Spatial and Size-class relations among Ectoparasites associated with the Indian Mackerel, *Rastrelliger kanagurta.*

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By

MS. CEEJEL PINTO

Roll Number: 22PO400003

ABC ID: 618621768201

PR Number: 20190220

Under the Supervision of

PROF. C.U. RIVONKER

School of Earth, Ocean, and Atmospheric Sciences

Marine Sciences

GOA UNIVERSITY

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Examined by:

Seal of the School

DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation entitled, **"Spatial and Size-class relations among Ectoparasites associated with the Indian Mackerel, *Rastrelliger kanagurta*"** is based on the results of investigations carried out by me in the Deparment of Marine Sciences at School of Earth Ocean and Atmospheric Sciences, Goa University under the Supervision of **Prof. C.U. Rivonker** and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will be not be responsible for the correctness of observations/ experimental or other findings given the dissertation.

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Pinto

Ceejel Pinto
Seat No.:22PO400003

Date: 02/05/2024

Place: Goa University, Taleigão Plateau, Goa

COMPLETION CERTIFICATE

This is to certify that the dissertation report **"Spatial and Size-class relations among Ectoparasites associated with the Indian Mackerel, *Rastrelliger kanagurta*"** is a bonafide work carried out by **Ms. Ceejel Pinto** under my supervision in partial fulfilment of the requirements for the award of the degree **of Master of Marine Science** at the School of Earth, Ocean and Atmospheric Sciences, Goa University.

Date: 03/05/2024

Prof. CU. Rivonker

SEOAS, GOA UNIVERSITY TALEIGAO PLATEAU GOA

School/Dept Stamp

3/5/24

Sr. Prof. Sanjeev C. Ghadi,
Senior Professor and Dean
Marine Sciences
School of Earth, Ocean, and Atmospheric Sciences
Date:
Place: Goa University, Taleigão Plateau, Goa

CONTENT

PREFACE

The dynamic relationship between mackerel and its associated ectoparasites forms a fascinating ecological narrative within marine ecosystems. Mackerel, a vital component of marine biodiversity, occupies a pivotal role in oceanic food webs, contributing to both ecosystem stability and commercial fisheries worldwide. However, this enigmatic fish is not without its challenges, as it often contends with a variety of ectoparasites that inhabit its body, influencing both its length and weight, and consequently, its overall health and ecological impact.

These ectoparasites encompass a diverse array of organisms, ranging from copepods and isopods to various types of worms and crustaceans. The presence of ectoparasites can significantly impact the length and weight of mackerel. Infestations may lead to alterations in the fish's behavior, reducing its feeding efficiency and inhibiting growth. Moreover, the physiological stress induced by ectoparasites can compromise the overall health and vitality of individual mackerel, potentially affecting population dynamics and ecosystem functioning.

In elucidating the intricate relationship between mackerel and its ectoparasites, this preface sets the stage for a deeper exploration of the ecological dynamics at play within marine ecosystems. By unraveling the complexities of this symbiotic relationship, we gain valuable insights into the interconnectedness of marine life and the delicate balance upon which it depends. This motivated me to study on the topic “Spatial and Size-class relations among Ectoparasites associated with the Indian Mackerel, *Rastrelliger kanagurta*

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LIST OF ABBREVIATIONS

Entity	**Abbreviation**
Degree Celsius	℃
Degree Fahrenheit	°F
Centimeters	Cm
Chlorophyll a	*Chl a*
East	E
Gonadosomatic Index	GSI
Grams	G
Gross domestic product	GDP
Metric tons	MT
Million metric tons	MMT
Norileca	*N.*
North	N
Primary productivity	PP
Private Limited Company	PVT LTD
Rastrelliger kanagurta	*R. Kanagurta*
Species	Sp

ABSTRACT

Marine habitats subjected to dynamic nature support diverse communities, among which few are known to be economically important. The Indian Mackerel, *R. kanagurta*, one important contributor is the pelagic fishery of India, due to water quality and climate changes is susceptible to ectoparasite infection. The Mackerel is subjected to dynamic habitats with continuous imbalance of environmental factors that attract such infections. The present study delves into the spatial distribution patterns and size-class relations of ectoparasites afflicting the Indian Mackerel, *Rastrelliger kanagurta*. During the present study 40 samples from two distinct locations were collected, the observation revealed that 27 mackerel specimens, were infected by ectoparasite isopods, manifesting on or within the skin, oral cavity, and branchial pouches. Notably, the prevalence of isopods in mackerel was 55% at Cacra Beach and 80% at Cutbona Jetty, with intensities recorded at 1.54% and 1.25% respectively. Intriguingly, the prevalence exhibited seasonal variation, with the lowest prevalence in November and the highest in February. Microscopic examination of ectoparasites revealed *Trichodina sp*. as the most diverse and abundant, while *Lecithocladium sp., Argulus sp.,* and *Cercaria sp.* were comparatively less prevalent. These findings offer valuable insights into the ecological dynamics of ectoparasites in marine environments, with implications for fisheries management and conservation efforts.

