



Impacts of COVID-19 Pandemic on Ornamental Fish Supply Chain in Sri Lanka

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Abstract

Sri Lanka is one of the leading ornamental fish exporters globally, with total export earnings of around 15 million USD in 2019. The novel human coronavirus (COVID-19) pandemic has become a great threat to many industries worldwide, including the ornamental fish trade. The present study was conducted to explore the qualitative and quantitative impacts of the pandemic on the ornamental fish supply chain in the Western Province of Sri Lanka with a sample size of 100 respondents representing the key stakeholders of the supply chain. The results concluded that all the stakeholders experienced a negative impact on their business process with the ongoing pandemic. There was a general reduction in sales and along the supply chain, the fish exporters were the least affected sector (7 % reduction), followed by breeders and growers (31 %), and aquarium fish dealers (38 %). The stakeholders who handled a diversified fish stock managed to do better than those who dealt with a single fish species during the pandemic. The supply of fish feeds was one of the significant constraints for all the stakeholders during a complete and partial lockdown. As a positive outcome of the pandemic, 30 % of the fish exporters received an unexpected increased number of export orders from their buyers. Government intervention is crucial to rebuild and strengthen the impacted key players within the ornamental fish supply chain under the pandemic situation.

Keywords: coronavirus, aquaculture, socio-economic, fish trade

Introduction

The fisheries sector comprising marine capture fisheries, inland capture fisheries and aquaculture, plays a vital role in the economy of Sri Lanka by contributing 1.3 % to the gross domestic production (GDP) in 2019 (MFARD, 2020). The ornamental fish sub-sector has grown significantly over the last decade in Sri Lanka, and it has contributed approximately 18 % of the total export earnings of the fisheries sector in 2019 (MFARD, 2020). The supply chain of the ornamental fish industry is highly specific and diversified with the country or region of origin (locality) and category of fish (fresh or marine) (Monticini, 2010). There are various stakeholders in the ornamental fish supply chain namely, breeders, growers, fishers (wild fish collectors), exporters, importers, aquarium fish dealers (retailers), and hobbyists who play a significant

role to maintain the healthy supply chain (Wijesekara and Yakupitiyage, 2001; Monticini, 2010). When considering the ornamental fish supply chain in Sri Lanka, the aquarium fish dealers are the major suppliers of the local market, and they are primarily located in cities (Wijesekara and Yakupitiyage, 2001). The fish farmers (breeders/growers) are varied both in size (small, medium, and large-scale) and the types of cultured species (Heenatigala, 2012). The contract growers assisted by exporters become the major fish growers in Sri Lanka (Wijesekara and Yakupitiyage, 2001). Fish exporters are the foremost local community who compete to maintain the Sri Lankans' share in the international export market. They fulfil their export shipments from their hatcheries and the small and middle-scale fish breeders and growers (Wijesekara and Yakupitiyage, 2001).

The novel human coronavirus disease (COVID-19) was first recorded from Wuhan city in China in December 2019 and identified as the 5th pandemic since the flu pandemic of 1918 (Liu et al., 2020). Most countries took necessary measures to prevent the community transmission of COVID-19 by implementing complete or partial lockdown of countries, and keeping the social distancing (Loneragan and Chalmers, 2020). The global economy plunged with decreasing global manufacturing processes of the essential goods due to the reduced workforce and the implementation of quarantine measures, disturbances for the supply chain of products, loss of local and international business opportunities, reduced market cash flow and revenue growth rates (Haleem et al., 2020).

The main activities of the ornamental fish supply chain are susceptible to disruption or cessation of operation due to the measures taken to control the COVID-19 pandemic, affecting the stakeholders' income and livelihood. As an instantaneous response to the coronavirus pandemic, traders were instructed to stop trading live animals and wildlife due to a suspicion that the pandemic occurred within a retailing and butchering market of wild animals in China (Roe et al., 2020). Moreover, there would be positive outcomes on the industry due to the ongoing pandemic through lifestyle changes. Most studies have only focused on the impacts of the COVID-19 pandemic on the supply chain of food fish-related capture fisheries and aquaculture, but the effects on the ornamental fish trade are overlooked. Therefore, the present study focuses on assessing the significant impacts on the ornamental fish supply chain and identifying policy measures essential to rebuilding the ornamental fish trade with the ongoing COVID-19 pandemic in Sri Lanka.

