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Unusual abundance of invasive *Tilapia* species in coastal waters of Devipattinam, Palk Bay, India

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Abstract

Worldwide, *Tilapia* sp. has gained a reputation as a highly sought-after, culturable species in the aquaculture industry thanks to its higher growth rate, excellent adaptive nature, low disease rate, and prolific breeding. Aquaculture is the only means to satisfy the dietary demand for fish protein in India, which has the highest population in the world. The first Tilapia species used for extensive aquaculture was *Oreochromis mossambicus*, which was introduced in India in the early 1950s under government patronage. Since then, aquaculture farms have been developed to culture Tilapia all over India, from the warmer tropical brackish waterbodies of Tamil Nadu to the cooler Himalayan regions.

The past few decades have witnessed a huge surge in Tilapia abundance in various natural water bodies, posing a serious threat to indigenous fish species. These highly adaptive fishes have now been observed surviving in fully marine environments in Palk Bay. Local fishermen are aware of the presence of these invasive species and regularly harvest them from the inshore waters. Several specimens of different ages have been found and recorded during a survey in coastal areas near Devipattinam, Tamil Nadu. It is assumed that these exotic species have found their way to the ocean from local aquaculture farms to local canals, eventually ending up in the ocean.

In a recent survey in January, 2023, adult specimens with fertile gonads were recorded. But most of the specimens found were juveniles and sexually immature, indicating that the inshore water of the Palk Bay region serves as a breeding and nursery ground for young ones. Surveys have shown that they are more abundantly found in coastal waters with an average depth of 2–5 meters, dominated by several sea grass species. Survival success is influenced by their ability to withstand oceanographic conditions and their interactive credibility with native indigenous species.

Keywords: *Tilapia* sp, abundance, invasive, Palk Bay.

Introduction

Tilapia, which is considered as world's most invasive species is found to be a threat to the indigenous fishes in majority of the countries. Tilapia is a native cichlid food fish species in the tropical eastern coastal waters of Africa (Trewavas, 1981). Tilapia has remarkable trophic plasticity and can obtain sexual maturity at a very early age, as a result they get overpopulated and become a competition for other fish species in terms of habitat and food (Gaikwad et al., 2017) we have explored the gut microbial community structure of tilapia using 16S rRNA gene sequencing on the Illumina Miseq platform. Our study showed significant differences in tilapia gut microbiota collected from different habitats (i.e. river and lakes. This cichlid fish are extremely hardy, and can tolerate polluted and poor water quality, temperature fluctuations, environment variations and even water with low dissolve oxygen content (Pérez et al., 2006)an issue of particular focus among conservation biologists. Colonizing

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a novel environment presents a genetic challenge to invading species because such species surely have not experienced the selective pressures presented by the environment. Here we ask, by what mechanisms and processes do alien species genetically naı¨ ve to their new environment, become successful invaders? We attempt to resolve this paradox by considering the interplay between an invader's ability to modify its new environment, and genetic modifications imposed by the new environment. We postulate that epigenetic adaptations, and adaptive mutations are likely play a role in enhancing invasion success.", "container-title": "Biological Invasions", "DOI": "10.1007/s10530-005-8281-0", "ISSN": "1387-3547, 1573-1464", "issue": "5", "journal Abbreviation": "Biol Invasions", "language": "en", "page": "1115-1121", "source": "DOI.org (Crossref. This cichlid fish species was introduced in many countries, including India, in the early years for aquaculture, fishing games, controlling pests etc. (Pullin et al., 1997). In 1952, Mozambique Tilapia was experimentally introduced in the Indian water bodies (Sugunan, 1995), as a rich source of fish protein, which later even proved to be a success, as claimed by several aquaculture experts (Eknath and Hulata, 2009), but the species dominated the indigenous food fish communities, as the former being a prolific breeder and hardy in nature (Kumar, 2000). Later on, other Tilapia species populations were also introduced such as *Tilapia zilli* (1986), *Oreochromis urolepis* (date unknown), *O. niloticus* (1987) and red hybrid Tilapia (date unknown) (Keshavanath et al., 2004). Tilapias are the second most important group of non-cyprinid fishes after carps, with a total production of 6.6 million tons in 2019 (Bardhan et al., 2021) and was forecasted to grow 3.7 percent in 2022, breaking the **6 million- metric-ton** barrier, according to the Global Seafood Alliance's (GSA) annual production survey (Evans, 2021).