Keywords: Ectoparasites, Indian Mackerel, Prevalence, Intensity, Branchial Pouches.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Fishing stands as a crucial industry in India, engaging more than 145 million individuals and securing the nation's position as the third-largest producer in global fisheries output. Contributing 1.07% to India's total GDP (Bhalkare, 2016), the sector encompasses a wide array of fisheries, spanning marine, freshwater, estuarine, and pearl fisheries. India's rich aquatic ecosystems host over 10% of the world's fish biodiversity, positioning the country among the 17 mega-biodiversity nations (Area Handbook Series, 1996). The marine fishing potential in Indian waters is estimated at 5.31 MMT, distributed across various categories: 43.3% demersal, 49.5% pelagic, and 4.3% oceanic (America University, 1996). With a coastline spanning 7,000 kilometers along the Arabian Sea and the Bay of Bengal, India boasts extensive marine resources.

Noteworthy hubs of fish production include Kerala, Karnataka, Maharashtra, Gujarat, Andhra Pradesh, West Bengal, Odisha, Goa, Daman Diu, and Tamil Nadu, along with emerging centers like Uttarakhand and Uttar Pradesh (Bhalkare, 2016). India's fish production stands at an impressive 13.7 MMT annually (Ngasotter *et al.*, 2020) solidifying its position as one of the world's leading fish-producing nations. In contrast, Goa contributes approximately 100,000 MT annually (Dessai, 2022) to this total, showcasing its notable role in India's overall fish production while acknowledging its comparatively smaller scale within the country's vast output.

Fish stands out as one of the world's most valuable natural resources, holding exceptional significance for the state of Goa, where it constitutes a daily dietary staple. More than 90% of Goa's population relies on fish as a primary food source (Directorate of Fisheries, Department of Goa, 2016). With a coastline extending 104 kilometers adorned with numerous bays and headlands, Goa's marine ecosystem thrives. Its expansive continental shelf, spanning 10,000 square kilometers (Sreekanth and Mujawar, 2021) and reaching depths of approximately 100 fathoms, further underscores the richness of its marine resources. The marine fish landings in Goa encompass an impressive diversity, recording about 550 different types of fish and shellfish (Sreekanth and Mujawar, 2021)

Indian mackerel contributes the major share of the total marine fish catch in Goa. Indian Mackerel along with Sardines contributes to above 50% of the total fish catch in Goa. Mackerel has a high nutritional profile, including omega 3 fatty acids, protein, vitamin B12, selenium, and vitamin D (Joseph, 2023). There are no carbohydrates, fiber, or sugar in raw mackerel. However, if processed it may include some carbohydrates. Mackerel has around 12 g of fat per 100 g serving with around 3 grams of saturated fat, 4.5 grams of mono-unsaturated fat, and 2.9 grams of polyunsaturated fat. It is abundant in omega-3 fatty acids. Mackerel is a complete protein, including 19 grams of the macronutrient and all nine essential amino acids in a 100-gram serving (Froese, 2009)

Indian Mackerel – Classification

Indian mackerel, scientifically known as *R. kanagurta*, is classified within the kingdom Animalia, phylum Chordata, class Actinopterygii (ray-finned fishes), order Perciformes (perch-like fishes), family Scombridae (mackerels, tunas, and bonitos), and genus *Rastrelliger*. The Scombridae family, includes over 30 different species of fish. Within the Scombridae family of the Perciformes order, the Indian mackerel (*R. kanagurta*) is one of the mackerel species.

The Indian mackerel is predominantly found in the warm shallow waters along the coasts of the Indian and Western Pacific Oceans (Integrated Taxonomic Information System, 2009). This species is highly valued as a food fish, especially in Southeast and South Asian cuisines. Typically, Indian mackerel inhabit shallow coastal waters with surface temperatures of at least 17°C (63°F) (Prajith and Khileri, 2016). Adults are commonly found in deep lagoons, harbors, and coastal bays, favoring turbid, plankton-rich environments. The food and feeding habits of Indian mackerel vary based on several factors, including the availability of food sources, changes in environmental conditions such as temperature, pH, and water salinity, as well as the size and feeding intensity of the fish (Sajna *et al.*, 2019). Adult feeds mainly on zooplankton (43.56%), phytoplankton (39.93%) and algae (2.89%) (Bhendarkar *et al.*, 2014)

The Indian mackerel possesses a fusiform body shape with a forked caudal fin, along with two dorsal fins followed by five finlets. Its total length typically ranges from 19 cm to 22.5 cm, although this may vary depending on factors such as location and year (Chidambaram *et al.*, 1952; Bhimachar and George, 1952; Pradhan, 1956; Gopakumar *et al.*, 1991). Spawning behavior varies regionally, with studies indicating spawning occurs between June to September along the west coast (Devanestan and John, 1940) while along the east coast, spawning typically begins in October and extends until April or May (Singh and Sharma 2021).

