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Natural Occurrence of Hybrid Koi and Mahseer in Artificial Ponds: Evidence of The Dangers of Releasing Non-Native Fish into The Wild

Darmawan Setia Budi[1,2*], Leonardo Davinci[3], Adam Pramudya Ardiyan[3], Muh. Herjayanto[4]

[1]Study Program of Aquaculture, Department of Health and Life Sciences, Faculty of Health, Medicine, and Life Sciences, Universitas Airlangga, Jl. Wijaya Kusuma No.113, Banyuwangi, East Java 68425, Indonesia.
[2]Sustainable Aquaculture and Environment Research Group, Universitas Airlangga, Banyuwangi, Indonesia
[3]Freshwater Fish of Indonesia (FFOI), Indonesia
[4]Department of Fisheries Science, Faculty of Agriculture, University of Sultan Ageng Tirtayasa, Jl. Raya Palka, Serang, Banten, Indonesia.

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E-mail addresses:
darmawansetiabudi@fpk.unair.ac.id
*Corresponding author

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ABSTRACT

The introduction of non-native species into new environments poses significant ecological risks, including the potential for hybridization with native species, leading to genetic pollution and the creation of hybrid species. This study investigates the natural occurrence of hybridization between koi (*Cyprinus carpio* var. koi), an ornamental species, and the native mahseer (*Tor dourorensis*) in an artificial pond in Padang, West Sumatra, Indonesia. The coexistence of these species over five years resulted in the emergence of hybrid offspring, which exhibited a blend of morphological traits from both parent species. Meristic and morphometric analyses revealed that the hybrids closely resembled mahseer in certain characteristics, particularly dorsal and caudal fin rays, while also displaying koi-like traits such as body color and fin shapes. The hybridization of these two species raises concerns about the genetic integrity of native mahseer populations and the potential ecological consequences. Hybrids may possess competitive advantages that could further threaten already vulnerable mahseer populations. The findings emphasize the urgent need for effective management strategies and regulations to prevent the release of non-native species into sensitive ecosystems. Public awareness campaigns and regulatory measures should be strengthened to mitigate the risks of hybridization and protect biodiversity in freshwater environments. This study serves as a critical reminder of the far-reaching consequences of introducing non-native species, particularly in regions with delicate ecological balances.

Keyword: biodiversity, environment, freshwater, hybridization, species.

INTRODUCTION

The introduction of non-native species into new environments, whether deliberate or accidental, plays a major role in global biodiversity decline. In freshwater ecosystems, non-native species significantly reduce fish beta-diversity by outcompeting native species. This often results in the displacement of endemic and threatened species, further intensifying biodiversity loss (Cavalcante *et al.*, 2024). One significant risk of introducing non-native species is hybridization with native species, which can lead to genetic pollution, loss of genetic diversity, and the creation of hybrid species that may outcompete native populations. An example of this is seen in Japan, where the escape of pet birds, such as the Rose-ringed Parakeet, raises concerns about their potential to establish populations and hybridize with local species (Nishida and Kitamura, 2024). The long-term ecological impacts of non-native species may take centuries to fully emerge, making it difficult to predict their effects and underscoring the

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importance of strict regulations (Liu *et al.*, 2024).

Koi (*Cyprinus carpio* var. koi) and mahseer (*Tor dourorensis*) represent two ecologically and economically significant fish species in freshwater ecosystems, each playing distinct roles. Koi, a domesticated variety of common carp, is primarily bred for ornamental purposes and has gained global popularity in aquaculture and ornamental fish markets. Extensive breeding programs have been developed to enhance the aesthetic appeal of koi, characterized by their vibrant colors and patterns (Hasnidar *et al.*, 2023). However, the introduction of koi into non-native environments raises concerns about their ecological impact, particularly regarding competition with native species and the potential for hybridization (Gomelsky *et al.*, 2023).