Tilapia in India are widely cultured in ponds, cages, raceways and tanks, while polyculture with carps and shrimps have been reported from the states of Andhra Pradesh, Gujarat and Tamil Nadu (Menaga and Fitzsimmons, 2007). Other states, particularly coastal states like Orissa, West Bengal are gearing up for the culture of *O. niloticus* and other closely related species (Singh et al., 2014) as they are one of the easiest and profitable fish to farm. Government of India, after realising the culturing of Tilapia by the farmers, without proper quarantine, biosecurity, and planning because of the numerous undocumented imports of Tilapia in the country, led out proper guidelines to expand the industry in a proper fashion. Incidents of inadvertent releases and escapement of *Tilapia* from aquaculture facilities frequently occurs (Singh et al., 2014). However, recent unusual abundance of *Tilapia* in the marine inshore water of Devipattinam coast along Palk Bay has been recorded. Wide size range of *Tilapia* sp. from juveniles to mature, were observed in the wild inshore waters of the Palk Bay, particularly in an area where Tilapia is hardly cultured. This scenario prompted us to study the population characteristics i.e., the abundance, size range, GaSI, GSI, maturity. The study was undertaken to ascertaining the invasion and colonization of the escapee *Tilapia* sp. through natural population in the marine inshore Palk Bay waters.

Materials and Methods

Study Area

The present study was conducted near the coastal area of Devipattinam, an ancient port town from Ramnathapuram district, near to Vaigai River estuary of Tamil Nadu (Figure 1). The study area falls in the Vaigai River basin, one of the important river basins which ends up in Palk Bay. The nearby mangrove ecosystem along Vaigai estuary has high nutrient inflow. The sediment is dominantly sandy, with coarse sand and silt. The inshore waters have high assemblage of Seagrass meadows, serving as a highly productive ecosystem by providing habitat, breeding, and feeding ground for various marine species and support as the backbone for fisheries. The muddy water of these study area is productive and boosting with life. But waste water run-off, high anthropogenic activities like fishing has played a significant role among the area. Local mechanised as well as non-mechanised boats operate in this region. *Nandu-valai*, *Thangu-valai* are some of the nets which is used to capture the crabs and fishes from here (Figure 2).

Physicochemical parameters

The water and atmospheric temperatures were recorded from the sampling sites using a digital thermometer. Samples were kept in dark at 20°C for 5 days, further processed by addition of phosphate buffer. After incubating in BOD incubator, the samples `were analysed by modified Winkler's method. The equation used to calculate BOD:

$$BOD\ (mg/L) = (DO - DO_5) \times \text{dilution factor},$$

where DO = volume of Oxygen in blank set and DO_5 = volume of oxygen in incubated set.

Fish Sampling

Samples of Tilapia fish were collected along Devipattinam coast, between the pre-monsoon months of January and February, 2023. Fishermen of that area, generally used bottom set gill net and push net (*thalluvala*i) for fishing purpose. *Thalluvalai* is indigenous gear, operated from plank built boats and these resembles a mini trawl net (Rajamani and Palanichamy, 2009). Fishes were collected from the study site and were identified using keys for fish identification from Jhingram, 1975 and FAO identification sheet as FAO, 2010. Total length (to nearest cm) was measured and weighed (g) using standard graduated scale and portable digital balance respectively. From the total catch, the abundance index of Tilapia was calculated using the formula:

$$AI = \frac{n(k) \times 100}{N}$$

Where, AI = abundance index,

n(k) = number of Tilapia caught at study site,

N = number of all fish species caught at the site.

