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Advances in Bioresearch

ORIGINAL ARTICLE

Estimation of economic loss due to infestation of Ostracoda *Vargula tsujii* (Myodocopa: Cypridinidae) in some marine food fishes off Pamban, the Southeast coast of India

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ABSTRACT
A research work was carried out to estimate the economic losses to fishermen due to infestation of Ostracoda Vargula tsujii in some marine food fishes in the region of Gulf of Mannar and Palk Bay during July 2019 to June 2020. Total 9251 fish samples representing10 major species were investigated for the infestation of Ostracoda Vargula tsujii. The fish species studied were Parupeneus indicus, Lutjanus fulviflamma, Priacanthus hamrur (Snapper), Carangoides gymnostethus, Carangoides malabaricus, Carangoides ferdau (Carangids), Cephalopholis sonnerati, Epinephelus coioides (grouper), Lethrinus ornatus and Plectorhinchus gibbosus (sea bream). The average prevalence of Ostracoda V. tsujii was 14.17% with 0.23% abundance (relative density) and 1.91 of mean intensity but varying with different seasons. The highest abundance was The total fish catch became unsuitable for human consumption by severe infestation of V. tsujii was 3.82%, therefore total loss of 749.81 ton of trash fish was estimated from total 19220 ton of capture per year, the estimated loss form Pamban landing centre alone INR 17.02 core (US$ 2.21). The authors had reported the infestation of Ostracoda Vargula tsujii in marine food fishes for the first time, the present study focuses on economic loss to the fishermen community due to severe infestation of Ostracoda V. tsujii estimated.
Keywords: *Ostracoda, Vargula tsujii, infestation, economic loss, marine food fishes, Rameswaram, Pamban*

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INTRODUCTION

Fisheries in India are an expanding industry, with varied aquatic resources and potential, engaging over 14.50 million people at the primary level and many more along the value chain. Transformation of the fisheries sector from traditional to commercial scale has led to an increase in fish production from 7.5 lakh tones in 1950-1951 to 137.0 lakh tone during 2018-2019, India had exported 13.9 lakh tones of seafood worth Rs 46,589.37 crore (USD 6,728.50 million)[1]. In fish production, India is constantly at the second position after China. While, India has made a sufficiently fast progress in achieving production of 7.2 million ton, and aiming for doubling it by 2020, there remains an opportunity for further increasing the production of fish from inland water bodies like reservoirs, wetlands, lakes and canals. Cage culture has the potential application in such water bodies and the results in Chandil reservoir in Jharkhand, is encouraging [1].

Indian fisheries and aquaculture is an important sector of food production, providing nutritional security to the food basket, contributing to the agricultural exports and engaging about fourteen million people in different activities. With diverse aquatic resources, the country has shown continuous and sustained increments in fish production since independence. Constituting about 6.3% of the global fish production, the sector contributes to 1.1% of the GDP and 5.15% of the agricultural GDP. The total fish production of 10.07 million metric tons presently has nearly 65% contribution from the inland sector and nearly the same from culture fisheries[2]. However, occurrence of disease has become a primary constraint to sustainable aquaculture production and product trade, thereby affecting the socioeconomic status of fishers in country like India. Different stress factors such as inadequate physicochemical and microbial quality of culture water, poor nutritional status and high stocking density can cause infection by opportunistic pathogens. Acute level of pollutants and suspended solids can directly bring about abnormalities and mortalities in seed fishes and adults. Different opportunistic bacterial pathogens and parasites cause devastating loss to fish industry in terms of high morbidity and mortality, diminishing growth and enhanced expenditure on use of chemicals as preventive and control measures. The prevention of fish diseases is essential for the betterment of the fisheries industry, the improvement of farming production, and the increase in fish resources. The details of fish diseases in Indian freshwater aquaculture system and potential for future development have been elaborated [2].

Infestation of metazoan and protozoan animals play an important role in the ecology of aquatic ecosystems. They can cause harm to the host by tissue damage and can also make the host more susceptible to secondary infection, by weakening host immunity and subsequent economic losses resulting from fish mortality [3], Endoparasitic diseases affect the normal health conditions and cause reduction of growth, abnormal metabolic activities and even death of affected fish. According to Kabata [4], factors that directly influence the abundance and prevalence of endoparasitic fauna of fishes include; age, diet, environment of fishes and season.

The estimation of the economic cost of a parasite event is frequently complicated by the complex interplay of numerous factors associated with a specific incident, which may range from direct production losses to downstream socio-economic impacts on livelihoods and satellite industries associated with the primary producer and landed fished [5].

Loss due to parasitic disease in culture fishes are well documented in the literature. Production loss in *Salmo salar* (Atlantic salmon) due to infection of *Caligus rogercresseyi* was estimated to be 31,266 t with worth of 193.6 million US$ by Shinn et al.[6]. Total production loss in *S. salar* farms globally in 2009 by infection Sea lice *(Lepeophthirius salmonis & Caligus species) was* 107,696 t with worth of 480 US$ [7]. Tavares-Dias and Martins (2017) had recorded the losses caused by parasitic infection diseases in the Brazilian fish farms which were estimated in US$ 84 million per year [7].