In contrast, Mahseer are native to the rivers and streams across South and Southeast Asia and are highly valued for their ecological role and economic significance as a food source and sport fish (Gustiano *et al*. 2013; Muchlisin *et al.*, 2022). Mahseer are omnivorous, consuming a diet that includes mollusks, aquatic plants, and small fish, making them key contributors to their native ecosystems (Muchlisin *et al.*, 2022). However, habitat degradation and overfishing have led to a decline in mahseer populations, prompting efforts to conserve and farm these species (Mellisa *et al.*, 2019). The potential hybridization between koi and mahseer process significant risks to the genetic integrity of mahseer populations. Hybrid off-spring may exhibit traits that give them competitive advantages over native mahseer, exacerbating the decline of native populations (Shahi *et al.*, 2023).

The phenomenon of hybridization between non-native and native species is particularly concerning due to the documented cases of genetic pollution. Hybrids often possess advantageous traits that enhance their survival and reproductive success in modified environments, leading to the displacement of native species (Bergmann *et al.*, 2010; Wang *et al.*, 2022). The long-term ecological consequences of such hybridization can be profound, potentially altering community dynamics and reducing biodiversity over time (Kamarudin *et al.*, 2021). Moreover, hybridization can dilute unique genetic traits within native populations, reducing their ability to adapt to environmental changes (Li *et al.*, 2018).

A case study in Padang, West Sumatra, Indonesia, exemplified the ecological concerns surrounding hybridization, where koi and mahseer have been cohabiting in an artificial pond for over five years. This study documents the natural occurrence of hybridization between koi and mahseer, raising critical concerns about the genetic integrity of mahseer populations and the broader ecological implications of the hybrid events exemplified. The emergence of hybrid fish exhibiting traits from both underscores the dangers of releasing non-native species into environments where they can disrupt ecological balances and contribute to genetic pollution. This case serves as a poignant reminder of the ecological risks associated with the introduction of non-native species, particularly when they have the potential to hybridize with native species, thereby threatening biodiversity and ecosystem health. Understanding the dynamics of these interactions is essential for developing effective management strategies to mitigate risks and protect native fish populations.

MATERIAL AND METHOD

Pond and fish

The hybrid koi and mahseer was observed in an artificial pond was located in Padang,

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West Sumatra, Indonesia, in May 2024. Previously, the pond has long been home to koi fish (*Cyprinus carpio* var. koi) as well as mahseer (*Tor dourorensis*). The fish were allowed to live together for five years in natural conditions by being fed commercial pellets regularly. After cohabiting for an extended period, fish with distinct morphology from both koi and mahseer have appeared, suggesting natural hybridization between the two species. Some of the fish that have emerged have reached the juvenile stage and exhibit a blend of the morphological traits of both koi and mahseer.

Morphological Assessment

Koi (n = 1; total length = 16.5 cm), Mahseer (n = 1; total length = 18.0 cm), and three suspected hybrids with total length 25.0, 23.0, and 18.0 cm were analyzed for their meristic and morphometric characteristics. To measure meristic characteristics, the fish were observed using a magnifying glass, and specific body parts were counted using a hand counter. Meristic characteristics were then calculated following the guidelines in Figure 1. Morphometric measurements were conducted by directly measuring the length of specific body parts using a ruler. The fish, positioned on a laminated millimeter paper block with the left side facing forward, were measured following the guidelines for morphometric characteristics. The morphometric parameters measured can be seen in Figure 2. To calm the fish and prevent stress, observations and measurements were performed under anesthesia using cold temperatures of 5 °C.

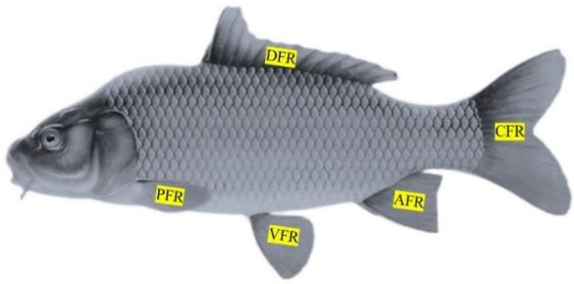

Figure 1. Measurement of meristic characteristics. PFR (pectoral fin rays), VFR (ventral fin rays), DFR (dorsal fins rays), AFR (anal fin rays), and CFR (caudal fin rays).