The Indian mackerel exhibits a spawning strategy where eggs are released in successive batches (Pradhan, 1956). Research by (Devanesaa and John, 1940; Francis Day, 1878) indicates that during each spawning event, a female *R. kanagurta* typically releases around 200-400 eggs into water depths of five fathoms, where fertilization occurs externally. Unlike some species, the eggs of Indian mackerel are not guarded and are left to develop independently (Froese, 2009).

Economic Importance

The fishing industry plays a pivotal role in driving socioeconomic development in India, serving as a major source of employment and income. In May 2020, as part of the Aatmanirbhar Bharat COVID-19 relief package, the Government of India introduced the Pradhan Mantri Matsya Sampada Yojana (PMMSY), a flagship project aimed at catalyzing the Blue Revolution by fostering sustainable and responsible fisheries development. This initiative underscores the government's recognition of the industry's importance and its potential for growth. The Indian Blue Revolution, also known as the Neel or Nili Kranti Mission, underscores the significant contribution of the fisheries and aquaculture sectors to the Indian economy.

R. kanagurta, holds significant economic importance globally. The species is a cornerstone of commercial fisheries, prized for its high market demand and versatile culinary applications. Its economic value extends throughout the seafood supply chain, from harvesting to processing, distribution, and retail. The mackerel industry provides livelihoods for millions of people worldwide, particularly in coastal communities where fishing is a primary economic activity (Jones, (2023). Moreover, mackerel exports contribute substantially to international trade, enhancing the economies of exporting countries and fostering global food security (Smith, 2022). The sustainability and management of mackerel fisheries are paramount to ensure their continued economic viability and ecological integrity. As such, research into mackerel biology, ecology, and fisheries management is essential for informing policies and practices that support the long-term sustainability and economic prosperity of mackerel-dependent industries.

Alterations in ocean temperature, currents, and precipitation patterns due to climate change, increased carbon dioxide levels in the atmosphere leading to ocean acidification, can impact the availability of prey and the health of mackerel larvae and juveniles (Smith, 2023). On the other hand, unsustainable fishing practices, coastal development, dredging, and habitat degradation due to pollution can destroy or fragment mackerel habitats (Johnson, 2023). These changes can have significant implications for mackerel populations, affecting their abundance, distribution, reproductive success, and overall health (Brown, 2023). Therefore, it's crucial to understand and mitigate the impacts of both natural and anthropogenic changes on mackerel habitats to ensure their long-term sustainability and conservation.

Role of Parasites

Fish serve as hosts to a wide range of parasites which are taxonomically diverse and that exhibit a wide variety of life cycle strategies. Most of the parasites are passed directly between ultimate hosts, while some navigate through a series of intermediate hosts before reaching a particular host in or on which they can attain sexual maturity (Smith,2023). Based on where the parasite is present, they can be categorized into two groups namely ectoparasites and endoparasites. Parasites play a vital role in fish biology, affecting the behavior, health, and distribution of fish (Johnson, 2023). As parasites are so common and mostly live in a dynamic balance with their host, they are frequently disregarded when evaluating the health of fish.

Changes in the environment can change the state of balance of the parasite between host and nature, leading to diseases. These changes can be change in surface temperature, climate, or anthropogenic such as pollution and urbanization (Lafferty and Kuris 1999). Warmer temperatures may accelerate the development of parasites, leading to increased infection rates in mackerel populations (Harvell *et al*., 2002; Marcogliese, 2008). Other disturbances in aquatic habitats, namely eutrophication, urbanization, and invasive species, are most likely to shift the dynamics of diseases, interact with the effects of climate change, and further alter pathogen-transmission patterns in aquatic habitats (Parry, 2007; Johnson *et al*., 2010; Paull and Johnson, 2011). Ocean acidification can weaken the health and immune defenses of mackerel, rendering them more susceptible to parasitic infections (Heuer *et al.,* 2014).

Numerous facultative as well as obligatory parasitic members of the order Isopoda are damaging parasites on fish affecting fish gills and skin. Parasites can cause mechanical, physiological, and reproductive damage (Iwanowicz, 2014). The infested fish shows pale gill filaments or presence of white patches on the body. In extreme cases, the infested fish may exhibit significant decaying, pale colorations, and extensive mucus secretion (Poulin, 1999). Fish that are severely infected with ectoparasites may develop gill lesions and skin damage (Sindermann, 1987). Parasites in the mouth affect the oral structures and can entirely replace the tongue of the fish. The large size and structure of parasites can act as physical irritants, which may be too responsible for the branchial tissue damage (Sindermann, 1987).

Bopyridae, Cryptoniscidae, Cymothoidae, Dajidae, Entoniscidae, Gnathiidae and Tridentellidae are parasitic in nature from the family Isopoda. Cymothoids are most common ectoparasitic isopods infesting different parts of various fishes. Among 4000 species of isopods have been described, and around 450 of these species are known to associate with fishes and vary from 0.5 mm to 44 cm long in size. The isopod, *N. indica* (Milne-Edwards, 1840) is widely distributed as a protandric hermaphroditic parasite (Aneesh et al., 2019) infecting several tropical fishes.