Cypridinid (myodocopid) ostracods are the diverse group of small aquatic crustaceans usually around 0.3 to 5mm in length. Their most distinct feature is their calcitic carapace, a hard bivalve, hinger shell that can entirely cover and protect the non-mineralised bodyparts and appendages. The scientific reports available on the Ostracoda are very limited. Ostracoda is an ancient, ecologically diverse, monophyletic group of crustaceans with a dense stratigraphic record. Occurrence of Ostracoda *Vargula tsujii* in some marine food fishes was first reported by Jayapraba et al.[8]. Parasitic and infectious diseases are common in finfish, but are difficult to accurately estimate the economic impacts on the production in a country with large dimensions like India. The aim of this study was to estimate the costs caused by economic losses due to infestation of Ostracoda *Vargula tsujii* in captured marine food fishes. An attempt was made to establish by the first time an estimative of overall losses in marine food fishes based on the field studies The loss incurred due to parasites diseases is yet to be calculated for captured fishes in India. Thus, keeping in view the importance of parasites diseases, the present study was designed to investigate the prevalence, abundance and mean density of parasites infestation as well as estimate loss due to infestation of Ostracoda *Vargula tsujii* in some captured food fishes from Pamban coast.

MATERIAL AND METHODS

Selection of food fishes infested with Ostracoda

Collection of host fish Samples

Major food fishes from Pamban landing centre which covers fishing boats over 100 from Palk Bay and Gulf of Mannar were selected to study the infestation Ostracoda *Vargula tsujii* and its impact on the loss due to tissue damage which made fishes unsuitable for human consumption. In the present study, ten major food fish species viz. *Parupeneus indicus*, *Lutjanus fulviflamma*, *Priacanthus hamrur* (Snapper), *Carangoides gymnostethus, Carangoides malabaricus, Carangoides ferdau* (Carangids), *Cephalopholis sonnerati, Epinephelus coioides* (grouper), *Lethrinus ornatus* and *Plectorhinchus gibbosus* (sea bream) were investigated in the present study. Pamban is one is one of the biggest captured fish landing center in South India, it operates 105 fishing boats from both Palk Bay and Gulf of Mannar region, each boat is estimated to capture about 2.5 ton per day, therefore 3 fishing days per week, for 46 weeks in a year by excluding 6 weeks ban, with total 138 fishing days in a year, the estimated quantity per year is 36225MT (105*2.5=262.5*138) (Source: CMFRI unpublished data). These 10 species food fishes contribute more than 50% of total fish landing volume in Pamban; hence this study was undertaken and estimated the loss by infestation.

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Total 10 species food fishes belonging to Snapper (3 nos.), Carangids (3 nos.), Grouper (2), Sea bream (2 nos.), were collected from freshly captured (by trawlers) fish stock in Pamban (9.27°N, 79.22°E), Gulf of Mannar, India. All fishes were dead at the time of capture and 35 - 105 fish samples of each species made every month and examined the infestation of ostracoda on the gills and other body parts. The fishes found with occurrence of Ostracoda in the gills were preserved in ice-box thermocol and taken to the lab for further examination and reported as monthly and seasonal average readings.

Collection, examination and identification of Ostracoda from host fishes

Fish samples found with infestation of ostracoda *V. tsujii* their gills were kept separately for further investigation. recorded. The gills were carefully separated to dislodge the Ostracoda *V. tsujii,* mouth, intestine and stomach parts were also examined for the infestation and placed on separate petri-dishes containing filtered water and examined by a magnifying glass to find out the infestation of Ostracoda *Vargula tsujii*. The fishes infested with ostracoda was dissected and picked up the Ostracoda present in gills, mouth, stomach and intensive with help of forceps and needle and abundance were recorded and reported as monthly average readings[8]. Identification Ostracoda species was done as described by Jayapraba et al.[8].. All ostracoda specimens collected were preserved in 4% formalin. The fishes were dissected and internal organs were examined to record the abundance and mean density of Ostracoda. Then the internal organ like stomach and intestine were separated and put into physiological saline solution (0.7% NaCl Solution) in a petri-dish. Each organ was then examined separately, stomach, intestine was split open and was shaken in a tube to dislodge the Ostracoda remaining attached to the epithelial lining. Then the collected Ostracoda were carefully preserved in 70% alcohol with a few drops of glycerine for 24 h. and species identification was done as described by Jayapraba et al. [8]. The prevalence, abundance and mean density of parasites were estimated according to Margolis [9].

Estimation of loss due to infestation of Ostracoda in captured food fishes

The loss due to tissue damage caused by severe infestation of *V. tsujii* was estimated as described below:
Total loss (INR) = Trash fish by infestation of Ostracoda (kg) X Farm gate price per Kg of fish.

Statistical analysis

Data are presented as means ± SD of at least twelve independent measurements. A one-way analysis of variance (ANOVA, SYSTAT version 7) was used to determine the prevalence and abundances of Ostracoda infested in fishes. A Tukey's HSD test was applied for post-hoc comparison studies and data were considered statistically significant when $p < 0.05$.

RESULTS

Ostracoda collected and investigated from food fishes

Species identification of Ostracoda was done based on the PCR analysis as described by Jayapraba et al. (2020) and it was identified as *Vargula tsujii*. Total 9251 samples from 10 major food fishes were examined for the infestation of Ostracoda *V. tsujii* and economic loss caused by it. Table 1 shows the total number of samples studied with their body mass (mean and SD) and length (mean and SD) of each species and they were: 3 snapper species viz. *Parupeneus indicus:*1562 nos., 180-330g (247 ± 55 g) and 280-332mm (295 ± 12mm), *Lutjanus fulviflamma:* 1255 nos., 220-400g (305 ± 85 g) and 275-360mm (303 ± 21 mm), *Priacanthus hamrur:* 440 nos., 250-350g (292 ± 42 g) and 270-340mm (310 ± 23 mm), 2 Carangoides viz. *Carangoides gymnostethus:* 1592 nos., 510-1250g (695 ± 140 g) and 290-410mm (345 ± 27 mm), *Carangoides malabaricus:* 1460 nos., 410-750g (595 ± 120 g) and 250-360mm (345 ± 27 mm), *Carangoides ferdau:* 457 nos., 450-1820g (955 ± 275 g) and 220-390mm (333 ± 47 mm), 2 grouper species *Cephalopholis sonnerati: :* 303 nos., 250-550g (370 ± 45 g) and 230-290mm (253 ± 27 mm), *Epinephelus coioides:* 654 nos., 400-1250g (950 ± 230 g) and 240-370mm (305 ± 52 mm) and 2 sea bream species viz. *Lethrinus ornatus: :* 1253 nos., 520-1660g (850 ± 275 g) and 270-370mm (310 ± 22 mm) and *Plectorhinchus gibbosus:* 275 nos., 450-2250 (900 ± 330 g) and 270-390mm (290 ± 15 mm).