Materials and Methods

Study area

The study was carried out from July to November 2020. The study sites were selected based on the

literature and secondary data from the National Aquaculture Development Authority (NAQDA) of Sri Lanka and the Association of Live Tropical Fish Exporters of Sri Lanka (SLTFEA). The distribution of most of the ornamental fish breeders, exporters and grow out communities was recorded around the Colombo district, and the industry has expanded to both developed and rural districts, including Gampaha, Anuradhapura and Kurunegala (Wijesekara and Yakupitiyage, 2001; NAQDA, unpubl. data). According to the breeders and growers, and exporters' registration details in NAQDA and the exporters' details in SLTFEA in 2020, 45 % of ornamental fish breeders and growers (Kalutara 19 %, Gampaha 18 % and Colombo 8 %), and 75 % of ornamental fish exporters (Colombo 36 %, Gampaha 34 % and Kalutara 5 %) were recorded from the Western Province (Fig. 1). Therefore, the Western Province was selected as the most appropriate site for the present study.

Data collection

The identified stakeholders under major sectors (exporters, breeders and growers, aquarium fish dealers, and government bodies) were interviewed using sector-specific structured and pre-tested research questionnaires containing closed-ended and open-ended questions. The data collection methodology was conducted using both random sampling and snowball sampling methods. Snowball sampling differs from the random sampling method to identify the close acquaintances of pre-interviewed survey participants, and all gathered participants through this sampling method are mainly generated within the same geographical region (Emerson, 2015). The sample size was quantified to 100 participants (n = 100) for the key stakeholders in the supply chain, which includes 10 ornamental fish exporters, 40 aquarium fish dealers, and 50 ornamental fish breeders and growers. The number of individuals surveyed from each district under three groups was determined based on the key stakeholders' proportional distribution within the three districts (Fig. 1). The fish breeders and growers and fish exporters were

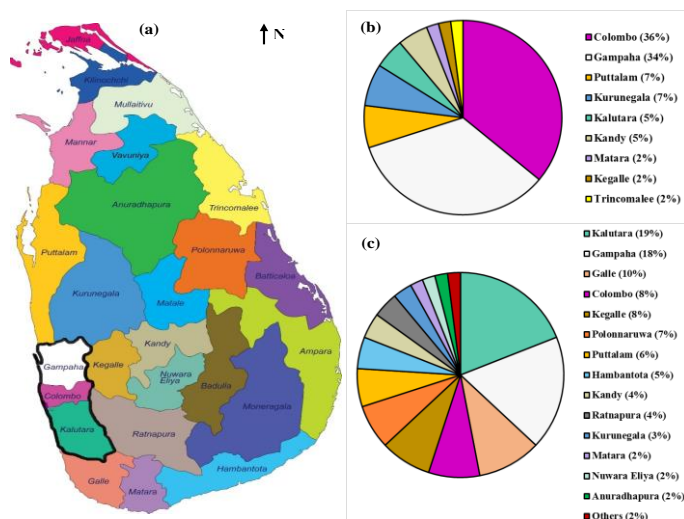


Fig. 1. (a) Sri Lankan map representing all the districts; three districts surveyed under the present study are represented by the highlighted boundaries (Source: National Housing Development Authority of Sri Lanka; http://www.nhda.lk/images/DistrictNetwork/srilanka47_New.png), (b) District wise percentage distribution of the ornamental fish exporters, & (c) District wise percentage distribution of the ornamental fish breeders and growers of Sri Lanka (Source: SLTFEA, 2020; NAQDA, unpubl. data).

selected using a random sampling method based on the registration records of NAQDA, while aquarium fish dealers were identified based on the snowball sampling technique due to the absence of a sample frame. Background information related to the current situation and future development of the ornamental fish industry due to the ongoing pandemic were gathered from the relevant government agencies; Department of Fisheries and Aquatic Resources (DFAR), National Aquatic Resources Research and Development Agency (NARA), NAQDA, and Sri Lanka Export Development Board (SLEDB).

Statistical analysis

The collected data were tabulated into Microsoft Excel and were analysed using the IBM SPSS Statistics 23.0 statistical package. The comparison of the exporters' performances (number of fish export destinations, number of shipments, amount of exported fish, number of freshwater fish suppliers, and number of marine fish suppliers) before and during the pandemic was analysed by the Wilcoxon signed-rank test. A one-way analysis of variance (ANOVA) was conducted to compare the reduction of mean fish sales quantities of the key stakeholders, i.e., exporters, breeders and growers, and aquarium fish dealers. The correlation among the variables was tested by using the Pearson correlation coefficient.

