Fish ectoparasite in public aquarium

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Abstract. Ectoparasite infestation is a problem related to fish health commonly found in aquaculture activities including ornamental fish that are kept in public aquariums for exhibition. Parasite infestation can trigger various diseases or other health problems. Identification and inventory of ectoparasites become necessary to avoid it. This paper describes the results of ectoparasite inventories in fish that kept in public aquariums facility. An inventory of ectoparasites was carried out through non-lethal sampling using skin scrapping and gill biopsy techniques by wet mount then observed under the microscope. Five groups of parasites (Protozoa, Monogeneans, Digeneas, Copepod, Isopod) infest nine species of fish in the aquarium facilities and dominated by Monogeneans. The highest number of parasite species was detected in seawater quarantine pond. *Carassius auratus auratus* is a freshwater fish which have the most parasitic infestations. Meanwhile, the seawater fish with the most parasitic infestations was *Diodon* sp. Parasitic infestation not always shows clinical symptoms. *Trachinoctus blochii* infested by *Cryptocaryon* sp. showed skin lesions and became fish have noticeable clinical change. Prevention of the entry of parasites, quarantine processes, and application of systems for breaking the life cycle of parasites important in parasite control in public aquarium.

1 Introduction

Indonesia is a country with high fish biodiversity and is estimated to have around 8,000 or more species of fish. There are 6,000 to 7,000 species of marine fish and 1,300 are freshwater fish [1]. The aquaculture industry in Indonesia continues to develop, which is mostly oriented towards food production. On the other hand, the hobby and ornamental fish market continue to increase and become popular along with the development of various aquarium technologies [2][3]. Indonesia is one of the main exporters of coral and marine ornamental fish where 650 species of marine ornamental fish and 400 of the 1,100 species of freshwater

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ornamental fish originate from Indonesia [4-7]. Keeping fish in an aquarium allows the water environment, beauty of form, colour patterns and fish behaviour to be observed clearly [8]. Most of small aquariums are owned and managed by individual hobbyists, while some larger aquariums are public aquariums. Unlike most conventional aquaculture activities, public aquariums, especially saltwater aquariums, are indoor facilities have more complex life support systems and technologies that are customized to the species or biota communities being kept. Physical, mechanical, chemical and biological filters are used to maintain water quality to meet the criteria [9]. Fish maintenance management is an important aspect to ensure that biota remain in healthy and good condition. However, several problems related to fish health and disease are often found in aquarium environments, such as parasites [10][11].

Parasites are pathogens commonly found in farmed fish and ornamental fish from nature. Fish can act as intermediate, paratenic, or definitive hosts of various stages of parasites [12]. Based on their target organs, parasites are divided into endoparasites which are found in internal organs and ectoparasites which are found on the surface of the body. Parasitic diseases are important to control because of their role as secondary and opportunistic infections [13]. Protozoa, trematodes, cestodes, nematodes, acanthocephalan, crustacea, and arthropods are groups of parasites commonly found in fish [12]. There have been several reports of ectoparasite inventories in aquaculture environments, but not so many for public aquarium [14-16]. Several reports explain protozoa and worms cause many problems in ornamental fish kept in aquariums [17-20]. Ectoparasites are rarely fatal, but the infestations can occur throughout the year [21]. This can be one of the causes of death found in freshwater aquariums and oceanariums [22].

The presence of ectoparasites infesting the biota in the aquarium needs attention because it can be the initial gateway for infection by other pathogens that cause fish health problems. Uncontrolled growth and transmission of ectoparasites can be a problem for the entire aquarium environment. This paper describes ectoparasites found in fish kept in public aquaria. The results can be used to determine the steps to control and prevent the entry and development of fish health problems related to ectoparasites.

2 Method

Ectoparasite inventory was conducted on 15 fish species (Table 1) that kept in aquarium facilities: schooling aquariums, main aquariums, touch pools, and maintenance facilities such as quarantine ponds (Figure 1) at the Pangandaran Integrated Aquarium and Marine Research Institute (PIAMARI) Aquarium, Pangandaran in November 2021.

Table 1. Sample of fish species in public aquarium facilities.

Aquarium / pond	Fish species
Schooling aquarium (SA)	*Chaetodon collare, Heniochus acuminatus, Pomacanthus semicirculatus, Siganus javus*
Touch pool (TP)	*Pomacanthus semicirculatus, Lactoria cornuta, Carcharhinus melanopterus, Ctenochaetus striatus, Epinephelus fuscoguttatus, Diodon* sp.
Main aquarium (MA)	*Trachinotus blochii*
Seawater quarantine pond (SQP)	*Chanos chanos, Pomacanthus semicirculatus, Gnathanodon speciosus, Siganus javus, Chaetodon auriga.*
Freshwater quarantine pond (FQP)	*Carassius auratus, Carassius auratus* auratus