Figures 1-10 show the infestation of *V. tsujii* on the gills of 10 species studied. Ostracods attached to the gills, mouth parts, intestine and stomach of 10 species studied were collected and studied. The largest number of ostracoda *V. tsujii* was found between adjacent gill filaments and on the out margin of gills as well. The size of *V. tsujii* examined in this study varied and it was 1.5 to 3.5 mm by anterior-posterior position and 1.3 ± 0.13 mm of dorso-ventral region with width of 0.7 ± 0.05mm (Fig 11). Variation in the number of Ostracoda collected from different organs of 10 species studied is shown in Fig 12. More than 60% of infestation was found only in gills (62.31%) followed by mouth (21.59%), intestine (11.93%) and least infestation was found in stomach (4.17%). Severe infestation of *V. tsujii* had caused some tissue damage to the host fishes which made them to unsuitable for human consumption (Fig 13) which contributed 3.82% of total estimated captured quantity. The overall prevalence, abundance and mean density of the total parasites are shown in Table 1. Highest level of prevalence of infestation Ostracoda *V.*

tsujii was found with *P. indicus* i.e. 21.33% *C. malabaricus* (18.16%) and *C. gymnostethus* (17.51%) and least was found with *P. gibbosus* (8.0%). Abundance (relative density) and mean density of infestation of *V. tsujii* in all these 10 species studied were given in the Table 1.

Infestation of Ostracoda in different organs of host fishes

The Ostracoda *V. tsujii* was isolated from different organs like body slime/skin, gill, stomach and intestine of examined fishes species. The number of ostracoda present in the fishes examined was done manually and size was measured by analog vernier caliper (accuracy level upto 0.02mm). An average no of. *V. tsujii* collected from 10 fish species are 111.06 ± 17.5 (*P. indicus)*, 61.50 ± 5.1 (*L. fulviflamma),* 18.96 ± 13.0 *(P. hamrur)*, 92.92 ± 10.6 (*C. gymnostethus), C.* 88.38 ± 9.5 (*C. malabaricus),* 11.64 ± 7.7 *(C. ferdau)*, 10.09 ± 12.8 (*C. sonnerati),* 32.85 ± 6.5 (*E. coioides)*, 68.41 ± 5.5 (*L. ornatus*) and 7.33 ± 6.0 (*P. gibbosus)* Table 2.

Comparative prevalence, abundance and mean density with respect to seasonality

The overall prevalence (%), abundance and mean density of the total parasites was observed to fluctuate seasonally during the study period. Prevalence of infestation with respect to seasonality in *P. indicus* in summer, pre-monsoon, monsoon and winter are 30.91%, 31.77%, 10.26% and 12.37% respectively, in *C. malabaricus* it was 21.93%, 22.77%, 10.79% and 17.12%, in *E. coioides* 15.66%, 22.85%, 7.44% and 15.11% and in *L. ornatus* 25.59%, 16.48%, 11.22% and 12.13% respectively and other species also it varied with season as shown in Table 2.

Estimation of economic loss due to infestation of Ostracoda

During the study period, a total of 9251 food fish samples belonging to 10 species were studied, of which only 1509 samples were found with infestation of *V. tsujii*. The estimated quantity of fish through capture in Pamban landing center is 36225MT, of which 19220 MT come from these 10 species studied in the present investigation. Total infestation of *V. tsujii* was 17.71%, but total trash fish which is unsuitable for human consumption due to severe infestation of *V. tsujii* estimated was 3.82%, i.e. 749.81MT. The farm gate price of these food fishes range from INR 150 to 300 per kg, with an average farm gate price of INR 220 per kg, the total loss estimated was INR 30.14 crore (US$ 3.91 million) per year (Table 3).

