a possible way to increase disease resistance. The aquarium fish *Danio rerio* is validated as a model organism, so experiments are conducted, including on nutrition and feeding, which can also be extrapolated to aquaculture fish.

According to a detailed study conducted by Zarantoniello et al. (2021), it was highlighted that, through nutritional programming, fishmeal can be 100% substituted with *H. illucens* prepupae meal without negatively affecting fish growth and welfare. Other research also confirms the possibility of partial or total replacement of fishmeal with *H. illucens* meal in the diet of zebrafish, without affecting production parameters (Barca et al., 2023; Fronte et al., 2021). Given the need for sustainable ingredients for feed formulation, the objective of the study by Vargas-Abúndez et al. (2019) was to develop insect-based diets for clownfish (*A. ocellaris*), which is one of the most popular marine ornamental fish and is also considered a model organism. By using experimental diets with different levels of *H. illucens* meal, results with favorable perspectives were obtained, with no negative effects recorded on fish growth and survival. In the feed of viviparous fish, fishmeal was replaced with cricket meal. In the experiments conducted by Perera & Bhujel (2022) and Perera et al. (2025), it was proven that it can completely replace fishmeal without affecting the growth performance of guppy (*P. reticulata*) and swordtail (*X. helleri*). Additionally, the findings indicate the potential of using cricket meal in ornamental fish feed without the need for additives to enhance fish coloration.

CONCLUSIONS

Similar to food fish aquaculture, for production to be efficient, the feeding of aquarium organisms must be carried out in accordance with species requirements and depending on the ontogenetic stage and physiological state. The proven effect of insects on the growth and welfare of aquaculture organisms recommends their use in the production of feed for ornamental fish farming. The trend towards developing sustainable products is a current priority. The ability of some species to assimilate nutrients and carotenoids from certain insects can contribute to the elimination of taste attractants and color enhancers from ornamental fish feed. The development of insect-based artificial feeds can constitute an economic advantage for the ornamental fish industry.

REFERENCES

Abdul Khader, S. M., & Altaff, K. (2021). Influence of Different Types of Diets on the Growth Performance of Juvenile Guppies (*Poecilia reticulata* Peters, 1859). *Jurnal Mangifera Edu, 5*(2), 93-102. https://doi.org/10.31943/mangiferaedu.v5i2.105.

Alfiko, Y., Xie, D., Astuti, R.T., Wong, J., & Wang, L. (2022). Insects as a feed ingredient for fish culture: Status and trends. *Aquaculture and Fisheries*, 7, 166–178.

Altaff, K., Sumithra, V., Janakiraman, A., & Hyder, A.A. (2015). Growth and survival of fingerlings of black molly (*Poecilia sphenops*) with different animal protein based formulated diets. *International Journal of Pure and Applied Zoology, 3*(4), 375-381.

Almunia, J., Fernandez-Maquierira, M., & Flores, M. (2024). Aquariums as Research Platforms: Characterizing Fish Sounds in Controlled Settings with Preliminary Insights from the Blackbar Soldierfish *Myripristis jacobus*. *Journal of Zoological and Botanical Gardens,* 5, 630–640. https://doi.org/10.3390/jzbg5040042.

Arapi, E.A., & Cable, J. (2025). Survey-based insights into treatments of infectious diseases in freshwater ornamental fish in the UK. *Academia Biology*, 3, 1-10. https://doi.org/10.20935/AcadBiol7832.

Barroso, F.G., de Haro, C., Sánchez-Muros, M.J., Venegas, E., Martínez-Sánchez, A., & Pérez-Bañón,

C., (2014). The potential of various insect species for use as food for fish. *Aquaculture*, 422–423, 193–201.

Bake, G.G., Ajibade, D.O., Gana, A.B., Yakubu, F.B., Samaila, J., Abdulkarim, I.A., Igili, O.E., Sadiku, S., & Gatlin, D.M. (2021). Growth performance, body composition, and apparent nutrient digestibility of hybrid catfish fingerlings fed with blended insect meal. *Nigerian Journal of Fisheries, 18*(1), 2118–2128.