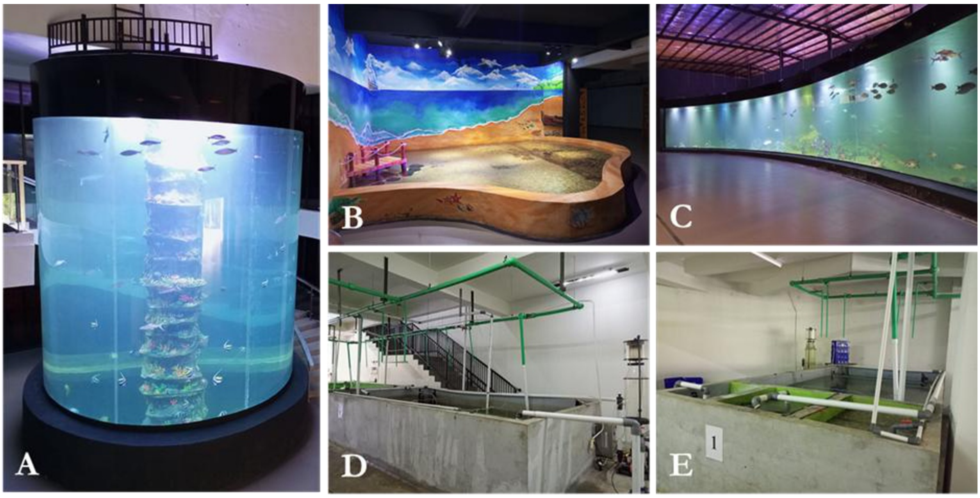

Fig. 1. (A) Schooling aquarium; (B) touch pool; (C) main aquarium; (D) saltwater quarantine pond; (E) freshwater quarantine pond.

Non-lethal sampling was conducted to collect ectoparasites on the skin and gills using the skin scraping and gill biopsy techniques by wet mount. The method for saltwater fish was used NaCl solution and freshwater fish used distilled water. Sample examination, identification of ectoparasites and observation of changes in the gills observed by using Olympus CX21 microscope and documented with an Optilab camera. Ectoparasite identification was carried out using the guidebook [23] and references [24-26]. Clinical symptom in fish were also observed.

In aquariums and quarantine pond facilities, in-situ water quality measurements were carried out, including temperature and dissolved oxygen (DO) with the Oakton PD 450 water quality checker; pH with Oakton EcoTests pH2; salinity with a refractometer. Water samples were taken for measurement of alkalinity and total organic matter (TOM) using titrimetric method, nitrite and phosphate levels using smart kit; nitrate levels using spectrophotometry and heavy metals (Pb, Hg and Fe) using spectrophotometry. The results of ectoparasite observations then used in calculating prevalence using the formula [27] :

$$Prevalence\ (\%) = \frac{\sum parasite{-}infested\ fish}{\sum fish\ being\ examined}\ x\ 100\% \qquad (1)$$

The results of the ectoparasite inventory were analyzed descriptively.

3 Result and discussion

Nine species from five groups of parasites were identified infesting nine species of fish in aquarium facilities. They are Protozoa, Monogenean, Digenea, Isopod and Copepod (Table 2). Most identified parasites are on the skin. Meanwhile, *Dactylogyrus* sp. was found on the gills and *Cryptocaryon* sp. was found on the skin and gills. Parasites were found infesting fish in all aquariums or quarantine ponds where sampling was carried out.

The seawater quarantine pond is a facility with the greatest number of parasites species. There are 4 species of parasites that infest 4 species of fish. All of this parasite species was also found in freshwater quarantine ponds infested one species of fish. These conditions indicate that parasites can be part of the health problems of ornamental fish in aquariums as well as in aquaculture environments [28-30]. Public aquariums are equipped with quarantine pond facilities which are used to quarantine new fish and handle sick fish in order to prevent the spread of disease. Because this area is used to keep and handle sick fish, it is possible to identify more parasite. In the main aquarium and schooling aquarium, 1 parasite species was identified each infesting 1 and 2 fish species respectively. Meanwhile, in the touch pool, 3 species of parasites were identified that infested 2 species of fish. Goldfish (*C. auratus* auratus) is a fish with the most number of parasite infestations. Three parasite species were identified and one of them was encapsulation of parasitic metacercaria. Marine fish with the largest number of parasite species infestation is the pufferfish (*Diodon* sp.) with 2 parasite species. In other fish species in the aquarium facility, 1 parasite species was identified in each pond (Fig. 2 and 3).

Table 2. Distribution of parasites and results of clinical examination on fish collection in public aquarium.

Aquarium/ pond	Fish species	Parasite	Organ	Clinical Sign
Schooling aquarium (SA)	*C. collare*	-	-	No clinical sign
	H. acuminatus	*Neobenedenia* sp. (M)	Skin	No clinical sign
	P. semicirculatus	*Neobenedenia* sp. (M)	Skin	No clinical sign
	S. javus	-	-	Exophthalmos
Touchpool (TP)	*L. cornuta*	*Trichodina* sp. (P)	Skin	No clinical sign
	P. semicirculatus	-	-	No clinical sign
	Diodon sp.	*Benedenia* sp. (M)	Skin	No clinical sign
		Cryptocaryon sp. (P)		
	E. furcofuttatus	-	-	No clinical sign
	C. striatus	-	-	No clinical sign
	C. melanopterus	-	-	No clinical sign
Main aquarium (MA)	*T. blochii*	*Cryptocaryon* sp. (P)	Skin & Gill	Open lesions and irregular haemorrhages under-eye area near the mouth and on the head between the eyes. Fish are weak and rub their bodies against parts of the aquarium.
Seawater quarantine pond (SQP)	*C. chanos*	-	-	Scales peeling, pectoral fin haemorrhage.
	P. semicirculatus	*Trichodina* sp. (P)	Gill	Thickening of gill mucus
	G. speciosus	Monogenea (M)	Gill	No clinical sign
	S. javus	*Lernaea* sp. (C)	Skin	No clinical sign
	C. auriga	Monogenea (M)	Skin	Exophthalmos
Freshwater quarantine pond (FQP)	*C. auratus*	*Ichtyoxenus* sp. (I)	Skin	Scales peeling, pectoral fin haemorrhage.
	C. auratus auratus	*Gyrodactylus* sp. (M)	Skin	Red ulcers at the base of the tail, skin peels easily.
		Dactylogyrus sp. (M)	Gill	
		Centrocestus sp. (D)	Gill	