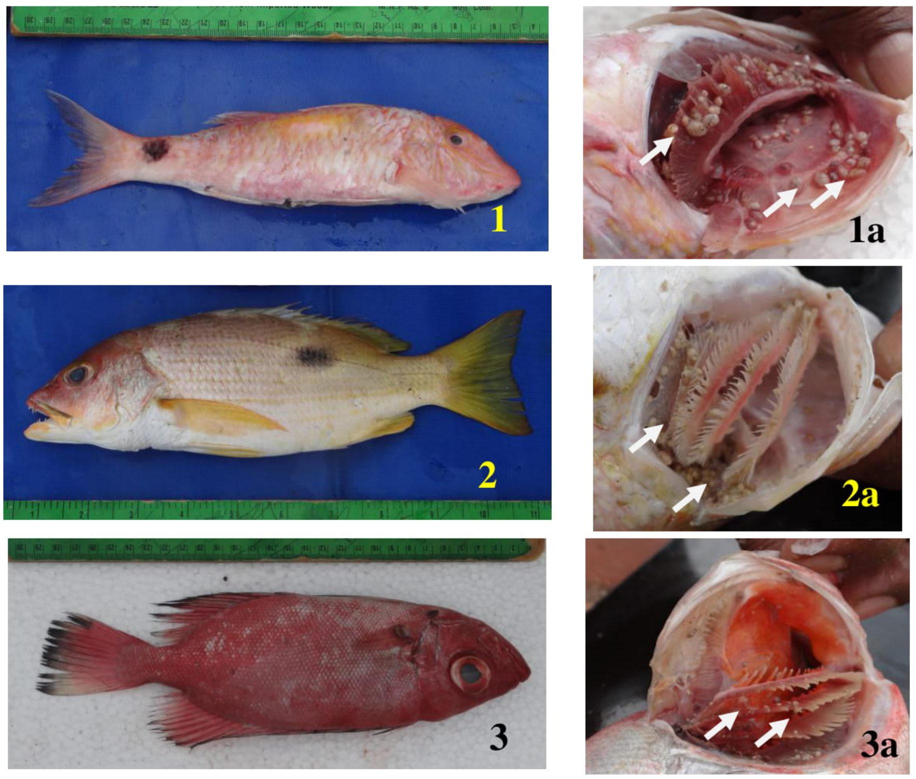

Figure 1-3: Infestation of Ostracoda *Vargula tsujii* in common marine food fishes belonging to Snapper: **1 & 1a.** *Parupeneus indicum* (Uruttu nagari) & Its infested gills; **2 & 2a.** *Lutjanus fulviflamma* (Kili nagarai) & Its infested gill, **3 & 3a** *Pricantus hamrur* (Chempalli) & Its infested gill

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Figure 4-6: Infestation of Ostracoda *Vargula tsujii* in common marine food fishes belonging to Carangids. **4 &4a** *Carangoides gymnostethus* (Thenga Parai) & Its infested gills, **5 & 5a** *Carangoides malabaricus* (Mutta Parai), **6 & 6a** *Carangoides ferdau* (Manja kili Parai) & Its infested gills.

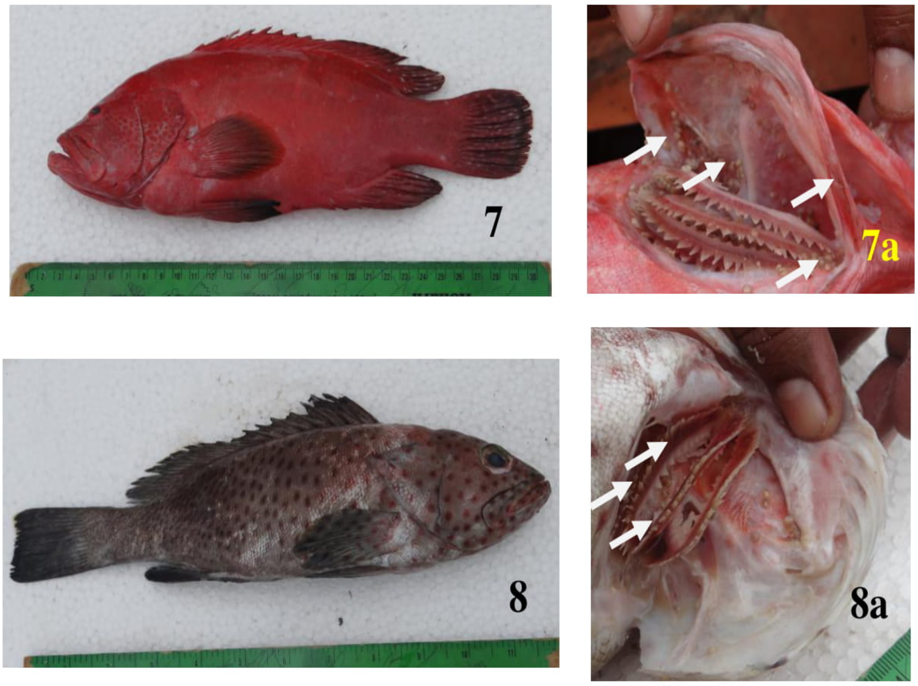

Figure 7 & 8: Infestation of Ostracoda *Vargula tsujii* in common marine food fishes belonging to Grouper: **7 & 7a** *Cephalopholis sonnerati* (Red Kalava) & Its infested gills, **8 & 8a** *Ephinephelus coioides* (Kalava) & Its infested gills.

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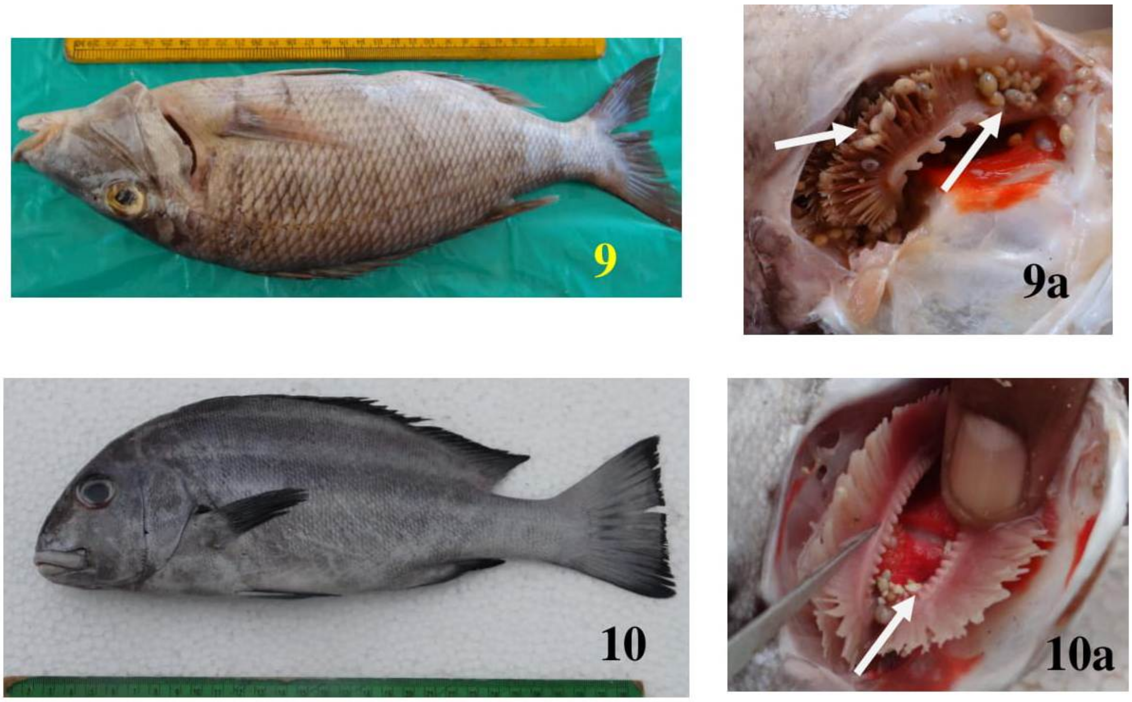