Anisakidosis is a fish-borne zoonosis caused by the ingestion of larval parasitic nematodes of the family Anisakidae, it is reported to cause allergic reactions in humans. Humans acquire the infection accidentally by eating mainly raw, salted marinated orundercooked fish or cephalopods (Aswathy, 2020). *Anisakis sp* larvae are found parasitizing a wide range of marine teleost species inhabiting the Atlantic and the Mediterranean, as well as the Pacific to the Antarctic area, affecting the fish product quality (Department of Fisheries India, 2020).

Ectoparasite infestation is one of the most hazardous threats to fish health causing low body weight gain, high mortality, and poor marketability due to skin and gill abrasions that promote ‘opportunistic microorganisms’ invasion (Eissa, 2002). Thus, parasitic infestations compromise the health of the infected fish and such fishes may be harmful for human consumption. (Sindermann, 1987). As most of the living organism induce in parasitism understanding its role in the environment will help understand changes in each fish population or stream ecosystem.

Understanding ecosystem dynamics is an essential and studying ectoparasites is the key in maintaining the ecological balance of the marine environments. Ectoparasites significantly influence the health and behavior of the host organisms, impacting pollution dynamics and trophic interactions. Investigating the spatial and size class relations provides valuable insights into complex relation within the ecosystem. This study will help determine abundance and various types of ectoparasites present, their prevalence in the two study sites.

1.2 AIMS AND OBJECTIVES

AIM

The aim of this dissertation work is to study the spatial and size class relation among ectoparasites associated with Indian Mackerel, *R. kanagurta.*

OBJECTIVES

- To investigate the spatial distribution of ectoparasites on Indian Mackerel.
- To analyze size class variation in ectoparasite abundance.

1.3 SCOPE

In the field of ectoparasites infesting Indian Mackerel could delve deeper into understanding the intricate relationships between environmental factors, host characteristics, and parasite dynamics. Longitudinal studies tracking environmental variables alongside parasite infestation rates could unveil crucial insights into population dynamics and seasonal variations. Investigating the mechanisms underlying host-parasite interactions, particularly how host size and age influence infestation rates, could shed light on potential control strategies.

CHAPTER 2: LITERATURE REVIEW

Lafferty (2008) conducted a study of parasite on estuarine fishes and highlighted that parasites in fishes are useful indicators of fish health and aquatic health in general as they are sensitive to intensive fishing and pollution with their abundance declining with time.

Quiazon (2015) conducted a study on aquatic parasites and its negative effect on food safety and security and reported that fish populations are affected by the parasitic diseases that directly and indirectly affect fish reproduction, growth, and survival, whereas intensifications of aquaculture operations cause fish health problems associated to parasitic diseases resulting to decline in production.

Barber (2006) highlighted the major interactions between parasites, behavior and welfare for teleost fishes and suggested that behavioral evolution such as their habitat selection, mate choice and shoaling decisions of the fishes can help, limit exposure to deleterious pathogens.

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Nico *et.al.*, (2014) conducted sampling and found a decrease in the Cymothoid's diversity as they move from the tropics to temperate and cold waters.

Lafferty (1999) examined effects of stressors on parasite population and highlighted that Eutrophication and thermal effluent often raise rates of parasitism.

McDowell *et al.*, (1999) reported that pollutants reduce the immunological capabilities of hosts, making them more susceptible to parasites.

Zarlenga *et al.,* (2014) highlighted that, human-induced environmental stressors significantly impact the genetic diversity and population dynamics of aquatic parasites, with pollutants and habitat degradation linked to disease outbreaks in fish. Chemical pollutants alter water quality, affecting both aquatic organisms and parasites directly. These stressors can reduce host immune function, increase susceptibility to infections, and disrupt abiotic factors crucial for parasite survival.

Altman and Byers (2024) highlight the diverse roles of parasites in ecological communities impacting not only host populations but also community structure, biodiversity, and energy flows. Variations in definitive host abundance and environmental factors play key roles, while anthropogenic activities also shape parasite dynamics by attracting or deterring hosts. This underscores the importance of integrating parasites into broader ecological contexts and mitigating human-induced disturbances for ecosystem health and biodiversity.

Rameshkumar and Ravichandran (2010) investigated the parasitic infestation in *R. kanagurta* and recorded that it is a host for parasite *N. phaeopleura.* The site of infestation was buccal cavity and body surface. Prevalence of infestation in *R. kanagurta* was highest in January (49.1%) and lowest in July (7.5%). It was also noted that females were more prone to the infestation with the value of 52.6%.

Rokkam and Triveni (2011) conducted a ectoparasitic survey on Indian Mackerel at Visakhapatnam coast, Bay of Bengal, and concluded that 15 species including three species of Monogenea, seven species of Digenea, and five species of Crustacea infected the fish. Digeneans were the dominant parasites. Less dominant were ectoparasitic monogeneans and crustaceans.

Khan (2012) analyzed the infestation of isopod parasites in *R. kanagurta*. Out of 862 fish examined, 294 were found to be infected by the parasites. The highest prevalence of infestation observed was (51.85%) and (57.14%) in May 2010 while the lowest was (12.50%) and (20%) in September 2010 in males and females respectively.