Notes : P= Protozoa; M= Monogenea; D= Digenea; C= Copepoda; I= Isopoda

Monogenean is a group of parasites with the most species found in aquarium facilities. This group of parasites is commonly found in freshwater, brackish water and marine environment. The parasite lives on the skin, gills, eyes, head, fins or body surface. Some Monogenean species can live in the nasal cavity, urogenital cavity and body cavity, but these biota are always referred to as ectoparasites [31]. In general, monogenean are specific, where each species will only infect one species of fish. This parasite does not have an intermediate host in its life cycle and is commonly found in aquaculture, public aquariums and home aquariums [31]. The freshwater monogenean found were skin fluke (*Gyrodactylus* sp.) and gill fluke (*Dactylogyrus* sp.) which can cause oxidative stress and gill damage of *C. auratus* through production of lipid peroxidation [32]. Monogenean identified on the skin of marine fish was Capsalidae group, *Benedenia* sp. and *Neobenedenia* sp. The previous reports have shown that both parasites were found infesting farmed marine fish and aquarium ornamental fish [33][34]. The identification of *Neobenedenia* infestation in H. *acuminatus* and P. *semicurculatus* complete the report of fish species that become the hosts for the parasite in captive environments or the wild such as *T. blochii, Lutjanus erythropterus, L. argentiventris, Gnathanodon speciosus, Lates calcarifer, Seriola lalandi, S. rivoliana, T. kennedeyi, Oligoptiles altus, Rachycentron canadum, Mycteroperca rosacea, Epinephelus coioides, Arothron caercaeruleopunctatus, Canthigaster bennetti, Sphoeroides annulatus, Coryphaena hippurus, Mugil curema, Nematoleotris decora, Pseudochelinus hexataenia, Pseudochromis fridmani, Verasper variegatus, Sebastes rubrivinctus, Neocirrhites armatus, Echeneis naucrates, Sparus aurata* [34-36]. Benedenia can be controlled by introducing *Laboides dimidiatus* into the aquarium [37].

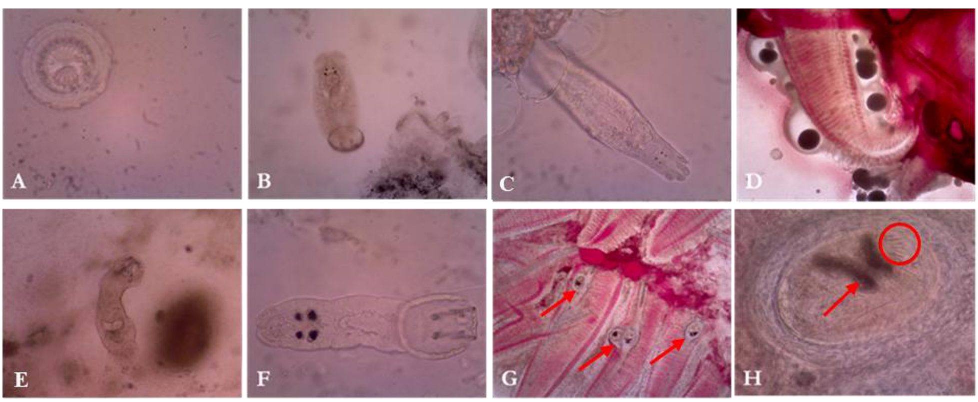

Fig. 2. (A) *Trichodina* sp. infestated *L. cornuta*; (B) *Neobenedenia* sp. invested *H. acuminatus*; (C) *Dactylogyrus* infestated *C. auratus*; (D) *Cryptocaryon* sp. infestated *T. blochii*; (E) *Gyrodactylus* sp. infestated *C. auratus* dan (F) *Benedenia* sp. infestated *Diodon* sp.; (G) encapsulation of parasitic metacercariae on the gills of *C. auratus* auratus; (H) oval-shaped encapsulation is characterized by the appearance of an actively moving parasite, having an X-shaped excretory bladder (arrow) and spined oral suckers (in circles).