Biometric studies

With the help of measuring board and graduated scale, the total length of each fish was calculated from tip of the snout to the extended tip of the caudal fin. Body weight is measured using portable digital balance to nearest grams (Fafioye and Oluajo, 2005) (Figure 3).

Importance of Length-Weight Relationship

In early research methodologies, Log transformed mean weights of fishes with different lengths were used to calculate Length- weight relationships (Nomura, 1962). Erzini, 1994 the magnitude of variability, the patterns of variability with age and size, and the degree of overlapping of distributions were investigated using simple as well as multivariate statistical methods. Departure from normality was a widespread phenomenon. The most important pattern of variability was an increase to a maximum at an intermediate age or size followed by a decrease. The degree of overlapping was generally high, with only one or two distributions not significantly overlap ed in most cases. The implications of these results for length frequency analysis and other areas of fPsheries are discussed.", "container-title": "Journal of Applied Ichthyology", "DOI": "10.1111/j.1439-0426.1994.tb00140.x", "ISSN": "0175-8659, 1439-0426", "issue": "1", "journalAbbreviation": "J Appl Ichthyol", "language": "en", "page": "17-41", "source": "DOI.org (Crossref, reported the importance of Length weight relationship in fishery population dynamics. The size of a fish is generally related to its age, as most of the ecological as well as physiological parameters are proportional to age (Santos et al., 2002). Researchers use the length-weight relationships (LWR) of fish species to understand and estimate their population dynamics, stock assessment and ecological status as by Erzini, 1994; King, 1996; Petrakis and Stergiou, 1995; Santos et al., 2002the magnitude of variability, the patterns of variability with age and size, and the degree of overlapping of distributions were investigated using simple as well as multivariate statistical methods. Departure from normality was a widespread phenomenon. The most important pattern of variability was an increase to a maximum at an intermediate age or size followed by a decrease. The degree of overlapping was generally high, with only one or two distributions not significantly overlap ed in most cases. The implications of these results for length frequency analysis and other areas of fPsheries are discussed.", "container-title": "Journal of Applied Ichthyology", "DOI": "10.1111/j.1439-0426.1994.tb00140.x", "ISSN": "0175-8659, 1439-0426", "issue":"1", "journalAbbreviation": "J Appl Ichthyol", "language": "en", "page": "17-41", "source": "DOI.org (Crossref. Reports on fish stock composition, life span, mortality and growth can also be obtained using the length-weight relationship (Bolger and Connolly, 1989).

The knowledge on LWR of fish species helps to understand the weight-at-age from total recorded catch weight and length-frequency distribution and to estimate the condition of fish samples and also to compare the life history of fish species between regions (Petrakis and Stergiou, 1995). LWR helps to build mathematical relation between variables and record variations from expected weight for length of fish samples (Le Cren, 1951).

Length-Weight Relationship of *Tilapia* sp.

The length weight relationship of *Tilapia* sp. was studied with samples collected along Devipattinam coast, Palk Bay, Tamil Nadu, India. The following equation was used to estimate the parameters of Length- Weight relationship of fish samples (Le Cren, 1951; Ricker, 1973) (Figure 3).

$$W = aL^b$$

Where, W= weight of the fish (g)

L= length of fish (cm)

a = initial growth coefficient or y-intercept

b = growth coefficient or slope

This also has the logarithmic form as equation to know whether the growth is isometric (b=3) or allometric (positive if b>3 and negative if b<3) (Ricker, 1973), is determined using LWR. The regression coefficient (r^2), significance level of r^2 and confidence limit of 95% of parameters 'a' and 'b' were estimated.

Gut content analysis (GaSI)

The intestines of the collected Tilapia fishes were dissected and fixed in 5% formalin solution for further inspection under microscope (Hynes, 1950) . The gut were placed on a petri dish and observed under the compound microscope in order to know more about the diet and feeding habits of the species (Figure 4).