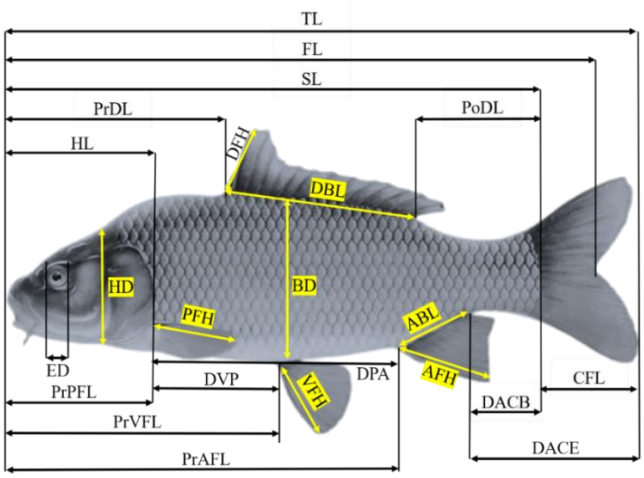

Figure 2. Measurement of morphometric characteristics. TL (total length), FL (fork length), SL (standard length), ED (eye diameter), HL (head length), PrDL (pre-dorsal length), PoDL (post-dorsal length), PrVFL (pre-ventral fin length), PrPFL (pre-pectoral fin length), PrAFL (pre-anal fin length), DACE (distance from anal fin to caudal fin end), DACB (distance from anal fin to caudal fin base), DPA (distance between pectoral and anal fin), DVP (distance between ventral and pectoral fin), DFH (dorsal fin height), DBL (dorsal fin base length), CFL (caudal fin length), and BD (body depth).

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Data presentation and analyses

Data was presented in tables and figures, and analyzed descriptively.

RESULT AND DISCUSSION

Result

Three specimens suspected to be natural hybrids between koi and mahseer were observed and analyzed for their meristic and morphometric characteristics. The following sections describe the notable features of these hybrid specimens compared to their purebred counterparts.

The meristic characteristics of the suspected hybrids were compared with those of purebred mahseer and koi (Table 1). All three hybrids shared similar meristic features with the mahseer, particularly in dorsal fin rays (D.I.19) and caudal fin rays (C.II.18). This suggests a strong genetic influence of the mahseer on these particular characteristics. In contrast, the koi exhibited distinct differences, with D.II.9 and C.II.16 values in dorsal and caudal fin rays, respectively.

Table 1. Meristic characteristics of suspected koi-mahseer hybrids and purebred koi and mahseer.

	Hybrid			Mahseer (*Tor dourorensis*)	Koi (*Cyprinus carpio var. koi*)
	1	2	3		
DFR	D.I.19	D.I.19	D.I.19	D.II.18	D.II.9
PFR	P.I.10	P.I.10	P.I.13	P.I.14	P.I.13
VFR	V.I.7	V.I.7	V.I.8	V.I.8	V.I.8
AFR	A.I.6	A.I.6	A.I.5	A.I.5	A.1.5
CFR	C.II.18	C.II.18	C.II.18	C.II.16	C.II.16

Note: DFR (dorsal fins rays), PFR (pectoral fin rays), VFR (ventral fin rays), AFR (anal fin rays), CFR (caudal fin rays).

The morphometric measurements provided further insight into the hybrid nature of the fish (Table 2). The total length (TL) of the hybrids ranged from 18.0 to 25.0 cm, larger than the purebred koi but smaller than some mahseer individuals. Other parameters, such as head length (HL) and body depth (BD), also indicated that the hybrids exhibited a combination of traits from both parent species. For instance, specimen I showed a higher body depth (6.0 cm), characteristic of mahseer, whereas specimen III had a more moderate body depth of 4.0 cm. To enable a direct comparison between specimens, all morphometric data have been standardized by expressing them as ratios relative to TL (Table 3).