Aloo (2014) investigated the parasitic fauna of commercial fish species along the Kenyan coast. Out of the 16 species, only eight were found to be infested with ecto-and endo parasites. They reported that the intensity of infestation increased with age and size. The rabbitfish was the most infested with parasites, while Sardinella and Leptoscarus were primarily infested with ectoparasites.

Kudtarkar *et al.*, (2015) analyzed 182 specimens with 117 collected from Mumbai and 65 from Goa. Notably, isopod parasites, primarily *N. indica* were found infesting 20 specimens from Mumbai and 15 from Goa predominantly attached to the gills and occasionally within the mouth cavity. Of the 117 host fishes examined at Mumbai Coast, 68 specimens were females and 45 were males. Among 65 fish studied from Goa Coast, 35 were females and 29 were males. Prevalence of infection was observed to be 23.08% in Mumbai and 16.81% in Goa. The highest prevalence of parasite infection occurred in October in Mumbai and March in Goa.

Das *et al.,* (2017) collected data on the spatio-temporal distribution of Indian mackerel along the south-west coast of India between 2004 and 2007. They reported that the distribution of the mackerel population significantly shifted northward during the post-monsoon season and suggested that changes may be influenced by fluctuations in environmental parameters such as temperature, salinity, Chl a concentration and PP of seawater.

Kottarathil *et al.,* (2018), worked on N. indica infestation in *R. kanagurta* along the Malabar coast of India. The monthly occurrence was charted for a period of 38 months and was subjected to statistical analysis. It was reported that only *R. kanagurta* was affected by *N. indica.* They also studied damage caused due to infestation and life cycle of the parasite.

Hathal *et al.*, (2018) collected fish samples from off Cochin coast along Southwest India. 20 species of fishes were analyzed from 12 families infestation of *N.indica* was noticed only in the host fish *R. kanagurta*. Totally 619 specimens of *R. kanagurta* were examined 175 specimens were found to be infested. Highest prevalence of infestation, mean intensity and abundance were recorded in the month of August 2018.

Hatha *et al.*, (2020) reported the first record of the isopod parasite *N.indica* in the branchial cavity of the host Atule mate collected from the Bay of Bengal. The study provides confirmation of the occurrence of *Cymothoa indica* and *N.indica* in the coastal waters of Odisha, as well as new host records for *N.arres* and *N.depressa*.

George and Nanajkar. (2020) collected fish samples from Panjim market, Goa. Of the five samples, only one (11.3 cm long and 2.1 cm width) was infested with the isopod, *N. indica* which was 27 mm length and 18 mm width. *N. indica* was observed for the first time with their ventral surface facing inwards towards the digestive tract of the host fish. They suggested that the parasite must have descended through the site of infestation towards the inside of the body. The research study also indicated that monitoring of the fishes is needed to avoid spoilage and mortality of the fishes.

Purivirojku (2020) studied the Fish Parasitic Isopods from the Gulf of Thailand. A total of 4140 marine fishes were examined and 8 species of parasites were reported from marine fishes.

Suresh *et al.*, (2021) conducted a morphological and seasonal analysis of ectoparasites on 240 individuals of Indian Mackerel from the Thiruvananthapuram coast during March-August 2018. They investigated three parasitic groups-Trichodinids, Digenean cysts and Cymothoids. The study reported the presence of all three groups of parasites on the body surface, buccal cavity, mouth, opercular cavity, and gills. They also reported that Trichodinids and digeneans had 100% prevalence on the gill samples.

Nizar *et al.*, (2021) collected 1795 fishes belonging to 38 species from fish landing centers across the Kerala Coast for 5 months. They identified a total of 32 species of copepods and 6 species of isopod affecting the gills of the fishes. Family Lernanthropidae had the highest prevalence (71.43%) among the parasites and the copepod *Euryphorus nordmannii* had the highest intensity. The study concluded that over 68% of marine fish species on the Kerala coast were heavily infected by isopods or copepods.

Yusni1 and Handayani (2022) conducted a comprehensive examination on 30 Indian Mackerel individuals, ranging from 17 to 25.3 cm in length at Belawan Ocean Fishing Port. The study revealed that all individuals were afflicted by ectoparasites, with the highest infestation observed predominantly in the gill region. Notably, the genus Dactylogyrus emerged as the dominant parasite found to infest approximately 18 individuals.

Mascarenhas and Dessai (2023) carried out the gut content analysis of *R.kanagurta*. The study reported that diatoms and dinoflagellates were the predominant planktonic feed for *R. kanagurta*. The study also reported that the stomach emptiness index revealed gluttonous feeding from November to March and comparatively gluttonous feeding in April with the highest mean GSI was observed in the month of April.