Various species of freshwater fish are known to be intermediate hosts for Digenean parasites. One of them is the metacercaria of Digenean *Centrocestus* sp. which is located in the gills of Cichlid and Carp fish [38]. In goldfish (*Cyprinid*), the reported species of *Centreocestus* sp. are *Centrocestus formosanus* both in ornamental goldfish [39], common carp and Koi [26][40]. The parasite was reported in 128 fish species, 83 genus and 26 family from 19 countries. Birds and mammals such as rodents and cats, and humans are recorded as definitive hosts [41]. In fish, this parasite is often found in an encysted or encapsulated state. The formation of metacercaria may damage to the structure of the lamella and gill arches, so that reducing the gill respiratory surface. It may cause respiratory disturbances in fish [40].

Trichodina sp. is found in several fish in touch pools and seawater quarantine pond. This parasite is ciliated Protozoa (Ciliata) which can infest the skin and gills of freshwater or marine fish. This parasite irritates the skin and stimulate excess mucus production. *Lernaea* sp. has been identified infesting *S. Javus* in marine quarantine ponds. This parasite is reported to commonly infest ornamental fish and cause disease and death in freshwater fish [42-44].

Several marine fish reported to be infested with Lernaea are *Acipenser stellatus, Odontesthes bonariensis,* and *Oncorhynchus mykiss* [45-47]. Lernaea was also found infesting fish in large aquariums with recirculating and gravel filter systems in Malaysia [29]. As previous reports have stated that Isopod are commonly found infesting *C. auratus*. Similar findings were also found in the same species of fish in quarantine ponds in aquarium facilities [48][49]. In some cases, infestation of Isopod from the genus Ichtyoxenus on *C. auratus* can cause damaging effects and inhibit host growth and castration [50].

The highest prevalence for marine facilities is *Neobenedinia* sp. which infests fish in Schooling aquariums. While the prevalence of several parasites in freshwater facilities is evenly distributed at 14.3% (Table 3).

Tabel 3. Prevalence of parasites in fish in public aquarium.

Aquarium/ pond	Parasite	Prevalence
Schooling aquarium (SA)	*Neobenedinia* sp.	50 %
Touchpool (TP)	*Trichodina* sp.	12.5 %
	Benedenia sp.	12.5 %
	Cryptocaryon sp.	12.5 %
Main aquarium (MA)	*Cryptocaryon* sp.	22,2 %
Seawater quarantine pond (SQA)	*Trichodina* sp.	10 %
	Monogenea	20 %
	Lernaea sp.	10 %
Freshwater quarantine pond (FQP)	*Ichtyosenus* sp.	14,3 %
	Gyrodactylus sp.	14,3 %
	Dactylogyrus sp.	14,3 %
	Centrocestus sp.	14,3 %

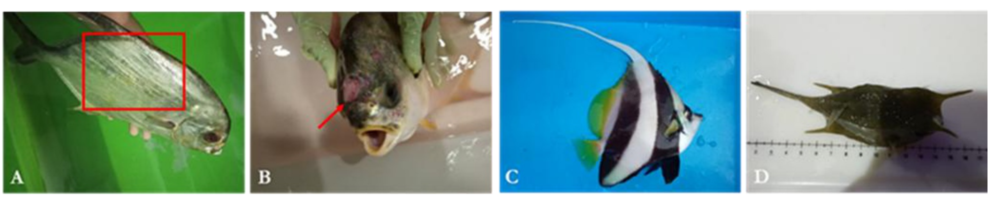

Fig. 3. (A) *T. blochii* infestated by *Cryptocaryon* sp.; (B) lesions on the head of *T. blochii*; (C) *Heniochus* sp. and (D) *L. cornuta* with parasite infestation without clinical sign.

Some parasitic infestations cause clinical sign in fish. Not every parasite infestation causes the clinical sign. Fish in touch pools and schooling aquariums have parasitic infestations but do not show any clinical changes. The appearance of clinical sign in organs can be influenced by various factors such as severity, number of infesting parasites, and temperature [51]. Clinical sign due to parasite infestation were clearly observed in the snubnose pompano (*T. blochii*) in the main aquarium where there were open lesions and eye damage (Figure 3). *T. blochii* showed the behaviour of rubbing its body against the surface of the aquarium. Open lesions are clinical sign that can be found on the skin of fish with parasite infestation cases in freshwater and marine ponds. Fish skin and scales act as a physical barrier that can be damaged by mechanical factors such as rough handling, friction with the pond surface or other fish due to high stocking densities and pathogen infections such as parasites. The damage on scales and skin may increase the susceptibility of fish to secondary infections and cause osmotic stress. Fish that are heavily infested by parasites can die due to bacterial infections that easily enter through open lesions on the skin [52]. Previous reports stated that *T. blochii* cultivated in open waters was not infested with parasites because this pelagic fish is not susceptible to parasite [53]. The parasite that infests the fish is *Cryptocaryon* sp. which is known as "white spot" for saltwater fish [54]. This Ciliate causes white spots on the skin, while the spots on the gills can be up to 1 mm in diameter. This parasite can cause severe gill damage [55] where the open wounds can trigger secondary infections. Infestation by this parasite is often reported when there are temperature fluctuations, low temperatures or environments with increased ammonia, nitrite / nitrate and low pH [56]. *Cryptocaryon* sp. is sensitive to copper and hyposalinity. This parasite can live at pH 5-10 with the optimal pH for reproduction and infectivity in 6-9 [57]. Some fish with parasite infestations also show health problems such as exophthalmia (pop-eye) as in *C. auriga* from schooling aquariums. Similar things were also reported from the maintenance of *Glaucosoma herbaricum* in a closed environment which had problems with exophthalmia and Monogenean infestation [58]. Exophthalmos is a common problem in wild or cultivated fish and is found in aquarium environments which is a sign of inappropriate water or parasitaemia [59][60].