Table 2. Morphometric characteristics (cm) of suspected koi-mahseer hybrids and purebred koi and mahseer.

Morphometric characteristics	Hybrid			Mahseer (*Tor dourorensis*)	Koi (*Cyprinus carpio var. koi*)
	1	2	3		
TL	25.0	23.0	18.0	18.0	16.5
FL	23.0	19.0	16.0	15.5	14.5
SL	21.0	17.0	14.0	14.5	13.3
PrDL	10.0	9.0	7.0	6.7	1.0
PoDL	4.0	3.0	2.0	5.6	3.0
HL	6.0	5.0	4.0	3.8	5.0
DFH	3.0	3.0	2.0	2.8	3.0
DBL	7.0	7.0	5.0	2.1	5.5
ED	1.0	1.0	1.0	0.8	0.5
BD	6.0	5.0	4.0	3.2	5.0
DPA	9.0	9.0	7.0	3.9	7.0
DVP	5.0	4.0	3.0	7.6	3.0

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Morphometric characteristics	Hybrid			Mahseer (*Tor dourorensis*)	Koi (*Cyprinus carpio var. koi*)
	1	2	3		
DACB	3.0	3.0	2.0	2.6	1.0
CFL	4.0	4.0	4.0	3.9	3.2
DACE	7.0	7.0	6.0	6.2	6.5
PrAFL	16.0	14.0	11.0	11.0	12.8

Note: TL (total length), FL (fork length), SL (standard length), PrDL (pre-dorsal length), PoDL (post-dorsal length), HL (head length), DFH (dorsal fin height), DBL (dorsal fin base length), DPA (distance between pectoral and anal fin), DVP (distance between ventral and pectoral fin), DACB (distance from anal fin to caudal fin base), CFL (caudal fin length), DACE (distance from anal fin to caudal fin end), PrAFL (pre-anal fin length).

Ratios of various morphometric measurements to TL (Table 3) highlighted further hybrid traits. Notably, the pre-dorsal length to total length ratio (PrDL/TL) in the hybrids ranged between 0.39 and 0.40, resembling both mahseer and koi proportions. The dorsal fin height to total length ratio (DFH/TL) was comparable to that of mahseer, ranging from 0.11 to 0.13 in the hybrids. Additionally, the caudal fin length to total length ratio (CFL/TL) in the hybrids was 0.16 to 0.22, again reflecting intermediate characteristics between the two species.

Table 3. Ratio of morphometric characteristics to total length (TL) in suspected koi-mahseer hybrids and purebred koi and mahseer.

Ratio of morphometric characteristics to total length (TL)	Hybrid			Mahseer (*Tor dourorensis*)	Koi (*Cyprinus carpio var. koi*)
	1	2	3		
FL/TL	0.92	0.83	0.89	0.86	0.88
SL/TL	0.84	0.74	0.78	0.81	0.81
PrDL/TL	0.40	0.39	0.39	0.37	0.06
PoDL/TL	0.16	0.13	0.11	0.31	0.18
HL/TL	0.24	0.22	0.22	0.21	0.30
DFH/TL	0.12	0.13	0.11	0.16	0.18
DBL/TL	0.28	0.30	0.28	0.12	0.33
ED/TL	0.04	0.04	0.06	0.04	0.03
BD/TL	0.24	0.22	0.22	0.18	0.30
DPA/TL	0.36	0.39	0.39	0.22	0.42
DVP/TL	0.20	0.17	0.17	0.42	0.18
DACB/TL	0.12	0.13	0.11	0.14	0.06
CFL/TL	0.16	0.17	0.22	0.22	0.19
DACE/TL	0.28	0.30	0.33	0.34	0.39
PrAFL/TL	0.64	0.61	0.61	0.61	0.78

Note: TL (total length), FL (fork length), SL (standard length), PrDL (pre-dorsal length), PoDL (post-dorsal length), HL (head length), DFH (dorsal fin height), DBL (dorsal fin base length), DPA (distance between pectoral and anal fin), DVP (distance between ventral and pectoral fin), DACB (distance from anal fin to caudal fin base), CFL (caudal fin length), DACE (distance from anal fin to caudal fin end), PrAFL (pre-anal fin length).