Cullere, M., Schiavone, A., Dabbou, S., Gasco, L., & Dalle, Zotte A. (2019). Meat quality and sensory traits of finisher broiler chickens fed with black soldier fly (*Hermetia illucens* L.) larvae fat as alternative fat source. *Animals, 9*(4), 140, 1-15. https://doi.org/10.3390/ani9040140.

Das, M. (2023). Effect of Insect Meals on the Growth Efficiency, Survival and Total Carotenoid Content of an Ornamental Fish *Xiphophorus maculatus* (Gunther, 1866). *Asian Journal of Fisheries and Aquatic Research, 22*(3), 1–9. https://doi.org/10.9734/ajfar/2023/v22i3570.

Das, M., Mondal, M., Ambiya, Md. G., Basu, A., Bej, A., Mistry, I. (2024). Dietary fishmeal protein replacement with superworm (*Zophobas morio*) larvae meal: Effect on growth, feed utilization, survival, digestive enzyme activity, skin colour enhancement of juvenile goldfish, *Carassius auratus*. *International Journal of Biosciences, 25*(5), 238-251.

Evers, H.G., Pinnegar, J.K., & Taylor, M.I. (2019). Where are they all from? Sources and sustainability in the ornamental freshwater fish trade. *Journal of Fish Biology,* 94, 909–916.

Fantatto, R.R., Mota, J., Ligeiro, C., Vieira, I., Guilgur, L.G., Santos, M., & Murta, D. (2024). Exploring Sustainable Alternatives in Aquaculture Feed: The Role of Insects. *Aquaculture Reports*, 37, 102228. 1-13.

FAO (2024). *The State of World Fisheries and Aquaculture 2024 – Blue Transformation in action*. Rome. https://doi.org/10.4060/cd0683en. Downloaded on 09.04.2025.

FAO (2025). *Responsible use of fishmeal in aquaculture*. FAO Innovation for Blue Transformation. Rome. Downloaded on 09.04.2025.

Fernando, A.A., Phang, V.P.E., & Chan, S.Y. (1991). Diets and feeding regimes of Poeciliid fishes in Singapore. *Asian Fisheries Science*, 4, 99-107.

Freccia, A., Sergio Bee Tubin, J., Nishioka Rombenso, A., & Gustavo Coelho Emerenciano, M. (2020). Insects in Aquaculture Nutrition: An Emerging Eco-Friendly Approach or Commercial Reality? In Lu, Q., & Serajuddin, M. (Eds), *Emerging Technologies, Environment and Research for Sustainable Aquaculture* (1-14). *IntechOpen.* DOI: 10.5772/intechopen.90489.

Fronte, B., Licitra, R., Bibbiani, C., Casini, L., De Zoysa, M., Miragliotta, V., Sagona, S., Coppola, F., Brogi, L., & Abramo, F. (2021). Fishmeal Replacement with *Hermetia illucens* Meal in Aquafeeds: Effects on Zebrafish Growth Performances, Intestinal Morphometry, and Enzymology. *Fishes*, 6, 28. 1-16. https://doi.org/10.3390/fishes 6030028.

Georgescu, B., Boaru, A.M., Muntean, L., Sima, N., Struti, D.I., Papuc, T.A., & Georgescu, C. (2022). Modulating the Fatty Acid Profiles of *Hermetia illucens* Larvae Fats by Dietary Enrichment with Different Oilseeds: A Sustainable Way for Future Use in Feed and Food. *Insects,* 13, 801, 1-16. https://doi.org/10.3390/insects13090801.

Georgescu, B., Georgescu, C., Păpuc, T., Vasiu, M., Struti, D., Boaru, A. (2025). The Performance of Protein Meal from *Hermetia illucens* Larvae in Hetero-Clarias Hybrid Farming. *Insects*, 16, 1279, 1-15. https://doi.org/10.3390/insects16121279.

Hawkey, K. J., Lopez-Viso, C., Brameld, J. M., Parr, T., & Salter, A. M. (2021). Insects: A Potential Source of Protein and Other Nutrients for Feed and Food. *Annual review of animal biosciences*, 9, 333–354. https://doi.org/10.1146/annurev-animal-021419-083930.