Figure 9 & 10: Infestation of Ostracoda *Vargula tsujii* in common marine food fishes belonging to Sea bream: **9 & 9a** *Lethrinus ornatus* (Velai meen) & Its infested gills, **10 & 10a** *Plectorhinchus gibbosus* (Tholan) & Its infested gills

Figure 11: Ostracoda *Vargula tsujii* collected from gills of *Parupeneus indicum* (Uruttu nagari); size ranges from 1.5mm to 3.5mm

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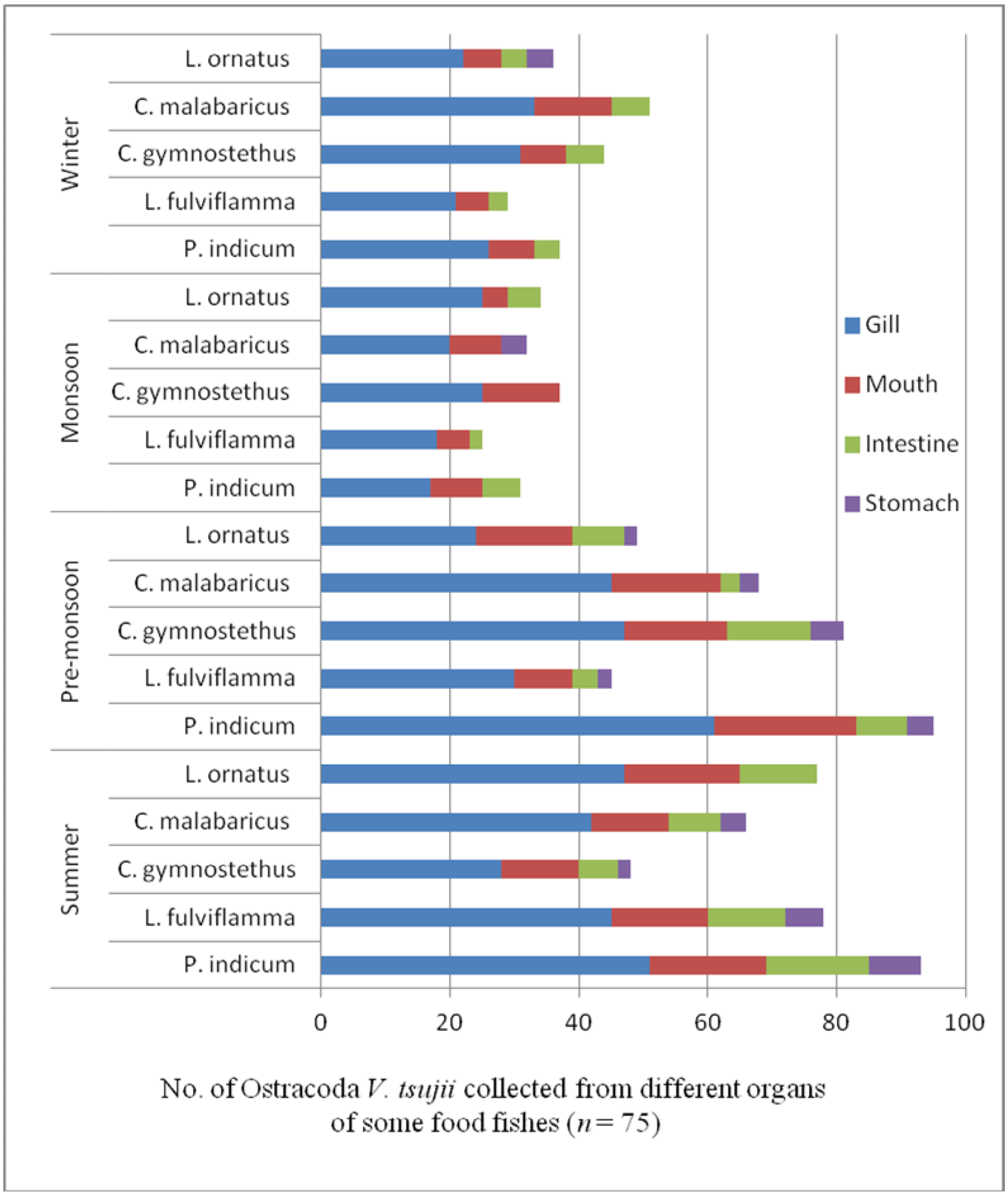

Figure 12: Number of Ostracoda *V. tsujii* recovered from the different organs of some major food fishes with respect to seasonality