Results

Demographics

The demographic factors and basic information regarding the business process of the major three stakeholders were investigated under eight categories (Table 1). Respondents mainly were males in all three sectors representing 90 % of exporters, 80 % of fish breeders and growers, and 75 % of aquarium fish dealers. Among two exporters (one male and female) from Kalutara district, only one female exporter participated in the current survey, resulting 100 % of female representation from the district under the exporters' category. All the responded exporters were with secondary or tertiary education qualifications. Surprisingly, 70 % of exporters had tertiary level educational qualifications such as diploma, university degree or postgraduate degree or diploma, while the remaining 30 % of exporters had completed their secondary level education, i.e. a general certificate of advanced level examination (GC/AL). Among the aquarium fish dealers, 97.5 % were with the secondary level (80 %) or tertiary level (17.5 %) educational background, while the rest (2.5 %) were with the general certificate of ordinary level (GC/OL) or below the GC/OL education. Among the fish breeders and growers, 82 % had a secondary educational background, while the rest (18 %) had a tertiary educational background.

Most of the breeders and growers had gained required

skills through a training course, diploma on ornamental fish breeding and culture or bachelor's degree, which covers the related course modules. Among these correspondents, 70 % of individuals had completed their training under the government organisations (60 % - NAQDA and 10 % - NARA), and 6 % of correspondents had completed a bachelor's degree at a state university related to the sector, while 24 % of respondents got their training through the private sector. Most of the fish exporters (70 %) got trained and developed their business through private sector training and self-experiences. Forty-five per cent of aquarium fish dealers had completed their training under the government organisations (35 % -NAQDA and 10 % - NARA), 25 % of aquarium fish dealers obtained their training from the private sector and 30 % did not receive proper training.

All breeders only bred and cultured freshwater fish species. Fifty per cent of exporters dealt with freshwater and marine fish species, while 30 % only handled freshwater fishes. The majority of the aquarium fish dealers (95 %) sell freshwater fish, while the rest maintain freshwater and marine fish. Considering the nature of the business, all the stakeholders were the sole owners of the business. Among them, the exporters had an average of 20-years business experience and the breeders and growers had an average of 12-years' experience, while aquarium fish dealers had the lowest average years(10-years) of expertise. The majority of the exporters (60 %) had conducted their export activities with all three major export destinations (USA, Europe and Asia). Thirty per cent of respondents exported their products only to Europe and 10 % to the USA (Table 1).

Species composition

Among the consignments exported, the Siamese fighting fish (*Betta splendens* Regan, 1910)(80 %) and guppy (*Poecilia reticulata* Peters, 1859)(70 %) were the major freshwater fish species, and starfish (Class: Asteroidea) was the key marine fish group followed by fire shrimp (*Lysmata debelius* Bruce, 1983). The majority of the ornamental fish breeders and growers preferred to farm and grow-out *B. splendens* (50 %) followed by freshwater angelfish (*Pterophyllum scalare* (Schultze, 1823)), (24 %) and *P. reticulata* (20 %) as the main fish species in their hatcheries. Goldfish (*Carassius auratus* (Linnaeus, 1758)) (70 %) was the dominant fish species in the local aquarium fish trade followed by *P. scalare* (65 %), zebra danio (*Danio rerio* (Hamilton, 1822))(60 %), and neon tetra (*Paracheirodon innesi* (Myers, 1936))(60 %) in the Western Province.

Impacts of COVID-19 on the key stakeholders of the ornamental fish industry

Impacts of COVID-19 on the ornamental fish exporters

The impacts of COVID-19 on the ornamental fish

Table 1. Demographics and basic information of the observed sectors of ornamental fish supply chain in the current survey of the Western Province of Sri Lanka.

Demographic factors			Sectors of the supply chain		
			Exporters	Breeders and growers	Aquarium fish dealers
Gender wise engagement (%)	Colombo	Male	100	88.2	78.9
		Female	0	11.8	21.1
	Kalutara	Male	0	80	100
		Female	100	20	0
	Gampaha	Male	100	73.9	46.2
		Female	0	26.1	53.8
Age category (%)	Less than 20		0	0	0
	21-40		60	80	60
	41-60		30	20	40
	Above 60		10	0	0
Education qualification (%)	GC/O/L or below		0	0	2.5
	GC/A/L		30	82	80
	Diploma		40	12	12.5
	Degree or above		30	06	05
Training (%)	NARA		0	10	10
	NAQDA		10	60	35
	Related degree		20	06	0
	Other		70	24	55
Export destination/Region (%)	USA only		10	NA	NA
	Europe only		30	NA	NA
	Asia only		0	NA	NA
	All regions		60	NA	NA
Fish category (%)	Freshwater only		30	100	95
	Marine only		20	0	0
	Both		50	0	05
Ownership (%)	Individual		100	100	100
	Partnership		0	0	0
Age of the business (Average year)			20	12	10

n = 100.