Table 4. Water quality of aquariums facilities.

Parameters	Aquarium facilities					Criteria for biota	
	SA	TP	MA	SQP	FQP	SW	FW
Temperature (°C)	29.8	26.8	29.4	27.6	27.9	28-30*	24-28*
Salinity (‰)	31	33	32	30	0	33-34*	1-3**
DO (mg/l)	7.8	7.5	6.58	8.23	6.49	>5*	Min 3*
pH	7.68	7.45	7.82	7.57	7.4	7-8.5*	5-7*
Nitrite (mg/l)	n/a	0.026	0.008	0.050	0.023	-	Maks 2*
Nitrate (mg/l)	0.42	2.20	0.666	n/a	7.762	0.06*	Maks 50*
Phosphate (mg/l)	0.43	2.200	0.666	0.012	1.970	0.015*	-
Alkalinity (mg/l)	121.4	129.4	1212.4	121.4	67.7	-	-
TOM (mg/ml)	80.21	78.64	52.01	52.01	6.64	-	-

Notes: SA (Schooling aquarium); TP (Touchpool); MA (Main aquarium); SQP (Saltwater quarantine pond); FQP (Freshwater quarantine pond); SW (Salt water); FW (Fresh water); *Government Regulation Number 22 of 2021 Concerning the Implementation of Environmental Protection and Management; ** [61].

Parasites can be found in water for medium for fish culture [62]. In addition, the introduction of new fish from outside the aquarium and fresh food such as fish, small shrimp or shrimp are potential sources of parasites entering the aquarium environment [63]. The seawater used in aquarium facilities comes from the waters of the East Coast of Pangandaran which is collected and goes through a filtration process with a sand filter, protein skimmer and ozonizer. While fresh water has been processed by physical filtration with membrane filters, sand filters, ozonizers. The filtration system is used to prevent the entry or reduce and prevent the spread of parasites in waters in the fish farming or maintenance environment [64]. Aquariums and ponds use sand filters, protein skimmers and ozonizers as filtration systems. It also applies periodic partial water changes. The siphoning process is carried out to remove organic matter in aquariums or ponds.

The physical parameters of aquarium and pond water is still under the environmental criteria for marine and freshwater biota (Table 4). However, the nitrate and phosphate values for the touch pool, main aquarium and schooling aquarium are above the criteria values for marine biota. In most cases, parasite infestation is also supported by poor water quality beside high density, feed deficiencies or stress [65]. The presence of parasites in fish can be affected by ammonia and temperature factors [66]. Temperature also affects eggs, hatching, parasite size, development rate, fecundity and oviposition period in Monogenean [67]. On the other hand, water quality can be more unstable in facilities with recirculation systems (RAS) which cause decreased of immunity in fish. The fish get more susceptible to pathogens including parasite infestations. RAS that are not equipped with disinfection facilities or equipment such as sterilization with ozone or UV have the potential to be suitable places for the growth of disease-causing organisms and the spread of these diseases [68]. Several previous reports also mentioned that ectoparasites such as Monogenean, Trichodina, Cryptocaryon were found in RAS facilities [69-71].

4 Conclusion

In aquarium facilities, 9 species from 5 groups of ectoparasites were identified in 9 species of marine or freshwater fish dominated by Monogenean species. Ectoparasite infestation can be accompanied by lesions on the body surface that are quite clearly visible. It can reduce the appearance or interfere the visualization of fish collections in the aquarium. Therefore, preventing the spread and breaking the life cycle of parasites is important. This can be done through antiparasitic compound treatment, implementing a system with technology that can control parasites, introducing parasite-eating fish or maintenance management.

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References

1. D. Sadili, Haryono, M. M. Kamal, Sarmintohadi, and I. Ramli, *Pedoman umum restoking jenis ikan terancam punah*. (Jakarta: Direktorat Konservasi Kawasan dan Jenis Ikan, KKP, 2015)
2. Hariyatno, Isanawikrama, D. Wimpertiwi, and Y. J. Kurniawan, "Membaca peluang merakit 'uang' dari hobi aquascape," *J. Pengabdi. dan Kewirausahaan*, **2**, 2, 117–125 (2018)
3. A. H. Kidd and R. M. Kidd, "Benefits, problems, and characteristics of home aquarium owners," *Psychol. Rep.*, 84, 998–1004 (1999)
4. D. Arinanto, "Ornamental fish," (*Export News*, April, Jakarta, 30, 2020)
5. K. Raja, P. Aanand, S. Padmavathy, and J. S. Sampathkumar, "Present and future market trends of Indian ornamental fish sector," *Int. J. Fish. Aquat. Stud.*, **7**, 2, 6–15 (2019)
6. A. L. Rhyne, M. F. Tlusty, P. J. Schofield, L. Kaufman, J. A. Morris, and A. W. Bruckner, "Revealing the appetite of the marine aquarium fish trade: The volume and biodiversity of fish imported into the United States," *PLoS One*, **7**, 5 (2012)
7. E. J. Livengood and F. A. Chapman, "Ornamental Fish Trade: An Introduction with Perspectives for Responsible Aquarium Fish Ownership," *Edis*, **2007**, 16, 1–8 (2007)
8. M. F. Tlusty *et al.*, "Opportunities for Public Aquariums to Increase the Sustainability of the Aquatic Animal Trade," *Zoo Biol.*, **32**, 1,1–12, (2013)
9. M. Karydis, "Organizing a public aquarium: Objectives, design, operation and missions. A review," *Glob. NEST J.*, vol. 13, no. 4, pp. 369–384 (2011)
10. C. A. Harms, "Treatments for parasitic diseases of aquarium and ornamental fish," *Semin. Avian Exot. Pet Med.*, **5**, 2,54–63 (1996)
11. A. Thomas, M. R. Dawson, H. Ellis, and M. A. Stamper, "Praziquantel degradation in