Figure 3 illustrates the visual comparison between the suspected koi-mahseer hybrids, purebred mahseer, and koi. The hybrid specimens exhibited body and chin shapes that fell between those of the two-parent species. Hybrid I (Figure 3. A1 and A2) exhibited a body shape that was slightly elongated and torpedo-like, resembling the mahseer. The scale color appeared blackish-gray, while the belly was white. The head was slightly pointed, and the dorsal fin was robust and upright, similar to the characteristic mahseer fin. The chin of hybrid I displayed a flap, a trait seen in mahseer, and the eyes were dark gray. The

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dorsal fin was sharp, further reflecting the mahseer lineage, and the back was relatively flat, aligning with the mahseer morphology.

Hybrid II (Figure 3. B1 and B2) also had an elongated body, though the mouth appeared slightly oval. The belly displayed a white-yellowish hue, and the head shape was more oval, resembling a koi. The dorsal fin stood upright like that of a mahseer, with the tip of the dorsal fin showing the distinctive upright posture found in mahseer. The caudal fin was slightly oval-shaped, reflecting a koi influence, while the ventral fin was curved, another koi-like trait. The chin structure followed the koi morphology. The body color was a golden white, and the back was flatter, echoing the mahseer's form.

The head of hybrid III (Figure 3. C1 and C2) was slightly pointed, and the back was relatively flat, again reflecting traits of the mahseer. The dorsal fin was erect but appeared slightly smaller than in the previous hybrids. Both the caudal and ventral fins were sharp, akin to those seen in mahseer. The body color was a combination of black and yellow, with a yellowish-white belly. The chin was slightly wider than that observed in the other hybrid specimens, suggesting a slight variation in hybridization.