GC/O/L - General Certificate of Ordinary Level; GC/AL - General Certificate of Advanced Level; NAQDA - National Aquaculture Development Authority; NARA - National Aquatic Resources Research and Development Agency; NA - Not applicable.

exporters were analysed under five criteria; exported fish, fish export destinations, shipments, freshwater fish suppliers and marine fish suppliers. The Wilcoxon signed-rank test results revealed that the number of fish export destinations ($Z = -2.53, P = 0.011$), number of shipments ($Z = -2.85, P = 0.004$), and the number of freshwater fish suppliers ($Z = -2.03, P = 0.042$) under the ongoing pandemic were significantly reduced ($P < 0.05$) than the pre-COVID-19 period whereas the quantity of exported ornamental fish ($Z = -0.37, P = 0.715$) and the number of marine fish suppliers ($Z = 0, P = 1$) did not change significantly ($P > 0.05$) with the ongoing pandemic.

The average complete shutdown period experienced by the exporters was limited to 2 months during the early stage of the pandemic under the country's

complete lockdown. Individual exporters achieved their targeted fish exports from a smaller number of freshwater ornamental fish suppliers during the lockdown. However, there was a significant drop in shipments for different export destinations under the pandemic. This is mainly due to the limited regular passenger air freights. As a response to the early stage of the pandemic, 40 % of fish exporters released their fish to the local ornamental fish market. Nevertheless, the exporters were not satisfied with their business profit within the local market. As a positive outcome, some exporters (30 %) received a comparatively higher number of orders during the COVID-19 pandemic. All exporters continued to pay adequate salaries for their employees during the complete and partial lockdown periods.

Impacts of COVID-19 on the ornamental fish breeders and growers

The ongoing COVID-19 pandemic affected the local ornamental fish breeders and growers in different ways. Thirty per cent of breeders and growers closed their hatcheries ranging from 1 to 5 months since March 2020, while the rest of hatchery owners (70 %) continued their hatchery practices throughout the complete and partial lockdown. Overall, the total fish production was greatly reduced during the period.

Fish breeders and growers took different strategies to overcome their market losses and effectively used their spare time during the complete or partial lockdown period. Four per cent of fish breeders and growers started to use a digital platform to sell their products. Surprisingly, 24 % of breeders engaged in breeding trials on new species (freshwater shrimps from Family: Atyidae), while 6 % experimented on low-cost culture unit preparation and development of new fish meal formulas to achieve better fish growth performances.

Impacts of COVID-19 on the aquarium fish dealers

All aquarium fish dealers ceased their sales activities ranging from 3 to 8 months. Based on the quantities sold, freshwater Sumatra barb (*Puntigrus tetrazona* (Bleeker, 1855)), and rosy barb (*Pethia conchonius* (Hamilton, 1822)), and *C. auratus* showed an increase in sales while there was reduced demand for other species, just after the complete lockdown (Fig. 2). *Danio rerio* had the highest average negative difference of sales quantity. Among the marine fishes traded within the local market, sales quantities of butterflyfish (Family: Chaetodontidae) were greatly reduced. Twenty per cent of aquarium fish dealers increased their unit fish prices to overcome their losses.

The sales of aquarium and fish tank accessories (fish tanks, filters & filtration equipment, skimmers, lighting setups, air pumps, and other items), aquarium plants and fish feeds were reduced by approximately

50 %. Some aquarium fish dealers changed their business strategies by starting online sales (5 %) and providing home delivery service (5 %) to sustain their business. A few aquarium fish dealers (10 %) engaged in fish breeding trials during the complete lockdown.

Impacts of COVID-19 on the sales of the key stakeholders within the supply chain

All the three stakeholder categories experienced a reduction in their average sales due to the pandemic. According to Tukey's post hoc test results, reduction of sales quantities of the exporters was significantly lower than the fish breeders and growers, and aquarium fish dealers during the pandemic (Table 2).