marine aquarium water," *PeerJ*, **2016**, 4, 1–12 (2016)
12. R. J. Roberts, *Fish pathology*, (Fourth. West Sussex: John Wiley & Sons, 2012)
13. C. Erlacher-Reid, "Techniques for addressing parasites in saltwater aquariums," in *Fowler's zoo and wild animal medicine current therapy*, **1**, 69, R. E. Miller, N. Lamberski, and P. Cale, Eds. (Missouri: Elsevier, 1967)
14. E. Yusni and N. Rambe, "Identification of ectoparasites in Fry Tilapia (*Oreochromis Niloticus*) in Aquaculture Pond," in *IOP Conference Series: Earth and Environmental Science*, **260**, 1 (2019)
15. A. H. Iriansyah, A. Budihardjo, and S. Sugiyarto, "Parasites prevalence which infecting freshwater fishes in Mulur Reservoir of Sukoharjo District, Indonesia," *Int. J. Bonorowo Wetl.*, **10**, 2, 92–97 (2021)
16. N. C. Y. Putri, L. T. Suwanti, S. H. Warsito, N. D. R. Lastuti, D. Rahardjo, and S. Aryaloka, "Detection of Ectoparasites in Farmed Striped Catfish (*Pangasius hypophthalmus*) in Karangpilang, Surabaya, Indonesia," *Vet. Biomed. Clin. J.*, **5**, 2, 63–69 (2023)
17. M. C. Florindo *et al.*, "Protozoan parasites of freshwater ornamental fish," *Lat. Am. J. Aquat. Res.*, **45**, 5, 948–956 (2017)
18. R. R. Dewi, Desrita, and A. Fadhilla, "The prevalence of parasites in ornamental fish from fish market in Medan," *IOP Conf. Ser. Earth Environ. Sci.*, **122**, 1 (2018)
19. H. N. Dominguez *et al.*, "Parasitological diagnosis in ornamental freshwater fish from different fish farmers of five Brazilian states," *Brazilian J. Biol.*, **83** 1–10 (2023).
20. Sufardin, Sriwulan, and H. Anshary, "Gyrodactylus (Monogenea: Gyrodactylidae) on marine ornamental fish Amphiprion percula from a marine aquaculture facility in Indonesia," *Biodiversitas*, **23**, 2, 1023–1030 (2022)
21. E. H. Hardi, *Parasit biota akuatik*. (Mulawarman University Press, 2015)
22. J. W. Fournie and G. Coast, "Parasitic Diseases of Aquarium Fishes," **1980**, 70–72, (1986)
23. G. L. Hoffman, *Parasites of North American Freshwater Fishes*, 2nd ed. (Comstock Publishing Associates, 1999)
24. Zafran, I. Koesharyani, K. Sugama, H. Ikenoue, and K. Hatai, *Manual for fish diseases diagnosis : marine fish and crustacean diseases in Indonesia*. (Singaraja: Gondol Research Institute for Aquaculture, MMAF of Indonesia, 2005)
25. M. Z. Ihwan *et al.*, "Report on marine Capsalid Monogenean parasites in cage-cultured of crimson snapper, *Lutjanus erythropterus* at Johore, Malaysia.," *Res. J. Fish. Hydrobiol.*, **11**, 8, 1–7 (2016)
26. B. G. D. Sumuduni, D. H. N. Munasinghe, and A. Arulkanthan, "Investigation of complete life cycle and species identification of a digenean gill parasite *Centrocestus* sp. infesting Koi carp (*Cyprinus carpio* Linnaeus, 1758) using morphology and morphometric characters," *Ceylon J. Sci.*, **49**, 2, 185–194 (2020)
27. A. O. Bush, K. D. Lafferty, J. M. Lotz, and A. W. Shostak, "Parasitology meets ecology on its own terms: Margolis et al. revisited," *J. Parasitol.*, **83**, 4, 575–583, (1997)
28. S. Kayis, F. Balta, R. Serezli, and A. Er, "Parasites on different ornamental fish species in Turkey," *J. Fish.*, **7**, 2, 114–120, (2013)
29. M. Shariff, Z. Kabata, and C. Sommerville, "Host susceptibility to Lernaea cyprinacea L. and its treatment in a large aquarium system," *J. Fish Dis.*, **9**, 393–401 (1986)
30. A. I. El-Mansy, "On the occurrence of adult females of Lernaea species (Crustacea: Copepoda) parasitic on goldfish *Carassius auratus* (Linnaeus) in some commercial aquaria in Egypt," *Egypt J. Aquat. Biol. Fish*, **13**, 1, 7–25, (2009)
31. J. C. Eiras, H. Segner, T. Wahli, and B. G. Kapoor, *Fish diseases*, 2. (New Hampshire: Science Publisher, 2008)
32. Z. Mozhdeganloo and M. Heidarpour, "Oxidative stress in the gill tissues of goldfishes