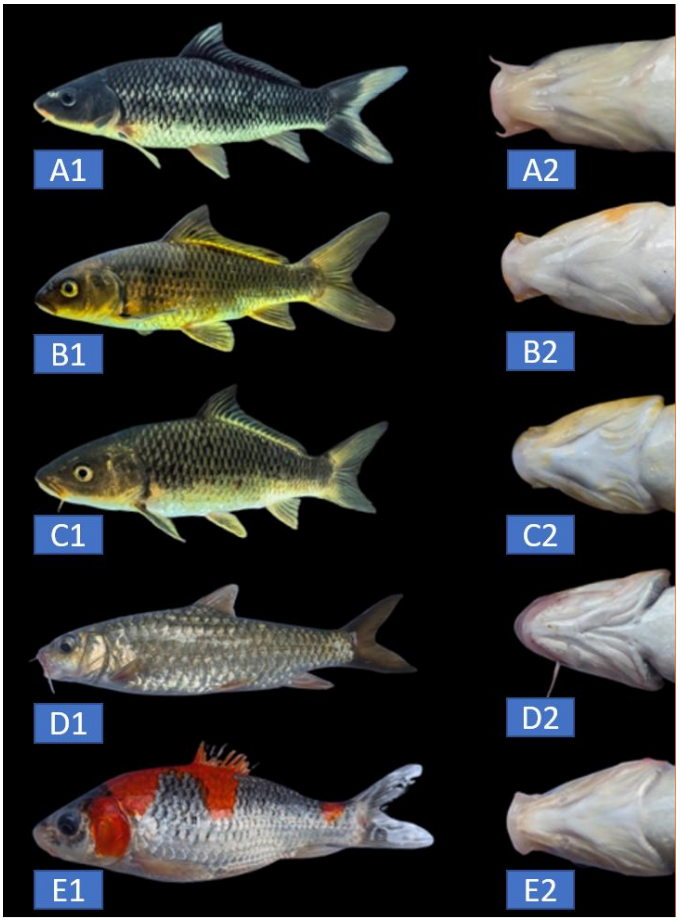

Figure 3. Visual appearance of body and chin in suspected koi-mahseer hybrids, purebred mahseer, and koi. The image shows the body (A1, B1, C1) and chin (A2, B2, C2) of three suspected koi-mahseer hybrids, alongside the body (D1) and chin (D2) of a purebred mahseer, and the body (E1) and chin (E2) of a purebred koi.

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Discussions

The phenomenon of hybridization between non-native koi and native mahseer in artificial ponds, as observed in Padang, West Sumatra, Indonesia, raises significant ecological concerns. The introduction of koi into environments where they can hybridize with native species like mahseer poses risks to the genetic integrity and ecological balance of local fish populations. Hybridization can lead to genetic pollution, where the unique genetic traits of native species are diluted, potentially compromising their ability to adapt to environmental changes and survive in their natural habitats (Cavalcante *et al.*, 2024; Liu *et al.*, 2024).

The morphological and genetic characteristics of the observed hybrids suggest a complex interaction between the two species. The hybrids exhibited meristic traits closely resembling those of mahseer, particularly in dorsal and caudal fin rays, indicating a strong genetic influence from the native species. This finding aligns with previous studies that have documented the competitive advantages hybrids may possess, which can exacerbate the decline of native populations (Bergmann *et al.*, 2010; Gomelsky *et al.*, 2023). The hybrids' intermediate morphological traits, such as body depth and head shape, further illustrate the blending of characteristics from both parent species, which may enhance their survival in altered environments (Li *et al.*, 2018).

The ecological implications of such hybridization are profound. As noted by Liu *et al.* (2024), the introduction of non-native species can lead to significant declines in local biodiversity, particularly in freshwater ecosystems where native species are already under threat from habitat degradation and overfishing. The long-term effects of hybridization may not be immediately apparent, as genetic changes can take generations to manifest fully, complicating efforts to predict ecological outcomes (Hasnidar *et al.*, 2023). Furthermore, the presence of hybrids may disrupt established community dynamics, leading to shifts in species interactions and resource competition (Cavalcante *et al.*, 2024; Liu *et al.*, 2024).

In the case of koi and mahseer, the potential for hybrid offspring to outcompete native mahseer for resources is particularly concerning. Mahseer are vital to their ecosystems, serving as both a food source and a key player in maintaining ecological balance (Muchlisin *et al.*, 2022). The introduction of koi, primarily bred for ornamental purposes, into these environments could lead to increased competition for food and habitat, further stressing already vulnerable mahseer populations (Shahi *et al.*, 2023).

Moreover, the documented case of hybridization in the artificial pond underscores the urgent need for effective management strategies to mitigate the risks associated with releasing non-native species into the wild. Regulatory measures should focus on preventing the introduction of non-native species into sensitive ecosystems and monitoring existing populations to assess the impacts of hybridization (Cavalcante *et al.*, 2024; Liu *et al.*, 2024). Public awareness and education about the ecological consequences of releasing ornamental fish into natural habitats are also crucial in preventing future hybridization events (Gozlan *et al.*, 2010).

CONCLUSION

In conclusion, the natural occurrence of hybrid koi and mahseer in artificial ponds serves as a critical reminder of the ecological dangers posed by the introduction of non-native species. The genetic and morphological evidence of hybridization highlights the potential for significant ecological disruption,

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emphasizing the need for stringent regulations and proactive management to protect native fish populations and preserve biodiversity in freshwater ecosystems.