Table 2. Mean sales quantity reduction of three sectors before and after the COVID-19 pandemic of the Western Province of Sri Lanka.

Stakeholders	Mean of the difference \pm SD
Exporters	-0.0660 ^a \pm 0.122
Breeders and growers	-0.3062 ^b \pm 0.327
Aquarium fish dealers	-0.3843 ^b \pm 0.364

Mean values \pm SD. Different superscript letters differ significantly ($P < 0.05$).

When considering the level of satisfaction, more than 50 % of exporters, 10 % of breeders and growers, and 5 % of aquarium fish dealers were highly satisfied with their business progress during the pandemic (Fig. 3).

Relationship between the number of rearing fish species and the sales volume change with COVID-19 pandemic

There was a negative significant correlation between the number of fish species rearing and the sales volume changing rate of the key stakeholders (Pearson correlation coefficient: $r = -0.18$, $P < 0.05$). It was clear that when a stakeholder of a value chain

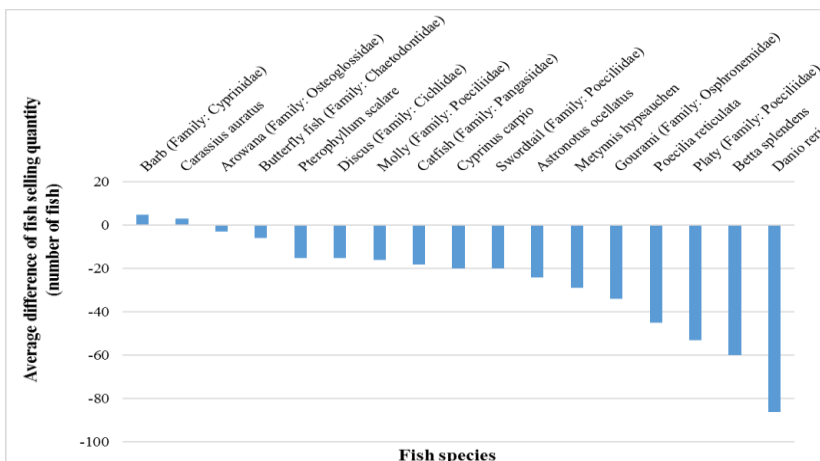


Fig. 2. Average sales quantities difference of the aquarium fish (number of fish) before and after the COVID-19 pandemic of the Western Province of Sri Lanka.

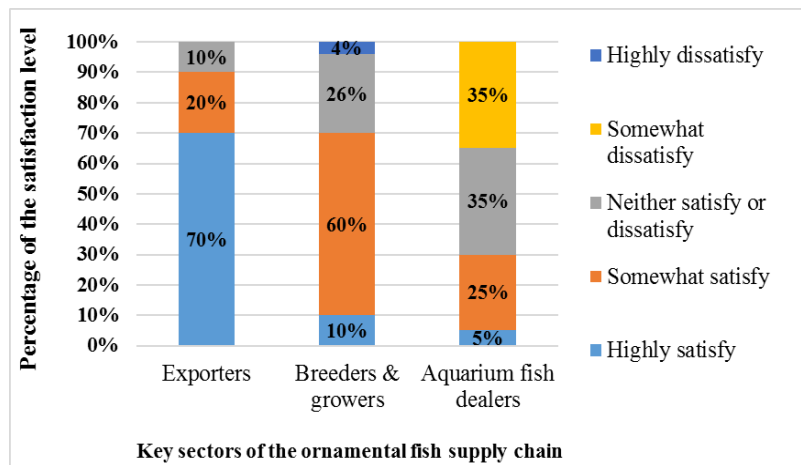


Fig. 3. Percentage satisfaction levels of the key stakeholders with the ongoing COVID-19 pandemic of the Western Province of Sri Lanka.

handles a high number of fish species, there is greater flexibility to tackle the negative impacts of external shocks on the industry. This was seen especially with the fish breeders and growers engaged in breeding and culturing a higher number of fish species that could overcome the effects of the pandemic to a considerable level than those dealing with a single fish species (guppy fish, *P. reticulata*).

Input resource constraints of the key stakeholders with COVID-19 pandemic

Only a few exporters (20 %) experienced a reduction of their workers. All the key stakeholder groups experienced reduced fish feed supply during the complete and partial lockdown period (20 % - fish exporters, 72 % - fish breeders and growers, and 70 % - small and medium-scale aquarium fish dealers). Some breeders and growers (36 %) experienced a similar situation even after relaxing travel restrictions. An increased price of fish feed was another significant constraint especially faced by the fish breeders and growers.