CHAPTER 3: METHODOLOGY

3.1 STUDY AREA

Goa, a coastal state situated on the western edge of India, encompasses an area of approximately 3,792 square kilometers. It is flanked by the districts of Sindhudurga to the north and Belgaum and Dharwad to the south, both located in the state of Karnataka. To the west, the Arabian Sea delineates its boundary. The study area selected were Cacra Beach (15.45132° N, 73.83659° E) and Cutbona Jetty (15°9′32.5″N 73°57′14.93″E) belonging to the North and South district of the Goa respectively.

Site 1, designated as Cacra Beach, is situated on the Taleigão Plateau, approximately 5.2 kilometers away from Bambolim and near Goa University, within the North district of Goa. The local community residing in this area predominantly sustains their livelihood through fishing activities, utilizing traditional fishing methods. The physiology of Cacra Beach encompasses the physical and biological features of the beach and its surroundings. These include its sandy shoreline, influenced by wave action and tidal fluctuations. The intertidal zone, teeming with diverse life forms like crabs and mollusks, is a dynamic habitat subject to exposure and immersion. Offshore waters support various marine species, while coastal vegetation like mangroves contributes to ecosystem stability. Human activities such as tourism and pollution also play a significant role in shaping the beach's environment, emphasizing the importance of conservation efforts and sustainable management practices coupled with the socio-economic reliance of the community on fishing, makes it an intriguing site for scientific research focused on coastal ecosystems, marine biodiversity, and the socio-ecological dynamics of traditional fishing communities

Site 2, was Cutbona Jetty, is situated in the village of Cutbona within the Salcete taluka, located in the South district of Goa. It lies approximately 18 kilometers away from Margao city. Renowned as South Goa's largest fishing hub, Cutbona Jetty accommodates over 300 trawl operators. The significance of this site stems from its central role in the regional fishing industry. The physiology, habitat, and physical attributes of Cutbona Jetty in South Goa encompass the complex dynamics and surroundings of this coastal site. This includes the diverse ecosystems within and around the jetty area, such as intertidal zones, offshore waters, and adjacent coastal habitats. These habitats support a wide array of marine and terrestrial species adapted to the unique conditions of the jetty environment. Important physical factors shaping Cutbona Jetty include its structural design, tidal patterns, wave action, and the presence of coastal flora such as mangroves. Trawl fishing operations at Betul Jetty bolster the local economy and sustain the livelihoods of fishing communities in the vicinity.