DISCUSSION

Infestation of metazoans animals have not only major impact on global finfish and shellfish aquaculture, having significant effects on farm production, sustainability and economic viability and it also causes heavy losses to the capture fishes also. Obligate and opportunistic parasites play a critical role in determining the productivity, sustainability and economic viability of global finfish aquaculture enterprises. The factors can range from direct losses in production to the more indirect costs of longer-term control and management of infections and the wider, downstream socioeconomic impacts on livelihoods and satellite industries associated with the primary producer. Certain parasite infections may be predictable, as they occur regularly, while others are unpredictable because they arise sporadically. In each case, there can be costs for treating and managing infections once they are established, but for predictable infections, there also are costs associated with prophylactic treatment and management[6]. Table 4 provides some estimates of economic loss associated with notable protistan and metazoan parasite events in some of the world's leading finfish production industries. Given the broad diversity of aquaculture, the 267 food finfish species and categories listed by the Food and Agriculture Organization (FAO) of the United Nations and the vast spectrum of parasites that can impact their production, it is almost impossible to ascribe a single value that captures all the losses induced by parasite activity in each

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industry. Likewise, despite continuous health monitoring by on-site diagnosticians, it is technically impossible to determine the cause of mortality of every fish on site [6].

Infection of parasites like copepod, nematode, cestoda, monogena and digenea to marine food fishes are well documented in the literature [10]. Moravec *et al.* [11] reported the infection of nematodes in the intestine of Indian goat fish *P. indicus*, occurrence of gill parasites Monogenoidea has been recorded in *L. fulviflamma* [13]. Ho & Kim [14] had reported the infestation of five species of copepod (Siphonostomatoida: Lernanthropidae) parasites on *P. hamrur* from the Gulf of Thailand. Infection of isopod *Catoessa boscii,* a buccal cavity parasite [15], copepod 22.5% of prevalence with copepod[16] and Nematode parasites [17] have been reported in Carangoides fishes. Occurrence of monogeneans parasites, in grouper fishes *C. sonnerati* and *E. coioides* [18, 19], different species of copepod, nematode and cestoda in sea bream *L. ornatus*[17] and *P. gibbosus* [20] were documented. However, no data is available on the level of impacts of infestation or infection of parasites and their tissue damage on host fishes and subsequent loss in economics in the literature were reported.

In the present study, an attempt was made to estimate the loss the infestation of Ostracoda *V. tsujii* some major marine food fishes from Pamban, one of the biggest fish landing center in south India with capturing capacity of 40-50 thousand tones per year. The highest prevalence of infestation of *V. tsujii* among the fishes examined was 38.36% in *P. indicus* and lowest was in *C. ferdau* but varying with seasons. With regard to organs, the highest number of *V. tsujii* was recorded on the gill (62.31%) followed by mouth (21.59%), intestine 11.93% and lowest number of infestation was found in the stomach (4.17%) of all the fishes examined (Fig 12).

The results reveal that the infestation of *V. tsujii* in food fishes examined was more severe during the summer and pre-monsoon seasons than other monsoon and winter seasons. Ectoparasitic infection was found occurred during the winter in fresh water fish *Lobeo rohita*[21,22], Kabata[4] revealed that the fishes are susceptible to disease in low temperature and low metabolic activity and winter had been identified as a period of high susceptibility of fish to parasites [23]. But in the present investigation, the infestation of *V.* tsujii in the food fishes tested was more in summer and pre-monsoon seasons. Gebawo observed that the prevalence of digeneans and nematode parasites was high in post rainy season (29.2%) followed by rainy season (21.4%) and dry season (4.9%) [24]. Greater prevalence of infection parasitic helminths of *Leporinus macrocephalus* from fish farms during the dry season [25]. But the finding in the present study indicates that the infestation of *V. tsujii* may not be a kind of parasitic mode of feeding behavior and it could be predator as reported earlier by the authors [8]. Infestation of Copepod parasite *Lepeophtheirus kabatai* was found in cultured orange spotted grouper, *E. coioides* and its control in captivity has also been described by Ranjan et al. [26] and the authors further reported that this parasite was also prevalent in wild fish with prevalence of 11%, but no economic loss due to intensity of its infestation either in cultured and wild fish was estimated [26].

Pamban registering about 360000 tones capture fish per year of which 192200 tones are contributed by the 10 major food species examined in the present study. Total infestation observed was 17.71%, however, the fish which is being wasted by severe infestation and tissue damaged by Ostracoda is 3.82% i.e. 749.81 tones of total landing quantity per year, considering the farm gate price as INR 220 per kg, the estimated total loss per year is INR 17.20 crore (2.21milion US$). Monir *et al*. [27] had estimated the economic loss due to infestation of endo and ectoparasites in three Indian major carp *Labeo rohita, Catla catla* and *Cirrhinus mrigala* and the total economic loss reported was BDT 35,552.50 ha^{-1} yr^{-1}. Similarly, loss due to argulosis by infestations of *Argulus* spp*.* was estimated to be RS 29,524.40 (US$ 615) ha-1 yr-1 in a carp culture farm [28].

High quality data and necessary resources are required to accurately estimate the loss by disease and infestation of parasites both in farmed and catches of wild fishes. The prevalence and severity of parasite infections will rise as global aquaculture continues to grow and intensify. In addition, the increased trade in finfish and their products may facilitate the spread of parasites into new environments. Changing climatic conditions will also place increased pressure on aquaculture systems, current production practices and the interactions among wild and farmed aquatic stocks, parasite life cycles and transmission pathways [6].