(*Carassius auratus*) parasitized by *Dactylogyrus* spp," *J. Parasit. Dis.* (2013)
33. K. Ogawa, M. G. Bondad-Reantaso, M. Fukudome, and H. Wakabayashi, "*Neobenedenia girellae* (Hargis, 1955) Yamaguti, 1963 (Monogenea: Capsalidae) from cultures marine fishes of Japan," *J. Parasitol.*, **81**, 2, 223–227, (1995)
34. U.-H. Nam, H.-J. Seo, I. Hwang, and J.-H. Kim, "*Neobenedenia girellae* infection of aquarium-raised snubnose pompano (*Trachinotus blochii*) in Korea," *J. Fish Pathol.*, **33**, 1, 15–21, (2020)
35. R. Ravi and Z. S. Yahaya, "*Neobenedenia melleni* parasite of red snapper, *Lutjanus erythropterus*, with regression statistical analysis between fish length, temperature, and parasitic intensity in infected fish, cultured at Jerejak Island, Penang, Malaysia," *J. Parasitol. Res.*, **ID1946283**, 8, (2016)
36. A. K. Brazenor, "The biology of the cosmopolitan fish parasite *Neobenedenia girellae*," (James Cook University, 2017)
37. A. Grutter, M. R. Deveney, I. D. Whittington, and R. J. G. Lester, "The effect of the cleaner fish *Labroides dimidiatus* on the capsalid monogenean *Benedenia lolo* parasite of the labrid fish *Hemigymnus melapterus*," *J. Fish Biol.*, **61**, 1098–1108, (2002)
38. Mertinez. Enrique, *Histopathology reviews and recent advances*. (Rijeka: InTech, 2012)
39. C. Ortega, R. Fajardo, and R. Enríquez, "Trematode *Centrocestus formosanus* infection and distribution in ornamental fishes in Mexico," *J. Aquat. Anim. Health*, **21**, 18–22 (2009)
40. B. G. D. Sumuduni, D. H. N. Munasinghe, and A. Arulkanthan, "Chronological analysis of the damages caused by the metacercariae of *Centrocestus formosanus* in the gills of *Cyprinus carpio* and lesions caused by the adult flukes in *Ardeola ralloides*: An experimental study," *Int. J. Vet. Sci. Med.*, **6**, 165–171 (2018)
41. R. A. Francis, *A handbook of global freshwater invasive species*. (Abington: Earthscan, 2012)
42. J. F. Gutiérrez-Galindo and M. I. Lacasa-Millán, "Population dynamics of Lernaea cyprinacea (Crustacea: Copepoda) on four cyprinid species," *Dis. Aquat. Organ.*, **67**, 111–114, (2005)
43. M. Mirzaei, "Prevalence and histopathologic study of Lernaea cyprinacea in two species of ornamentalfish (*Poecilia latipinna* and *Xiphophorus helleri*) in Kerman, South-East Iran," *Turkiye Parazitol Derg*, **39**, 222–226 (2015)
44. N. Steckler and R. P. E. Yanong, "Lernaea (anchorworm) infestations in fish (2021)
45. A. Bozorgnia, N. Sharifi, M. R. Youssefi, and M. Barzegar, "*Acipenser stellatus* as a new host record for *Lernaea cyprinacea* linnaeus, 1758 (crustacea; copepoda), a parasites of freshwater fishes in Iran," *J. Aquac. Mar. Biol.*, **7**, 3, 123–125 (2018)
46. M. Mancini *et al.*, "Ecology and implications of parasitism by *Lernaea cyprinacea* Crustacea: Copepoda) on Argentinian silverside *Odontesthes bonariensis* (Teleostei: Atherinopsidae)," *Panam. J. Aquat. Sci.*, **16**, 1, 30–36 (2021)
47. E. Toksen, M. A. Zoral, and C. Sirin, "Occurence of Lernaea spp. infection in rainbow trout (*Oncorhynchus mykiss*) farmed in Turkey," *Bull. Eur. Ass. Fish Pathol.*, **35**, 1, 8–13, (2014)
48. J. Xu, M. Zhang, and P. Xie, "Trophic relationship between the parasitic isopod *Ichthyoxenus japonensis* and the fish *Carassius auratus* auratus as revealed by stable isotopes," *J. Freshw. Ecol.*, **22**, 2, 333–338 (2007)
49. M.-L. Tsai and C.-F. Dai, "*Ichthyoxenus fushanensis* , new species (Isopoda : Cymothoidae), parasite of the fresh-water fish *Varicorhinus barbatulus* from Northern Taiwan," *J. Crustac. Biol.*, **19**, 4, 917–923 (1999)
50. C. J. Hua *et al.*, "Effects of the parasitic isopod *Ichthyoxenus japonensis* Richardson, 1913 (Isopoda, Cymothoidae) on the growth and gonad development of the goldfish