Different taxa of food were identified and counted, also gastro somatic index (GaSI) was calculated using the equation (Biswas, 1993)

$$GaSI = \frac{\text{Total weight of the Gut (including food contents)}}{\text{Weight of fish}} \times 100$$

Gonado Somatic Index (GSI)

The collected fish samples were brought to the laboratory for sex determination. Tilapia fish generally do not exhibit external dimorphism, and the sex can be determined only after cutting open the abdomen and studying the gonads. Gonads are removed from the fish and weighed (to the nearest cm), GSI was calculated using the equation

$$GSI = \frac{\text{Total weight of Gonad}}{\text{Total weight}} \times 100$$

Fecundity

Eggs present in the ovary of female mature fish sample was weighed and the following formula was used to measure fecundity of the fish sample.

Fecundity=number of eggs in one gm of ovary x total weight of ovary (g)

Results

The physicochemical components of the study site are represented in table 1. Temperature ranged between 27 and 28 °C, while the pH ranged between 8.30 and 8.37. Total alkalinity of the study site was recorded between 1923-2100 µmol/kgSW. Site 2 of the study area, recorded a comparative lower dissolved oxygen of 5.78 mg/l, while the other two sites had DO of 6.78 and 6.11 mg/L. The site 3 had the highest BOD count of 7.08 mg/l, while the salinity of the water ranged between 32-33 PSU (Table 1). ODV plots were plotted against salinity and temperature with respect to depth at the study sites (Figure 6). The abundance index of *Tilapia* sp. was found to be 13. 59%, during the study. The size of the fish samples was found to be 18.9 ± 3.99 cm.

Length-weight relationship of the present investigation revealed that Tilapia of both the males and females collected from Devipattinam showed an isometric growth (nearly b=3), which means the weight increases proportionally to the cube of the length as the exponent value observed was almost 3 (table 2).

Gut analysis of the specimen revealed that the food items mainly include crustaceans (majorly including copepods) for 40%, molluscs (including bivalves, small snails, and cephalopods) for 18%, smaller plankton for 12%, polychaete worms for 5%, fish parts for 4% and the remaining 21% consisted the miscellaneous unidentified items (Figure 5). The unidentified food remains could not be identified as they were found in advance stages of digestion. Gonadal examination of the sampled fishes from different sites revealed that all life stages (immature, maturing and matured) fishes were available in the study waters. The current sampled pool contained more numbers of mature female specimens (table 3). Gonads of examined specimens revealed Gonado-somatic index (GSI) of 2.89 – 3.04. The calculated absolute fecundity ranged between 778.14 and 820 (table 3). During the study period, several other fish samples were like Mullets, *Lutjanus* sp., *Plotosus* sp., *Scatophagus argus*, *Monodactylus argenteus*, *Arothron immaculatus*, *Rastrelliger kanagurta*, *Atule mate*, *Peneus monodon*, Nurse shark and Sting rays were identified in the catch.

Discussion

In early research methodologies, Log transformed mean weights of fishes with different lengths were used to calculate Length- weight relationships (Nomura, 1962). Erzini, 1994the magnitude of variability, the patterns of variability with age and size, and the degree of overlapping of distributions were investigated using simple as well as multivariate statistical methods. Departure from normality was a widespread phenomenon. The most important pattern of variability was an increase to a maximum at an intermediate age or size followed by a decrease. The degree of overlapping was generally high, with only one or two distributions not significantly overlap ed in most cases. The implications of these results for length frequency analysis and other areas of fPsheries are discussed.", "container-title": "Journal of Applied Ichthyology", "DOI": "10.1111/j.1439-0426. 1994. tb00140.x", "ISSN": "0175-8659, 1439-0426", "issue":"1", "journalAbbreviation": "J Appl Ichthyol", "language": "en", "page":"17-41", "source":"DOI.org (Crossref, reported the importance of Length weight relationship in fishery population dynamics. The size of a fish is generally related to its age, as most of the ecological as well as physiological parameters are proportional to age (Santos et al., 2002). Researchers use the Length-weight relationships of fish species to understand and estimate their population dynamics, stock assessment and ecological status as by Erzini, 1994; King, 1996; Petrakis and Stergiou, 1995; Santos et al., 2002 the magnitude of variability, the patterns of variability with age and size, and the degree of overlapping of distributions were investigated using simple as well as multivariate statistical methods. Departure from normality was a widespread phenomenon. The most important pattern of variability was an increase to a maximum at an intermediate age or size followed by a decrease. The degree of overlapping was generally high, with only one or two distributions not significantly overlap ed in most cases. The implications of these results for length frequency analysis and other areas of fPsheries are discussed.", "container-title": "Journal of Applied Ichthyology"","DOI": "10.1111/j.1439-0426.1994. tb00140.x", "ISSN": "0175-8659, 1439-0426", "issue": "1", "journal Abbreviation": "J Appl Ichthyol", "language": "en", "page": "17-41", "source": "DOI.org (Crossref. Reports on fish stock composition, life span, mortality and growth can also be obtained using the Length-weight relationship (Bolger and Connolly, 1989).