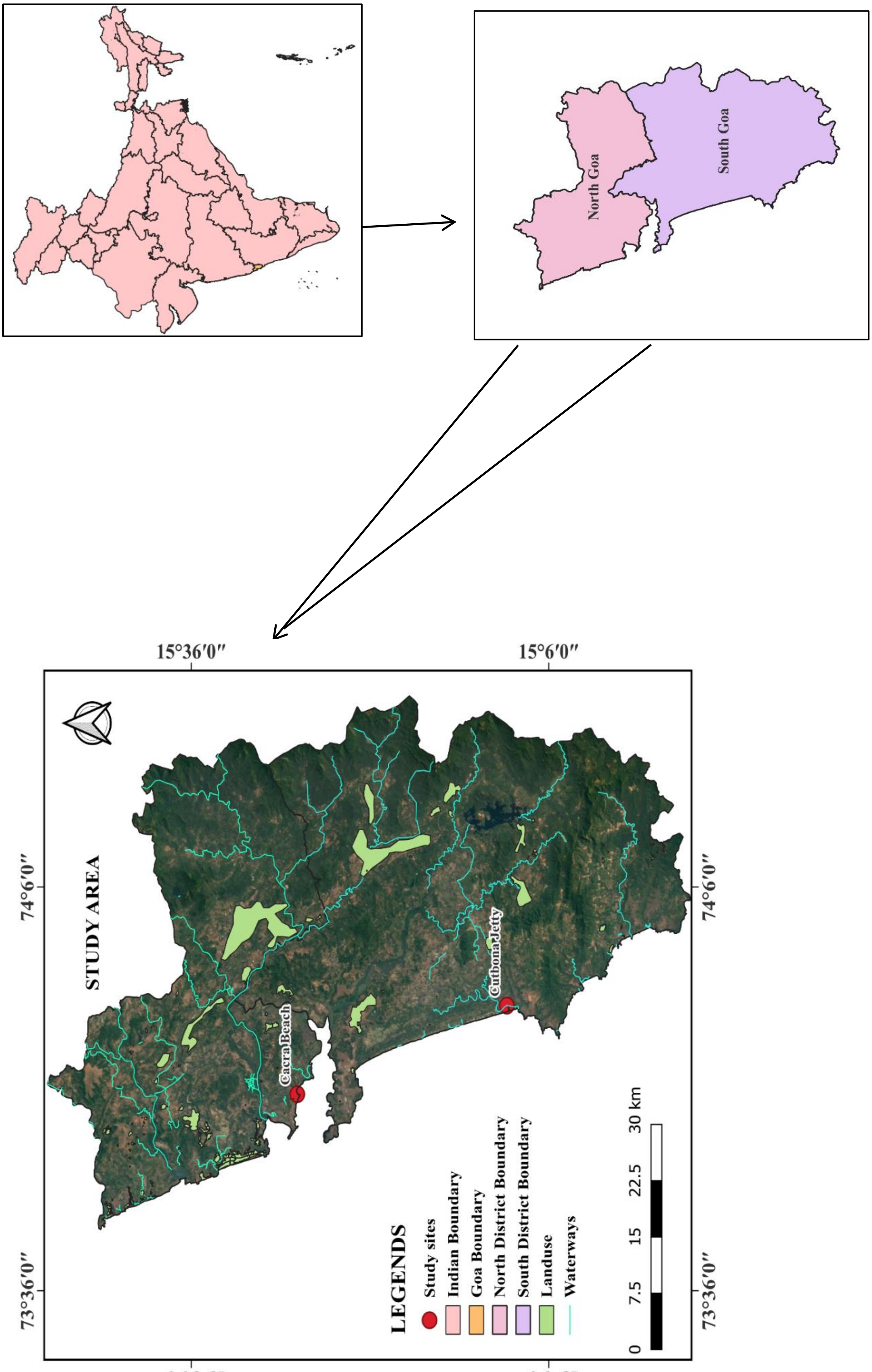

North Goa
South Goa
15°36′0″
15°6′0″
74°6′0″
73°36′0″
STUDY AREA
Cacra Beach
Cutbona Jetty
LEGENDS
Study sites
Indian Boundary
Goa Boundary
North District Boundary
South District Boundary
Landuse
Waterways
0
7.5
15
22.5
30 km

Plate 3.1 Study site 1: Cacra Beach Plate 3.2 Study site 2: Betul Jetty

"Rampon" fishing is a revered tradition within Goan coastal communities, representing a deep-rooted cultural practice intertwined with livelihood activities. In this customary method, local fishermen, referred to as "ramponkars," employ specialized techniques and equipment to harvest marine resources from the sea by using crafted long nets, "ramponkars" navigate their canoes along the coastline, deploying nets in a semi-circular manner across extensive stretches of water. The retrieval of the nets yields a diverse array of marine species, reflecting the abundance of marine life found in Goan waters.

Mechanical fishing involves the utilization of motorized vessels equipped with trawl nets to harvest marine species efficiently. These nets, typically constructed from synthetic materials, are towed behind the trawler through the water, capturing fish and other target species in bulk.

3.2 SAMPLING

40 samples of Mackerel were collected from two distinct locations: Cacra Beach and Cutbona Jetty. The sampling period spanned from November 2023 to February 2024. 5 samples of Indian Mackerel were collected from each site every month. Samples were collected from traditional fishermen from Site 1, whereas samples were collected directly from trawl owners which landed at Cutbona jetty at Site 2. Subsequently, the collected samples were transported to Goa University for parasitological examination. Immediate analysis was conducted to preserve the sample in the natural state.

3.3 PARASITOLOGICAL EXAMINATION

In the present study, morphometric measurements of fish samples were conducted to assess their length and weight. Measurements were obtained using a SAB 124 CL-INCAL weighing machine, manufactured by Scarletec Mechatronics PVT LTD. Parasitological examinations were carried out following the protocol suggested by Kennedy (1977). External body parts such as the skin, gill rakers, eye vesicles, and fins were meticulously examined for the presence of both macroscopic and microscopic parasites. Additionally, skin scrapings were scrutinized under a microscope for the detection of parasites. The buccal cavity was also subjected to thorough examination. Microscopic analysis was performed using a Radical RXL-4B and Olympus SZX 16 microscope, manufactured by Radical Scientific Equipment’s PVT LTD and Olympus Corporation, respectively. To preserve the integrity of the samples, the buccal cavity, gills, and skin were scraped using a sterile scalpel blade and transferred to separate watch glasses containing sodium chloride solution. Subsequently, the samples were mounted on clean slides using a dropper and covered with a coverslip, with tapping to eliminate air bubbles. Microscopic examination of the prepared slides commenced with a low magnification objective (10x or 20x), gradually increasing to higher magnification (40x). Photographic documentation of observed parasites was undertaken for comprehensive record-keeping and analysis.