Harsha Haridas, Saravanan, K., Praveenraj, J., Ravindra Sontakke, Gladston, Y., Ajina, S.M., Deepitha, R., Sreepriya Prakasasn, Kiruba Sankar R., & Dam Roy, S. (2019). Training Manual on freshwater ornamental fish breeding and Aquascaping Techniques. *ICAR-CIARI,* Port Blair, India. 39 pp.

Henry, M., Gasco, L., Piccolo, G., & Fountoulaki, E., (2015). Review on the use of insects in the diet of farmed fish: Past and future. *Animal Feed Science and Technology,* 203, 1-22.

Kamalii, A., Antony, C., Ahilan, B., Uma, A., & Prabu, E. (2023). Dietary Protein Replacement of Fish Meal with Black Soldier Fly Larvae Meal: Effects on Growth, Whole-Body Composition, Digestive Enzyme Activity, Muscle-Growth-Related Gene Expression and Haemato-Biochemical Responses of Juvenile Goldfish, *Carassius auratus*. *Turkish Journal of Fisheries and Aquatic Sciences, 23* (2), TRJFAS21837. 1-11. http://doi.org/10.4194/TRJFAS21837.

Kari, Z.A., Téllez-Isaías, G., Hamid, N.K.A., Rusli, N.D., Mat, K., & Wei, L.S. (2023). Effect of Fish Meal Substitution with Black Soldier Fly (*Hermetia illucens*) on Growth Performance, Feed Stability, Blood Biochemistry, and Liver and Gut Morphology of Siamese Fighting Fish (*Betta splendens*). *Aquaculture Nutrition*, 6676953, 1-15. https://doi.org/10.1155/2023/6676953.

Karydis, M. (2011). Organizing a public aquarium: objectives, Design, operation and missions. A review. *Global NEST Journal, 13* (4), 369-384.

Kowalska, J., Rawski, M., Homska, N., Mikołajczak, Z., Kierończyk, B., Świątkiewicz, S., Wachowiak, R., Hetmańczyk, K., & Mazurkiewicz, J. (2021). The first insight into full-fat superworm (*Zophobas morio*) meal in guppy (*Poecilia reticulata*) diets: a study on multiple-choice feeding preferences and growth performance. *Annals of Animal Science*, 22, 371-384

Irungu, F. G., Mutungi, C., Mutungi, C., Faraj, A. K., Affognon, H., Kibet, N., Tanga, C. M., Ekesi, S., Nakimbugwe, D., & Fiaboe, K. K. M. (2018). Physico-chemical properties of extruded aquafeed pellets containing black soldier fly (*Hermetia illucens*) larvae and adult cricket (*Acheta domesticus*) meals. *Journal*

of Insects as Food and Feed, 4(1), 19–30. https://doi.org/10.3920/JIFF2017.0008.

Lafi, R.M.S., & Al-Shammari, N.A.H. (2025). The status of ornamental fish in scientific research: Trends and themes. *Veterinary Sciences: Research and Reviews, 11*(2), 252-264.

Linh, N. V., Wannavijit, S., Tayyamath, K., Dinh-Hung, N., Nititanarapee, T., Sumon, M. A. A., Srinual, O., Permpoonpattana, P., Doan, H. V., & Brown, C. L. (2024). Black Soldier Fly (*Hermetia illucens*) Larvae Meal: A Sustainable Alternative to Fish Meal Proven to Promote Growth and Immunity in Koi Carp (*Cyprinus carpio* var. koi). *Fishes*, 9, 53. 1-16. https://doi.org/10.3390/fishes9020053.

Magalhães, R., Sánchez-López, A., Leal, R.S., Martínez-Llorens, S., Oliva-Teles, A., & Peres, H. (2017). Black soldier fly (*Hermetia illucens*) pre-pupae meal as a fish meal replacement in diets for European seabass (*Dicentrarchus labrax*). *Aquaculture*, 476, 79–85. https://doi.org/10.1016/j.aquaculture.