Figure 13: Tissue damage caused by the infestation of Ostracoda *Vargula tsujii* in common marine food fishes: **a-***Carangoides malabaricus* (Mutta Parai), **b-***Carangoides gymnostethus* (Thenga Parai), **c-***Lethrinus ornatus* (Velai meen), **d-***Lethrinatus* sp, **e-** *Plectorhinchus* sp. **f-** *Parupeneus indicum* (Uruttu nagari)

Table 1 Prevalence %, abundance and mean density of infestation of Ostracoda in major food fishes in different season of the year in Gulf of Mannar and Palk Bay (July 2019 to June 2020)

Host fishes	Length group (mm)	Body mass (gm)	No. of fishes examined	No. of fishes infested	No. of V. tsujii recovered / fish	Prevalence %	Abundance	Mean density
Snapper								
P. indicus	280 - 332	180 - 330	1562	333	111.06 ± 17.5	21.33	0.16	0.77
L. fulviflamma	225 - 360	220 - 400	1255	184	61.50 ± 5.1	14.70	0.14	0.96
P. hamrur	270 - 340	250 - 350	440	57	18.96 ± 13.0	12.93	0.35	2.72
Carangids								
C. gymnostethus	290 - 410	510 - 1250	1592	279	92.92 ± 10.6	17.51	0.13	0.75
C. malabaricus	250 - 360	410 - 750	1460	265	88.38 ± 9.5	18.16	0.15	0.82
C. ferdau	220 - 390	450 - 1820	457	35	11.64 ± 7.7	7.64	0.20	
Grouper								
C. sonnerati	230 - 290	250 - 550	303	30	10.09 ± 12.8	9.99	0.40	3.96
E. coioides	240 - 370	400 - 1250	654	99	32.85 ± 6.5	15.07	0.28	1.84
Sea bream								
L. ornatus	270 - 370	520 - 1660	1253	205	68.41 ± 5.5	16.38	0.16	0.96
P. gibbosus	270 - 390	450 - 2250	275	22	7.33 ± 6.0	8.00	0.35	4.36

Table 2 Seasonal variation Prevalence of Ostracoda *Vargula tsujii* recovered from different marine food fishes with respect to different seasonality during July-2019 to June-2020

Host fish	Summer			Pre-monsoon			Monsoon			Winter			Average%
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Snapper													
P. indicus	21.25± 1.8^{ab}	33.14 ± 2.2^{ab}	38.36 ± 4.0^{ab}	32.60 ± 3.1^{ab}	30.00 ± 1.9^{ab}	32.71 ± 3.7^{ab}	11.22 ± 1.1^{ab}	13 ± 0.9^{ab}	6.58 ± 0.4^{ab}	14.3 ± 1.0^{ab}	15.7 ± 1.1^{ab}	7.12 ± 0.7^{ab}	21.83 ±2.4^{ab}
L. fulviflamma	29.73± 3.3^{ab}	20.59 ± 1.4^{ab}	28.06 ± 2.5^{ab}	11.8 ± 0.8^{ab}	16.58 ± 1.5^{ab}	16.51 ± 1.8^{ab}	10.19 ± 0.5^{ab}	8.38 ± 0.8^{ab}	6.1 ± 0.4^{ab}	6.2 ± 0.7^{ab}	13.9 ± 1.2^{ab}	8.4 ± 0.4^{ab}	14.70 ± 1.2^{ab}
P. hamrur	22.68 ± 2.3	17.32 ± 1.8	29.74 ± 3.0	0.0	2.58 ± 0.2	15.22 ± 1.3	17.28 ± 0.9	5.57 ± 0.2	0.0	19.38 ± 1.7	9.16 ± 0.9	16.21 ± 1.0	12.93 ± 1.2
Carangids													
C. gymnostethus	23.30 ± 2.1^{ab}	9.30 ± 1.1^{ab}	15.41 ± 1.3^{ab}	28.17 ± 2.2^{ab}	21.02 ± 1.5^{ab}	31.81 ± 2.8^{ab}	12.75 ± 0.4^{ab}	8.2 ± 0.6^{ab}	16.45 ± 1.0^{ab}	12.72 ± 0.8^{ab}	16.67 ± 1.9^{ab}	14.27 ± 1.1^{ab}	17.51 ± 1.5^{ab}
C. malabaricus	30.52 ± 2.7^{ab}	21.18 ± 2.1^{ab}	14.10 ± 1.1^{ab}	24.42 ± 2.0^{ab}	25.33 ± 2.0^{ab}	18.57 ± 1.6^{ab}	16.40 ± 1.0^{ab}	4.20 ± 0.2^{ab}	11.78 ± 1.2^{ab}	13.41 ± 1.1^{ab}	19.51 ± 2.2^{ab}	18.44 ± 1.5^{ab}	18.16 ± 2.0^{ab}
C. ferdau	14.40 ± 1.0	9.20 ± 1.0	0.0	0.0	0.0	13.1 ± 1.2	3.0 ± 0.5	7.65 ± 0.5	7.15 ± 0.7	10.0 ± 0.9	17.77 ± 1.3	9.36 ± 0.7	7.64 ± 0.2
Grouper													
C. sonnerati	15.0 ± 1.2	18.12 ± 1.6	7.88 ± 0.5	25.1 ± 2.1	11.02 ± 0.8	4.44 ± 0.2	12 ± 0.2	3.0 ± 0.0	0.0	0.0	9.19 ± 0.6	14.11 ± 1.2	10.44 ± 1.2
E. coioides	13.1 ± 0.8	20.4 ± 1.8	13.5 ± 1.1	27.17 ± 2.3	21.80 ± 2.0	17.20 ± 1.0	14.32 ± 1.0	4.0 ± 0.0	4.0 ± 0.0	5.55 ± 0.2	15.28 ± 1.5	24.50 ± 2.1	15.00 ± 1.1
Sea bream													
L. ornatus	33.63 ± 2.8^{ab}	27.63 ± 2.5^{ab}	15.81 ± 1.0^{ab}	16.48 ± 1.5^{ab}	18.27 ± 1.4^{ab}	14.70 ± 1.1^{ab}	9.0 ± 1.1^{ab}	7.62 ± 0.9^{ab}	17.05 ± 1.2^{ab}	14.11 ± 1.0^{ab}	9.04 ± 0.5^{ab}	13.26 ± 1.1^{ab}	16.38 ± 1.5^{ab}
P. gibbosus	1.85 ± 0.1	5.60 ± 1.6	6.50 ± 0.0	22.15 ± 1.8	13.16 ± 1.0	18.92 ± 1.5	2.12 ± 0.2	3.0 ± 0.0	5.0 ± 0.0	0.0	10.14 ± 1.2	7.60 ± 0.2	7.92 ± 0.1