Involvement of the government institutions to strengthen the ornamental fish industry

The responsible government agencies related to the ornamental fish trade, such as DFAR, NARA, NAQDA, SLEDB, took immediate actions, initiated new programmes, and strengthened their ongoing long-term programmes to overcome the identified critical issues due to the COVID-19 pandemic. Some of the short-term and long-term initiatives of the government bodies are summarised below.

Short-term initiatives

- The export-oriented ornamental fish supply chain was identified as an essential service, and special permits were issued for the stakeholders

to operate under the curfew/lockdown condition.

- Discussions and negotiations were made with airlines to get their services for the exporters during the pandemic.
- Stakeholder meetings/discussions were organised to control the fish feed prices within the local market.

Long-term initiatives

- Local fish feed production facilities were implemented under the public and private partnership with the support of the Food and Agriculture Organization (FAO).
- Continuous support for the ongoing research projects in important areas of the ornamental fish sector (development of locally manufactured fish feed, disease resistance fish species, and introduction of the new research-based technologies for the fish growers (Bio-floc system)).
- The anticipated plans were discussed to conduct virtual ornamental fish trade exhibitions to promote the local ornamental fish industry under the ongoing pandemic.

Discussion

Demographics and species composition

This study found that ornamental fish exporters are well-established in Colombo, Gampaha, Puttalam, Kurunegala, and Kalutara, while fish breeders and growers are well-established in Kalutara, Gampaha, Galle, Colombo, and Kegalle districts. EDB (2013, 2020) showed that the distribution of most of the ornamental fish breeders, exporters and grow out communities

were established around the cities (Colombo and Negombo) within the Western Province of Sri Lanka. And later, the ornamental fish industry expanded towards the North, North-central, Central, North-western, and East provinces in Sri Lanka.

The present study revealed that the majority of the respondents had a secondary or tertiary level education. The exporters had the highest level of tertiary education among three key categories and the main reason could be the necessity of improved and updated knowledge to manage their business and resource availability to continue their education. The exporters also have the highest average number of years of experience in the industry compared to the breeders and growers, and aquarium fish dealers. This is mainly because exporters started their business as a breeder/grower or retailer and expanded their activities as exporters with the gained experiences. A higher proportion of respondents acquired technical knowledge and expertise through government organisations' training programmes, which highlighted the importance of government training facilities to support the industry.

All the breeders who participated in the present study only engage in freshwater fish breeding. However, there are few marine fish breeders in Sri Lanka (EDB, 2013). The main reason behind this issue is the lack of breeding technology and facilities and the high initial cost of marine ornamental fish breeding facilities. Thus, this sector requires more funding for research to establish relevant technological knowledge (EDB, 2013). Few aquarium fish dealers (5 %) sell marine fish species for local hobbyists due to the difficulties and high cost of the seawater collecting procedures, high fish prices, and maintenance difficulties. The arowana fish (Family: Osteoglossidae) was highlighted as a high-value freshwater fish group in both local and export ornamental fish markets. These fish are mainly imported to Sri Lanka from Southeast Asian countries to meet local and export market demand due to the absence of commercial-scale breeding in the country. However, Asian arowana (*Scleropages formosus* (Müller & Schlegel, 1840)) has been successfully bred in Polonnaruwa district for the first time in Sri Lanka (EDB, 2017), and this is a positive development of high-value fish species breeding within the country.

Overall performance of the key stakeholders with COVID-19

All three groups of the ornamental fish supply chain were negatively affected by the measures imposed by the government of Sri Lanka to avoid the spreading of COVID-19. Similar negative impacts were observed in the Indian ornamental fish trade due to various management measures taken to control the pandemic (Ail and Swain, 2020). Nevertheless, the exporters had the least disruption due to adequate resource availability, knowledge and experience in the business and market process. During the early stage of the

pandemic, when air freights were restricted and limited, exporters sent their fish to the local market and became an added competitor for the local market. This can be considered an instant, flexible decision of the fish exporters to overcome the sudden shock of the pandemic.

In response to the pandemic, 90 % of exporters boosted their online marketing campaigns during the total lockdown period to stay in touch with their buyers and find new buyers. Also, Winarsih et al. (2021) highlighted that small and medium-scale enterprises (SMEs) need to work with their available online platforms and digital skills to upgrade their business strategies and sustain the ongoing and future business against the pandemic. Shifting from passenger flights to cargo flights negatively affected the exporters' supply chain through different ways, such as increased cost for the cargo air freights and the extended time of the air freights to the final destinations.