Maia, C.M., Gauy, A.C.D.S., & Gonçalves-de-Freitas, E. (2025). Fish Welfare in the Ornamental Trade: Stress Factors, Legislation, and Emerging Initiatives. *Fishes*, 10, 224. 1-16. https://doi.org/10.3390/.

Makkar, H.P.S., Tran, G., Heuzén, V., & Ankers, P. (2014). State-of-the-art on use of insects as animal feed. *Animal Feed Science and Technology*, 197, 1-33.

Marchio, E.A. (2018). The Art of Aquarium Keeping Communicates Science and Conservation. *Frontiers in Communication,* 3, 17, 1-9. doi: 10.3389/fcomm.2018.00017.

Miller-Morgan, T. (2010). *A Brief Overview of the Ornamental Fish Industry and Hobby*. In: Roberts, H.E. (Ed.), Fundamentals of Ornamental Fish Health (pp. 25-32). USA: Blackwell Publishing House.

Miller, S.M.& Mitchell, M.A. (2009). *Ornamental fish.* In: Mitchell M.A., Tully T.N. (Eds.), Manual of Exotic Pet Practice (pp. 39-72). Amsterdam, NL: 10.1016/B978-141600119-5.50007-X.

Mohanta, K.N. & Subramanian, S. (2011). Nutrition of Common Freshwater Ornamental Fishes. *Technical Bulletin*, 27, 1-60.

Motte, C., Rios, A., Lefebvre, T., Do, H., Henry, M., & Jintasataporn, O. (2019). Replacing Fish Meal with Defatted Insect Meal (Yellow Mealworm *Tenebrio molitor*) Improves the Growth and Immunity of Pacific White Shrimp (*Litopenaeus vannamei*). *Animals*, *9*(5), 258. https://doi.org/10.3390/ani9050258.

National Research Council (NRC). (1993). *Nutrient requirements of fish.* National Academy Press, Washington DC.

Nogales-Mérida, S., Gobbi, P., Józefiak, D., Mazurkiewicz, J., Dudek. K., Rawski, M., Kieronczyk, B. & Jozefiak, A. (2019). Insect meals in fish nutrition. *Reviews in Aquaculture*, 11. 1080-1103.

Novák,J., Barroso Magalhães, A.L., Faulkes, Z., Yonvitner, A.M.V., Dahanukar, N., Kawai, T., Kalous, L., Patoka, J. (2022). Ornamental aquaculture significantly affected by the "Czech aquarium phenomenon". *Aquaculture*, 555, 738259. 1-14. https://doi.org/10.1016/j.aquaculture.2022.738259.

Novák, J., Hohl, D., Stuchlík, M., Hofmann, J., Tlusty, M., Magalhães, A., Maceda-Veiga, A., Akmal, S., Yue, G., Kumkar, P., Marr, S., Sara, J., Stern, N., Rhyne, A. L., Furse, J., Kalous, L., & Patoka, J. (2025). Revisiting the History of Ornamental Aquaculture in Europe to Understand the Benefits and Drawbacks of Freshwater Fish Imports. *Reviews in Aquaculture, 17* (2). 1-21. https://doi.org/10.1111/raq.13008.

OECD (2025). *OECD Review of Fisheries 2025*, OECD Publishing, Paris, https://doi.org/10.1787/560cd8fc-en. Downloaded on 16.04.2025.

Oteri, M., Di Rosa, A.R., Lo Presti, V., Giarratana, F., Toscano, G., & Chiofalo, B. (2021). Black Soldier Fly Larvae Meal as Alternative to Fish Meal for Aquaculture Feed. *Sustainability*, 13, 5447. 1-17. https://doi.org/10.3390/su13105447.

Penning, M., Reid, G. McG., Koldewey, H., Dick, G., Andrews, B., Arai, K., Garratt, P., Gendron, S., Lange, J., Tanner, K., Tonge, S., Van den Sande, P., Warmolts, D., & Gibson, C. (Eds). (2009). Turning the Tide: A Global Aquarium Strategy for Conservation and Sustainability. *World Association of Zoos and Aquariums*, Bern, Switzerland, 1-90.