Means followed by same letter (or no letter) are not significant at the 0.05 probability level

Table 3 Estimation of loss due to infestation of Ostracoda *V. tsujii* in some common marine food fishes with respect to seasonality in Pamban landing center

Season	Host fish	Estimated capture capacity/yr (t)	Total infested (%)	Total trash fish by infestation (%)	Estimated loss/yr (t)	Farm gate price (INR/Kg)	Estimated total loss/yr (INR)	Estimated loss/yr (UD$)
Summer	*P. indicus*	1450	30.9	4.65	67.425	150	10113750	131347
	L. fulviflamma	800	26.12	5	40	150	6000000	77922
	C. gymnostethus	1250	16	4.2	52.5	250	13125000	170455
	C. malabaricus	35	21.93	5.1	1.785	250	446250	5795
	L. ornatus	1650	25.69	4.55	75.075	300	22522500	292500
Pre-monsoon	*P. indicus*	1450	33.77	5.8	84.1	150	12615000	163831
	L. fulviflamma	1150	14.96	3.8	43.7	150	6555000	85130
	C. gymnostethus	1250	27	2.5	31.25	250	7812500	101461
	C. malabaricus	350	22.77	4.7	16.45	250	4112500	53409
	L. ornatus	1800	16.48	3.6	64.8	300	19440000	252468
Monsoon	*P. indicus*	260	10.26	2.8	7.28	150	1092000	14182
	L. fulviflamma	175	8.22	2.2	3.85	150	577500	7500
	C. gymnostethus	950	12.46	3.9	37.05	250	9262500	120292
	C. malabaricus	450	10.79	2.9	13.05	250	3262500	42370
	L. ornatus	1100	11.22	4.1	45.1	300	13530000	175714
Winter	*P. indicus*	1350	12.37	3.2	43.2	150	6480000	84156
	L. fulviflamma	550	9.5	3	16.5	150	2475000	32143
	C. gymnostethus	400	14.55	3.05	12.2	250	3050000	39610
	C. malabaricus	300	17.12	4	12	250	3000000	38961
	L. ornatus	2500	12.13	3.3	82.5	300	24750000	321429
Total/average		19220	17.71	3.82	749.815	220.00	170222000	2210675

Table 4 Some notable parasites induced loss in fin-fish aquaculture during 1998 – 2013 (15 years data)

Host fish	Parasites	Country	Year	Equivalent production loss (t)	Estimated loss (US$ in million)	References
Salmo salar (Atlantic salmon)	*Caligus rogercresseyi*		2009	31,266	193.6	[6]
	Desmozoon lepeophtherii	Scotland	2010	82	0.36	[6]
	Kudoa thyrsites	Canada	2010	2,190	15	[6]
	Paramoeba perurans	Scotland	2011	13,600	81	[6]
	Sea lice *(Lepeophthirius salmonis & Caligus species)*	Global	2009	107,696	480	[6]
	Desmozoon lepeophtherii	Norway	2002	600-1000	2532	[29]
	Desmozoon lepeophtherii	„	2001	35% loss	36925	[30]
	Desmozoon lepeophtherii	„	2003	40% loss	33664–67328	[31]
	Desmozoon lepeophtherii	Scotland	2009	82	363390	[32]
Seriola quinqueradiata (Japanese amberjack)	*Benedenia seriolae*	Japan	2001	33,637	214	[6]
	Kudoa yasunagai	Japan	2012	162	1.6	[6]
	Neobenedenia melleni	Japan	2013	29,150	Over 200.00	[6]
Dicentrarchus labrax (European seabass)	*Diplectanum aequans*	Italy	2006	110-220	0.92-1.85	[6]
Seriola dumerili (Greater amberjack)	*Benedenia seriolae* & *Zeuxapta seriolae*	Australia	2003	39	0.53	[6]
Diplodus puntazzo (Sharp-snout sea bream)	*Enteromyxum leei*	Mediterranean	2004	400	2.63	[6]
Rachycentron canadum (Cobia)	*Neobenedenia melleni*	Taiwan	2001	284	1.8	[6]
Thunnus maccoyii (Southern bluefin tuna)	*Caligus chiastos* and *Cardicola forsteri*	Australia	2008	85	1.4	[6]
	Uronema nigricans	Australia	2003	95	2.13	[6]
Oreochromis niloticus and *O. mossambicus* (Tilapia species)	*Uronema nigricans*	United States	1998	2,045-5,115	6.77-16.93	[6]

CONCLUSION

As aquaculture expands and intensifies the economic losses for parasite diseases are likely to increase. The findings made in the present study may help fin-fish farmers to take necessary measures to control infestation like Ostracoda if it occurs.

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