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In this study, the b values got for pooled samples was 2.962, signposted a high growth in this environment. The females grow superior to the males generally due to their large ovary size and this is the reason for increased b values in female fishes. The energy gained by food and oxygen consumption by female fishes was not consumed on fights with other fishes or for reproduction which a male fish usually does, hence the females have an increase in b value than male (Laxmikanth et al., 2022, Laxmikanth et al., 2023). Physicochemical parameters play a main role in signifying an area that is healthy or contaminated. This study reveals that maximum salinity in Devipattinam coast was 33 PSU and maximum temperature was 28°C. Dissolved oxygen in this region was 6.78 mg/l which is more than optimum water quality condition due to that the area has rich in seagrass ecosystem. The average pH in Devipattinam was 8.32 which is higher than ambient level pH of Southeast coast of India. And, the total alkalinity value was 2100 µmol/kgSW. Both pH and total alkalinity indicated that the ecosystem health in terms of ocean acidification phenomenon (Anand et al., 2021, Ravichandran et al., 2022, Devi et al., 2023). The details about seasonal variations in physicochemical parameters of the Palk Bay is further required to represent the key ecosystem health and it will help researchers to study the dynamics in this region. The effects of pollution, climate change and seasonal variation can also easily be detected by studying the water, air and soil quality. This study helps to find the determined critical areas in the Palk Bay and quality issues of the coastal regions.

As concluding remarks from the results of this study, Tilapia is considered a world's most invasive species, it is found to be a threat to the indigenous fishes in Palk Bay, India. The present investigation revealed that Tilapia of both the males and females collected from Devipattinam showed an isometric growth, which means the weight increases proportionally to the cube of the length as the exponent value observed was almost 3. This in turn reveals that the Palk Bay is suitable for good growth of Tilapia although its population is frequently occurrence along the Devipattinam site region hence further investigation have to be taken to survey in entire Palk Bay region to conserve the innate species.