Perera, C.G.S., & Bhujel, R.C., (2022). Replacement of fishmeal by house cricket (*Acheta domesticus*) and field cricket (*Gryllus bimaculatus*) meals: Effect for growth, pigmentation, and breeding performances of guppy (*Poecilia reticulata*). *Aquaculture Reports*, 25, 101260, 1-9.

Perera, G.C., Senanayake, S.N., Sandaruwani, D., Salgadu, M.K.S., Rajapakshe, A., & Athauda, S. (2025). Replacement of Fishmeal by Three Cricket Meals (*Acheta domesticus*, *Gryllus bimaculatus*, *Teleogryllus mitratus*) in Swordtail (*Xiphophorus helleri*) Fry Feed: Effect of Growth, Stress Tolerance, Pigmentation and Histopathological Alterations. *Turkish Journal of Fisheries and Aquatic Sciences*, 25, TRJFAS26460. 1-10. http://doi.org/10.4194/TRJFAS26460.

Pour, F., Maniat, M., Vahedasl, A., & Ghayem, S. (2014). Enhancement of growth performance and body composition in molly fish (*Poecilia sphenops*) associated with dietary intake of garlic (*Allium sativum*). *International Journal of Biosciences, 5*(8). 115-121.

Raghavan, R., Dahanukar, N., Tlusty, M.F., Rhyne, A.L., Krishna Kumar, K., Molur, S., & Rosser, A.M. (2013). Uncovering an obscure trade: Threatened freshwater fishes and the aquarium pet markets. *Biological Conservation,* 164, 158–169.

Ragozzino-Paulino, P., Cocato, M.L., & de Souza Sarkis, J.E. (2025). Nutritional Potential of Edible Insects as Alternative Ingredients in Fish Feed: A Path to Modern Aquaculture. *Aquaculture Nutrition*, 28, 7009004. 1-30. Doi: 10.1155/anu/7009004.

Renna, M., Schiavone, A., Gai, F., Dabbou, S., Lussiana, C., Malfatto, V., Prearo, M., Capucchio, M. T., Biasato, I., Biasibetti, E., De Marco, M., Brugiapaglia, A., Zoccarato, I., & Gasco, L. (2017). Evaluation of the suitability of a partially defatted black soldier fly (*Hermetia illucens* L.) larvae meal as ingredient for rainbow trout (*Oncorhynchus mykiss* Walbaum) diets.

Journal of Animal Science and Biotechnology, 8, 57. 1-13. https://doi.org/10.1186/s40104-017-0191-3.

Safian, D., Wiegertjes, G.F., & Pollux, B.J.A. (2021). The fish family Poeciliidae as a model to study the evolution and diversification of regenerative capacity in vertebrates. *Frontiers Ecology Evolution*, 9, 613157, 1-15. Doi:10.3389/fevo.2021.613157.

Sales, L. & Janssens, G.P.J. (2003). Review Nutrient requirements of ornamental fish. *Aquatic Living Resources*, 16, 533-540.

Shepherd, C.J., & Jackson A.J. (2013). Global fishmeal and fish-oil supply: inputs, outputs and markets. *Journal Fish Biology, 83*(4), 1046-1066.

Sicuro, B. (2018). Nutrition in ornamental aquaculture: the raise of anthropocentrism in aquaculture? *Reviews in Aquaculture*, 10, 791-799.

Sirimanna, S.R., & Dissanayake, C. (2019). Effects of culture conditions on growth and survival of *Poecilia sphenops* and *Poecilia reticulata*. *International Journal of Aquatic Biology, 7*(4), 202-210. https://doi.org/10.22034/ijab.v7i4.570.

Stamer, A., Wesselss, S., Neidigk, R., Hoerstgen-Schwark, G. (2014). Black soldier fly (*Hermetia illucens*) larvae-meal as an example for a new feed ingredients' class in aquaculture diets. *Proceedings of the 4th ISOFAR Scientific Conference, 'Building Organic Bridges'*, 1043-1046.