Carassius auratus Linnaeus, 1758," *J. Crustac. Biol.*, **37**, 3, 356–358 (2017)
51. A. Vasemagi, M. Visse, and V. Sisand, "Effect of environmental factors and an emerging parasitic disease on gut microbiome of wild salmonid fish," *mSphere*, **2**, 6, 13 (2017)
52. R. W. Rottmann, R. Francis-Floyd, and R. Durborow, "The role of stress in fish disease, (1992)
53. N. Nofasari, T. S. Raza'i, and R. Wulandari, "Identifikasi dan prevalensi ektoparasit pada ikan air tawar dan laut dilokasi budidaya perikanan Bintan Kepulauan Riau," *Intek Akuakultur*, **3**, 1, 92–104 (2019)
54. Y. Li, B. Jiang, Z. Mo, A. Li, and X. Dan, "*Cryptocaryon irritans* (Brown, 1951) is a serious threat to aquaculture of marine fish," *Rev. Aquac.*, **1**, 1–19, (2021)
55. W. H. Wildgoose, *BSAVA manual of ornamental fish*, Second edi. (BSVA, 2021)
56. A. Colorni and P. Burgess, "*Cryptocaryon irritans* Brown 1951, the cause of 'white spot disease' in marine fish: an update," *Aquarium Sci. Conserv.*, **1**, 217–238 (1997)
57. L. Zhou, J. Huang, Y. Jiang, J. Kong, X. Xie, and F. Yin, "pH regulates the formation and hatching of *Cryptocaryon irritans* tomonts, wgich affects cryptocaryoniasis occurrence in *Larymichthys crocea* aquaculture," *ASM Journals*, **88**, 7 (2022)
58. F. J. Stephens, J. J. Cleary, G. Jenkins, B. Jones, S. R. Raidal, and J. B. Thomas, "Health problems of the Western Australian dhufish," (Murdoch, 2002)
59. W. J. Hargis, "Disorders of the eye in finfish," *Annu. Rev. Fish Dis.*, **1**, 95–117 (1991)
60. A. I. E. Noor El Deen and M. S. Zaki, "Eye affection syndrome wild and cultured fish," *Life Sci. J.*, **9**, 3, 2568–2575 (2012)
61. S. Kucuk, "The effects of salinity on growth of goldfish, *Carassius auratus* and crucian carp, *Carassius carassius*," *African J. Biotechnol.*, **12**, 16, 2082–2087 (2013)
62. J. L. Sanders and M. L. Kent, "Development of sensitive assy for the detection of *Pseudoloma neurophilia* in laboratory populations of the zebrafish Danio rerio," *Dis. Aquat. Organ.*, **96**, 2, 145–156, (2011)
63. M. Imran, M. S. Sajid, S. O. Swar, M. K. Khan, M. A. Malik, and A. Ahmad, "Parasitic diseases of fish," *Vet. Pathobiol. Public Heal.*, 203–215 (2021)
64. J. Bregnballe, *A guide to recirculation aquaculture*. (FAO & EUROFISH, 2015)
65. M. Hailu and M. A. Mitiku, "The Effects of fish parasites in freshwater culture and Capture fisheries and their treatment mechanisms," *Int. J. Zool. Anim. Biol.*, **4**, 2,(2021)
66. W. S. K. Kolia, Sunarto, and T. Widiyani, "The relationship between water quality and prevalence of ectoparasites on cultured Nile tilapia at two reservoirs in Central Java, Indonesia," in *IOP Conference Series: Earth and Environmental Science*, 824 (2021)
67. K. S. Hutson, A. J. Mooney, I. Ernst, A. K. Brazenor, M. Scheel, and J. Atalah, "A decision support tool for parasite management in fish aquaculture," *Rev. Aquac.*, 1–15, (2022)
68. R. Yanong, "Fish health management considerations in recirculating aquaculture systems - Part 2: Pathogens," *IFAS Extension*, **Cir121**, 1–8, (2003)
69. A. Trujillo-González, R. C. Edmunds, J. A. Becker, and K. S. Hutson, "Parasite detection in the ornamental fish trade using environmental DNA," *Sci. Rep.*, **9**, 5173 (2019)
70. I. Jiménez-García, C. R. Rojas-García, C. N. Castro-José, S. Pavón-Suriano, F. Lango-Reynoso, and M. del R. Castañeda-Chávez, "Growth enhancement, survival and decrease of ectoparasitic infections in masculinized nile tilapia fry in a recirculating aquaculture system," *Trop. Subtrop. Agroecosystems*, **15**, SUP2, 51–56, (2012)
71. D. Standing, T. Brunner, T. Aruety, Z. Ronen, A. Gross, and D. Zilberg, "Mortality of *Cryptocaryon irritans* in sludge from a digester of a marine recirculating aquaculture system," *Aquaculture*, (2016)