As a positive outcome of the pandemic, some exporters received a comparatively increased number of orders from their buyers during the winter season of certain countries/regions. This increased demand is mainly due to the conversion of people's normal lifestyle to an indoor lifestyle due to the lockdown and movement restrictions (Fernando, personal communication, 27 July 2020). Since most individual exporters have their own hatcheries, they met their buyers' demand just after the complete lockdown, despite the reduced number of freshwater ornamental fish suppliers. Nevertheless, the exporters showed minimal involvement in supporting their associate fish breeders and growers during the pandemic.

As the essential player of the ornamental fish supply chain, the exporters can support the small-scale breeders through different arrangements such as increasing the unit price of fish purchasing, financial supports such as loans and agreements on fish purchasing. Most of the fish exporters who handled freshwater and marine ornamental fish species experienced a less negative impact. In contrast, exporters limited to one fish category (freshwater or marine) faced significantly reduced demand and shipments. A similar situation was observed among the fish breeders and growers. This showed that diversification of fish species in the value chain is a vital strategy to absorb the external shocks.

Breeders and growers were the second most negatively affected group in the ornamental fish value chain. They suffered from over-stocking fish and high fish mortality. Similar effects were reported among the Indian ornamental fish farmers at the early stage of COVID-19 pandemic (Ail and Swain, 2020). In response to the pandemic, some breeders and growers harvested their fish at early growth stages and sold their harvest to the local aquarium fish dealers at low prices. Similarly, Kumaran et al. (2021) observed 'panic harvesting' in Indian shrimp farming during the

lockdown, and farmers had to sell their stocks at the lowest price to mitigate the financial losses.

Aquarium fish dealers were recognised as the most negatively affected sub-sector within the ornamental fish value chain. This might be due to the travel restrictions, low financial stability, lack of fish, fish feeds and accessories for their business. A few aquarium fish dealers started online marketing to cope with the situation. Ail and Swain (2020) also reported the importance of online marketing and delivery facilities of aquarium fish during the pandemic in India. The study on capture fishery by Azmy et al. (2021) along the Sri Lankan coasts reported that stakeholders within the fishery sector had to deal with the limited accessibility to their fishery activities. This included little or no access to the market process, customers, and fisheries services during the pandemic due to the restrictions imposed by the Sri Lankan government. Stakeholders of the ornamental fish value chain (majority of the small-scale) also faced similar issues during the early stage of COVID-19.

Resource limitations due to COVID-19

All the breeders and growers and aquarium fish dealers (small and medium scale) did not experience a reduction in the number of workers for their operations. This is because they are both entrepreneurs and work mainly on their own business, and they get support from their family members. This was a positive attribute for them that they were independent of external human resources for their business activities during external shocks like pandemic situations. However, this situation was completely different with the large-scale breeders and growers, and aquarium fish dealers. Kumaran et al. (2021) showed that large-scale businesses were negatively affected by reduced workers due to restrictions imposed with the COVID-19 pandemic. Transportation restrictions and the fear of current virus infection were the foremost reasons for reducing permanent and temporary workers (Kumaran et al., 2021).

Import restrictions and disturbances on the local fish feed distribution channels are the foremost reasons for the feed limitation within the aquaculture sector during the pandemic (FAO, 2020). A study regarding the aquaculture sector in Malaysia identified feed limitation as a critical issue during the early stage of the COVID-19 (Azra et al., 2021). The fish exporters who had hatcheries faced a reduction of live and dry fish feeds within their feedstocks in the early stage of the pandemic in Sri Lanka. This study found that 20 % of the live marine fish exporters did not face any feed shortage because they released their marine fish stocks back to the ocean during the early complete lockdown period. During the complete lockdown period, the breeders and growers, and aquarium fish dealers experienced difficulties in purchasing fish feeds for their hatcheries and supplies for shops.

Production of local low-cost, high nutritional dry and live feeds will help avoid the dependability of high cost imported feeds. Some fish feed production facilities were recently established to supply local fish feed demand within the country. Increased production of the live fish feeds (Brine shrimp *Artemia* spp. Leach, 1819) from the saltern facilities is an important aspect for controlling the high-priced live feeds in aquaculture (Van Stappen et al., 2020). Production of dry cysts of *Artemia* spp. from salterns is currently occurring within the country, but these cysts have low hatchability. In line with the current issue, NARA has been researching to develop technologies to extract high-quality cysts of *Artemia* spp. and produce low-cost commercial feeds for the local demand (Epasinghe, personal communication, 10 August 2020).