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

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REFERENCES

Bergmann S.M., Sadowski J., Kiełpiński M., Bartłomiejczyk M., Fichtner D., Riebe R., Lenk M., & Kempter J. 2010. Susceptibility of Koi × Crucian Carp and Koi × Goldfish Hybrids to Koi Herpesvirus (KHV) And the Development of Khv Disease (Khvd). J. Fish Dis., 33(3), 267–272.

Cavalcante L., Occhi T., Olden J.D., & Padial A.A. 2024. Nonnative Species Drive the Global Loss of Freshwater. Arpha Prepr, 1–35.

Gomelsky B., Novelo N. D., & Warner J. L. (2023). Inheritance And Expression of Koi Color Dominant Mutations in Koi × Goldfish Hybrids. N. Am. J. Aquac. 85(1), 48–52.

Gozlan R. E., Britton J. R., Cowx I., & Copp G. H. (2010). Current knowledge on non-native freshwater fish introductions. J. Fish Biol., 76(4), 751-786.

Gustiano, R., Kontara, E. K., Wahyuningsih, H., Subagja, J., Asih, S., & Saputra, A. (2013). Domestication of mahseer (*Tor soro*) in Indonesia. Communications in agricultural and applied biological sciences, 78(4), 165-168.

Hasnidar., Tamsil, A., & Akram, A. M. (2023). PKM Budidaya Ikan Koi Di Kelurahan Balang Baru Kecamatan Tamalate Kota Makassar [Pkm Koi Fish Cultivation in Balang Baru Village Tamalate District, Makassar City]. J. Pengabdi. Mayarakat Kauniah, 1(2), 180–187.

Kamarudin M.S., Ismail A.M., Syukri F., & Latif K.K. 2021. Histo-Morphological Development of The Digestive Tract of Larval Hybrid Malaysian Mahseer (*Barbonymus gonionotus* ♀ × *Tor tambroides* ♂). J. Surv. Fish. Sci., 7(2), 1–17.

Liu, D., Essl F., Lenzner B., Moser D., Semenchuk P., Blackburn T.M., Cassey P., Biancolini D., Capinha C., Dawson W., Dyer E., Guénard B., Economo E.P., Kreft H., Pergl J., Pyšek P., Kluenen M.V., Rondinini C., Seebens H., Weigelt P., Winter M., Purvis A., & Stefan D. 2024. Regional Invasion History and Land Use Shape the Prevalence of Non-Native Species in Local Assemblages. Glob. Chang. Biol., 30, E17426.

Li, W., Liu, J., Tan, H., Yang, C., Ren, L. I., Liu, Q., ... & Liu, S. (2018). Genetic effects on the gut microbiota assemblages of hybrid fish from parents with different feeding habits. Frontiers in microbiology, 9, 2972.

Mellisa, S., Hasri, I., Agung, W., Nurfadillah, N., & Putra, D. F. (2019). Induction of gonadal maturation in mahseer fish (*Tor douronensis*) using the PMSG hormone, antidopamin. In: IOP Conference Series: Earth and Environmental Science, 348, 012101

Muchlisin Z. A., Nur F. M., Maulida S., Handayani L. S., & Rahayu S.R. (2022). Mahseer, The History of The King of The River. E3s Web of Conferences, 339, 03006.

Nishida S., & Kitamura W. 2024. An Influx of Non-Native Bird Species into The Natural Environment Owing to The Accidental Release of Pet Birds in Japan. Animals, 14(2), 1–12.

Shahi N., Singh B., Mallik S.K., Sarma D., & Surachetpong W. 2023. Rna-Seq Reveals Differential Gene Expression Patterns Related to Reproduction in The Golden Mahseer. Fishes 8(352), 1–20.

Wang Q., Liu J.H., Wen B., Gao J.Z., & Chen Z.Z. 2022. Gut Microbiota Communities of Reciprocal Hybrids from Koi (*Cyprinus carpio*) And Goldfish (*Carassius auratus*) are More Similar to Koi Than Goldfish. J. Appl. Microbiol., 133(2), 960–971.