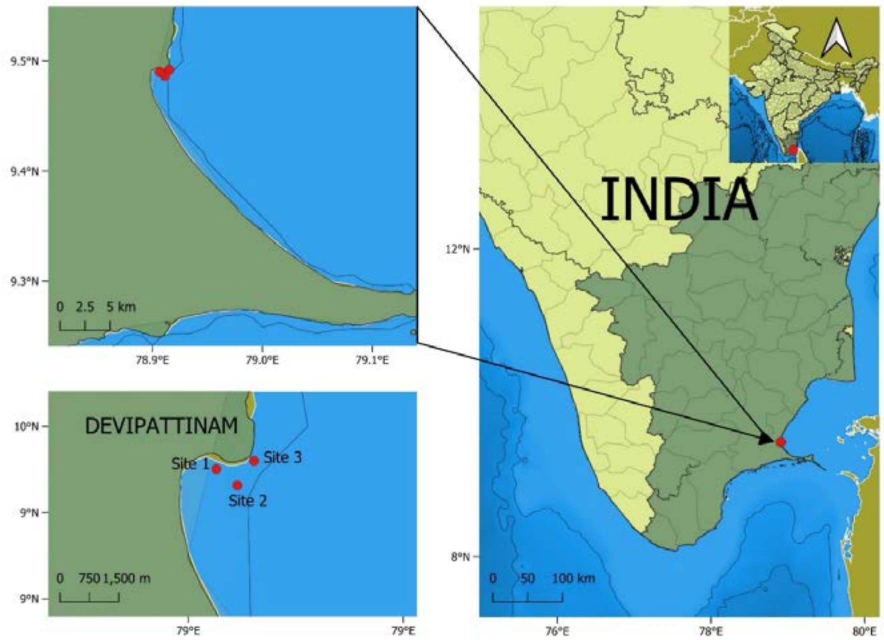

Figure 1. Map showing selected study sites along Devipattinam coast, Palk Bay

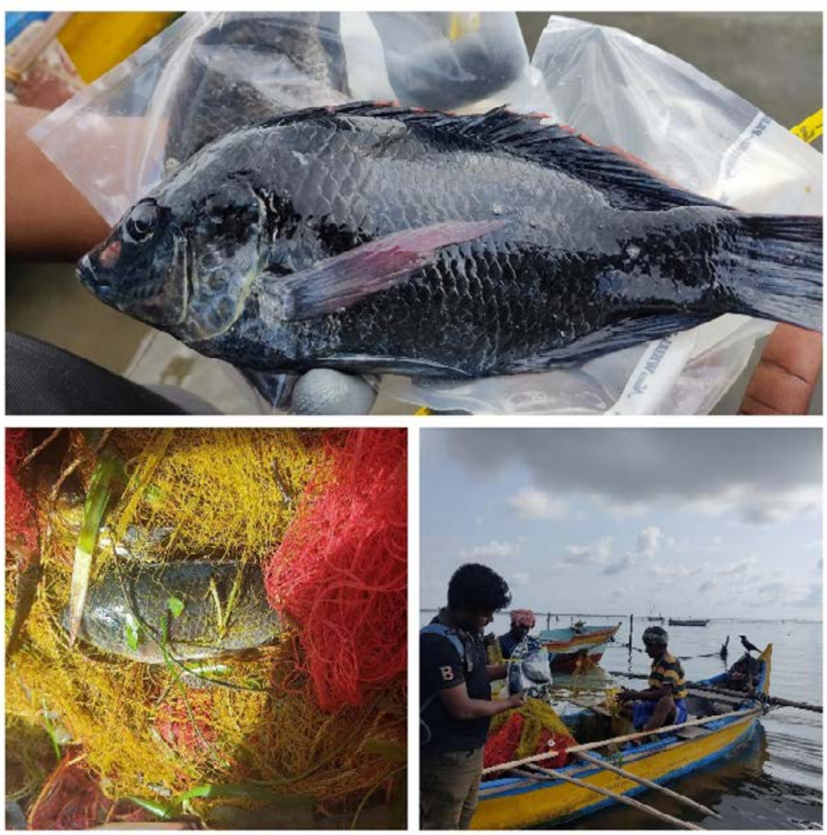

Figure 2. Sampling of *Tilapia* sp.

Figure 3: Determining the length of the fish samples.