Surendra, K.C., Olivier, R., Tomberlin, J.K., Jha, R., & Khanal, S.K. (2016). Bioconversion of organic wastes into biodiesel and animal feed via insect farming. *Renewable Energy*, 98, 197–202.

Tamaru, C.S., Cole, B., Bailey, R., Brown, C. & Ako, H. (2001). A Manual for Commercial Production of the Swordtail, *Xiphophorus helleri*. *CTSA Publication*, 128, 1-38. Downloaded on 2025.08.10.

Tilami, S.K., Turek, J., Červený, D., Lepič, P., Kozák, P., Burkina, V., Sakalli, S., Tomčala, A., Sampels, S., & Mráz, J. (2020). Insect Meal as a Partial Replacement for Fish Meal in a Formulated Diet for Perch *Perca fluviatilis*. *Turkish Journal of Fisheries and Aquatic Sciences*, 20. 867-878. http://doi.org/10.4194/1303-2712-v20_12_03.

Tomberlin, J.K., van Huis, A., Benbow, M.E., Jordan, H., Astuti, D.A., Bava, I., & Zheng, L. (2015). Protecting the environment through insect farming as a means to produce protein for use as livestock, poultry, and aquaculture feed. *Journal of Insects as Food and Feed, 1*(4), 307-309. https://doi.org/10.3920/JIFF2015.0098. Downloaded on 2025.08.10.

Tran, G., Heuzé, V., & Makkar, H.P.S. (2015). Insects in fish diets. *Animal Frontiers, 5* (2), 37–44.

Turek, J., Sampels, S., Khalili Tilami, S., Červený, D., Kolářová, J., Randák, T., Mráz, J., Másílko, J., Steinbach, C., Burkina, V., Kozák, P., & Žlábek, V. (2020). Insects in the feed of rainbow trout, *Oncorhynchus mykiss* (Actinopterygii, Salmonidae): Effect on growth, fatty acid composition, and sensory attributes. *Acta Ichthyologica et Piscatoria, 50* (2). 171-181. https://doi.org/10.3750/AIEP/02785.

Valdez, J. W., & Mandrekar, K. (2019). Assessing the Species in the CARES Preservation Program and the Role of Aquarium Hobbyists in Freshwater Fish Conservation. *Fishes, 4*(4), 49. https://doi.org/10.3390/fishes4040049.

Van Huis, A., van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). *Edible Insects: Future Prospects for food and feed security*, FAO, ONU, Rome, 187 p.

Vargas-Abúndez, A.J., Randazzo, B., Foddai, M., Sanchini, L., Truzzi, C., Giorgini, E., Gasco, L., Olivotto, I., (2019). Insect meal based diets for clownfish: Biometric, histological, spectroscopic, biochemical and molecular implications. *Aquaculture*, 498, 1-11.

Velasco-Santamaría, Y. & Corredor-Santamaría, W. (2011). Nutritional requirements of freshwater ornamental fish: a review. *Revista MVZ Córdoba*, 16 (2), 2458-2469.

Vrij, M. (2013). Insects as alternative raw material for use in fish feeds. *Aquacultuur*, 26, 1. https://edepot.wur.nl/286377.

Zarantoniello, M., Randazzo, B., Cardinaletti, G., Truzzi,C., Chemello, G., Riolo, P., Olivotto, I. (2021). Possible Dietary Effects of Insect-Based Diets across Zebrafish (*Danio rerio*) Generations: A Multidisciplinary Study on the Larval Phase. *Animals*, 11, 751, 1-18. https://doi.org/10.3390/ani11030751.

https://eur-lex.europa.eu/legal-content/RO/TXT/PDF/?uri=CELEX:32017R0893&from=EN (accesed on 03.02.2026)

https://openknowledge.fao.org/handle/20.500.14283/i3253e (accesed on 14.01.2026)

https://sealineexports.in/the-role-of-fish-meal-in-pet-food-formulations/ (accesed on 12.11.2025)

https://www.999.dk/en/products-and-segments/segments/pet-food/ (accesed on 25.11.2025)