Drivers to sustain the current industry

The significant negative impacts on the trade performances were observed among the SMEs within the ornamental fish value chain of Sri Lanka. To overcome these effects, SMEs need support from the government and private sector. A similar study on the coastal fisheries sector in Sri Lanka highlighted that the fishers expect financial assistance and subsidies from the government to cope with the pandemic (Azmy et al., 2021). To mitigate the effects of COVID-19 pandemic, the Malaysian government provided monetary stimulus packages as incentives to the SMEs within the aquaculture sector to lessen the negative impacts and ensure the future sustainability of the aquaculture industries (Waiho et al., 2020). Azmy et al. (2021) reported that collaborative private-government partnership is greatly needed to ensure the long-term position of the SMEs in the capture fisheries sector against the COVID-19 by introducing technology such as online order and delivery facilities. In the present study, the key players of the ornamental fish supply chain made similar requests for monetary and technological facilities.

In India, novel investment projects were identified under the title 'Made in India' to promote the locally produced aquarium tanks and accessories to compete with the imported products and as a step to develop the small-scale trades within the country (Ail and Swain, 2020). Similar strategies have to be implemented within the Sri Lankan ornamental fish trade to overcome COVID-19 impacts. Most small-scale fish breeders and growers used to sell their fish to the local market through a middleman to sustain their business during the pandemic. The engagement of the middleman has badly affected the small-scale breeders and growers. To avoid these issues, the relevant authorities/organisations must assist and develop direct transaction platforms within the ornamental fish trade.

Some of the medium and large-scale breeders expect to increase their current production by expanding their hatchery practices. This is a positive move despite the

pandemic. Such offers must be facilitated by the relevant public and private authorities to increase ornamental fish production. Integrated top-down and bottom-up approaches can be embedded as the most important channels of mitigation measures to rebuild and strengthen the ornamental fish value chain by facilitating and monitoring the entire value chain against the pandemic. Even though the government institutions have taken several initiatives to support the ornamental fish industry with the ongoing COVID-19 impacts, it is suggested that the government has to create knowledge-based stakeholders who will feel more secure in facing challenges and risks in the future.

Conclusion

All three key sectors of the ornamental fish supply chain experienced negative impacts during the COVID-19 pandemic. Travel restrictions, reduced market demand, high fish mortality, over-stocking, reduced supply of fish feeds, and long-term shutdown periods were identified as critical issues experienced by all the key players in the supply chain. The exporters were the least affected sector, followed by breeders and growers and aquarium fish dealers. Lack of fish feeds during the pandemic had significantly affected the local fish breeders and growers. As a positive outcome, the ornamental fish sector was identified as an essential services category to resume their activities even under the travel restrictions within the country. Surprisingly, some exporters received comparatively high export orders during the pandemic. Additionally, some stakeholders started digital/online marketing and delivery services to sustain their businesses. And the large-scale breeders began to expand their production facilities to meet the future high demand in the export market. In the early pandemic, government institutions of Sri Lanka played a significant role in supporting all the stakeholders in the ornamental fish value chain and continued their activities to uplift the industry. Under the ongoing pandemic, the financial assistance and subsidies for the stakeholders are vital to sustain (SMEs in the trade) and expand (large-scale farmers and exporters) the ornamental fish trade. Government organisations should support the development and strengthen the small and medium-scale breeders/growers' networks. It will enable them to thrive in the highly competitive trade through producing high-quality fish for the export market demand, pricing their fish, sharing knowledge and expertise among the members, and reducing the production cost. The assistance for the exporters on their capacity development, such as the expansion of the exporters' owned and supported hatcheries and business promotions, is substantial to expand the export-oriented supply chain, which generates more revenue into the trade. Moreover, knowledge sharing and technology transfer activities (application of biosecurity, novel culture techniques, disease identification, treatments, and communication), long-term research (low cost and high nutritional fish feed

development, fish breeding (high-value freshwater species and high demand marine fish species), and new varieties development activities) are essential to establish among the stakeholders within the industry. It is suggested that government institutions, agencies, and other stakeholders in the sector need to thoroughly study the effects of COVID-19 pandemic and suggestions to establish a long-term development plan to strengthen the sector.

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