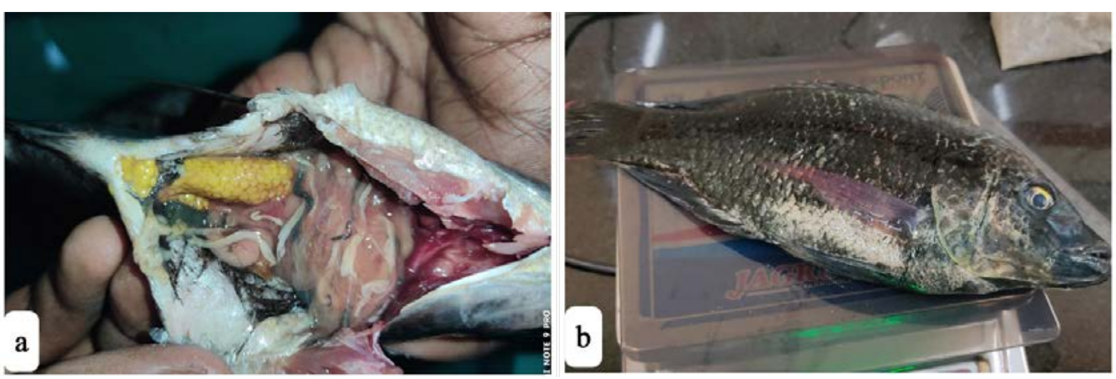

Figure 4: a) Gut analysis of the fish sample and b) Weighing of the fish sample

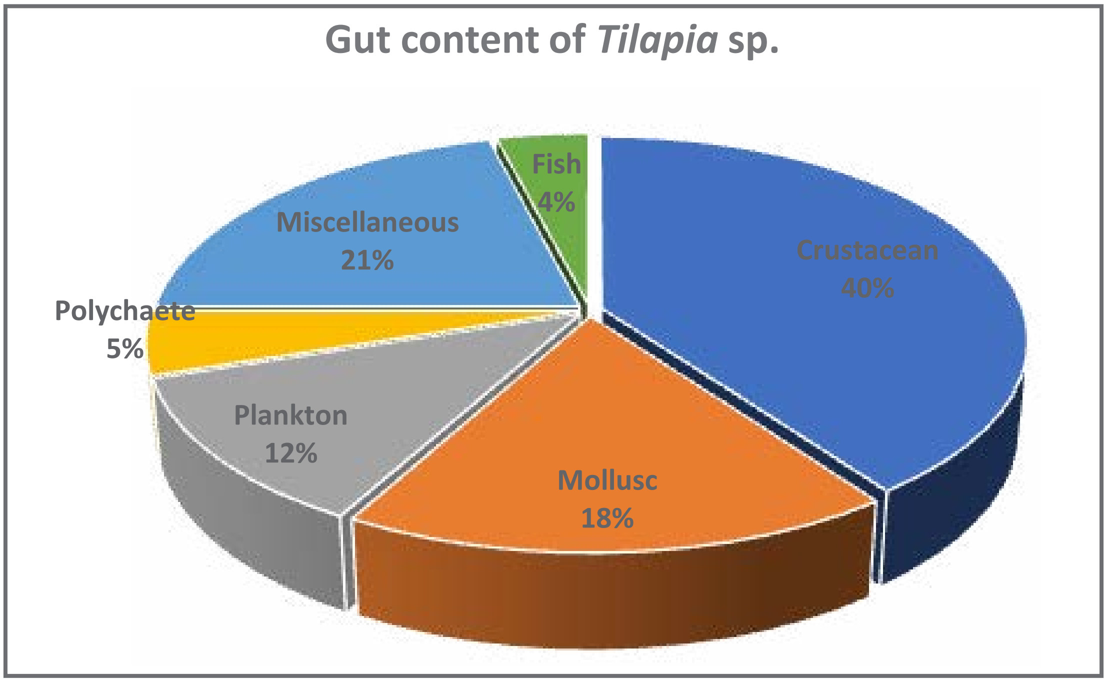

Figure 5: Gut content of the fish sample

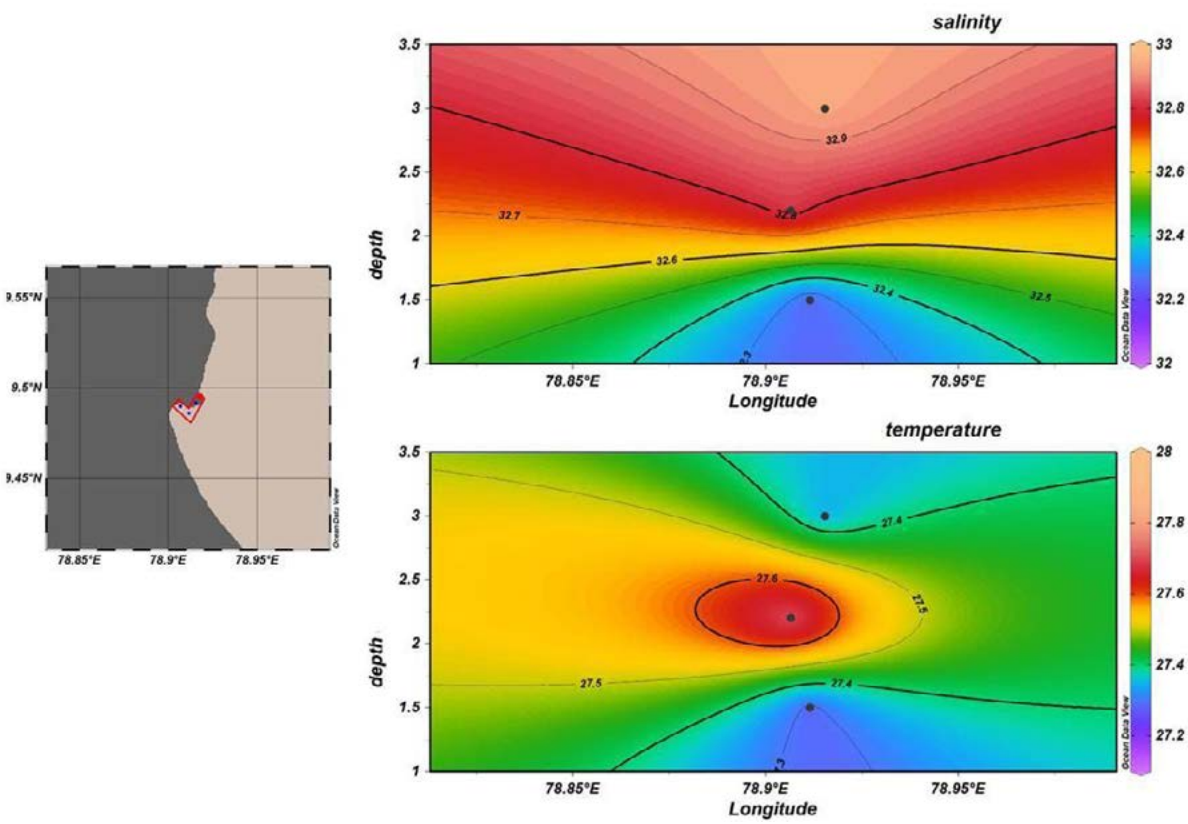

Figure 6. ODV plots representing salinity and temperature at the study sites

Table 1. Physicochemical parameters in different sites in Devipattinam, Palk Bay

Parameters	Site-1	Site-2	Site-3
Temperature (°C)	27.1	28	27.2
pH	8.37	8.30	8.31
DO (mg/L)	6.78	5.78	6.11
Salinity	32	33	33
Water depth	1.5	2.2	3
BOD (mg/L)	6.42	6.75	7.08
Total alkalinity (µmol/ kgSW)	1923	1929	2100

Table 2: Statistical description of LWR parameters of *Tilapia* sp.

Sex	N	Length (cm)			Weight (gm)			Parameters of LWR		
		Min	**Max**	**Mean±SD**	**Min**	**Max**	**Mean±SD**	**a**	**b**	**r^2**
Pooled samples	7	11.4	24.1	18.9 ± 3.99	27	239	159 ± 67.07	0.024	2.962	0.928

Table 3: Catch contribution and Biometry of *Tilapia* sp. captured from study site

Year	Abundance (%) of Tilapia sp.	Length range (cm)	Weight range (gm)	GaSI	Sex Ratio		GSI	Fecundity
					Female	**Male**		
Jan, 2023	13.59%	11.4-24.1	27-239	3.18-4	5	2	2.89-3.04	778.14 - 820

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