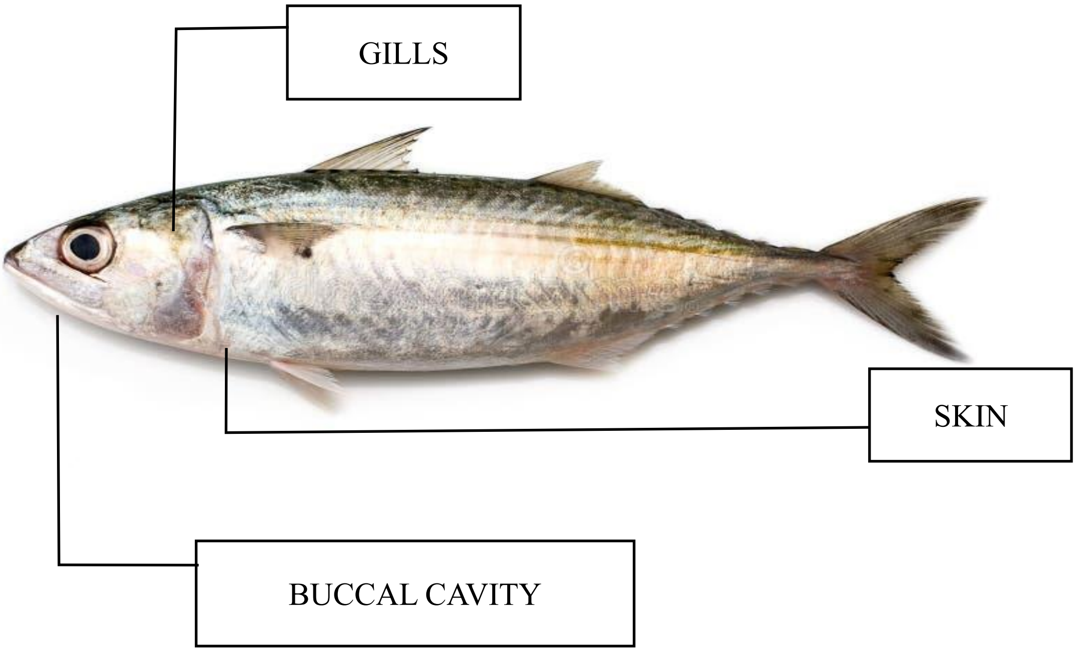


Fig 3.2 examination of ectoparasites at 3 regions of *R. kanagurta* https://indian-mackerel-5183823.jpg (800×323) (dreamstime.com)

Plate 3.3 Light microscope used for the examination of microscopic ectoparasites.

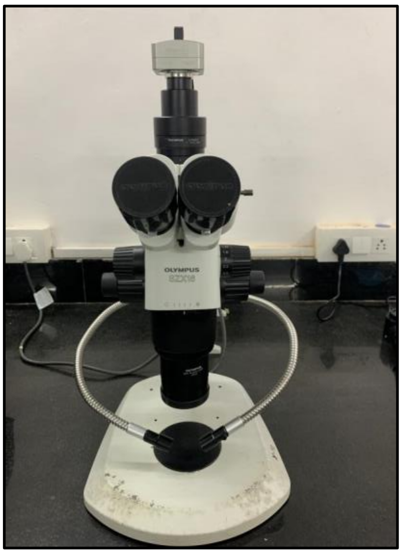


Plate 3.4 Stereo zoom microscope used for the examination of microscopic

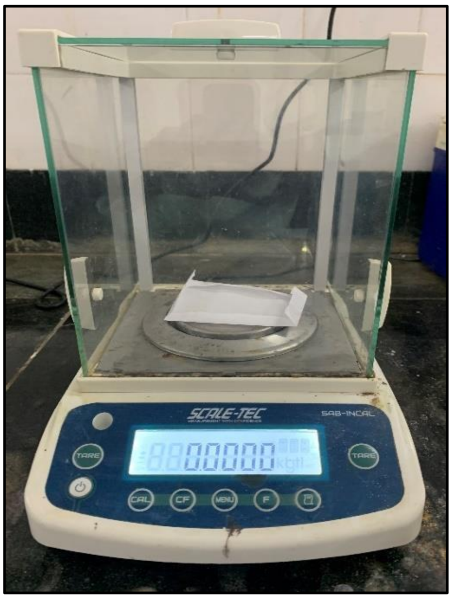


Plate 3.5 Weighing balance used for weighing the sample.

Plate 3.6 Fish infested by *N. indica* in the mouth region.

3.4 PRESERVATION OF MACROSCOPIC PARASITES

The isopods observed during the screening were transferred to a Petri plate and were cleaned of mucus and other debris using 70% ethanol. Subsequently, they were preserved in a 10% neutral buffered formalin solution, following the methodology outlined by Ortlepp (1922) and Suresh, et al. (2021). This preservation method ensures the integrity of the specimens for further analysis and examination, allowing for accurate identification and study of their morphology, anatomy, and any associated parasites or pathogens.

Plate 3.7 Preservation of macroscopic parasites.

Plate 3.8 Preservation of macroscopic parasites.

3.5 STATISTICAL ANALYSIS AND GRAPHS

The collected data were statistically analyzed, with prevalence calculated according to the formula provided by Kabata (1985). Infection categories were determined based on prevalence, utilizing the reference table outlined by Williams and Williams (1996). Graphical representations were generated using Microsoft Excel, facilitating the visualization and interpretation of the data trends and patterns.

Formula to calculate prevalence and intensity:

$$\text{Prevalence} = \frac{\text{Number of fish samples infected with parasites}}{\text{total number of fish samples observed}} \times 100\%$$

$$\text{Intensity} = \frac{\text{Total number of infesting parasites}}{\text{number of infested fish samples}}$$

Table 3.1 Referral table for infection category

Prevalence (%)	**Infection Category**
<0.01	Almost never
<0.01-0.01	Very rarely
1-9	occasionally
10-29	Often
30-49	Commonly
50-69	Frequently
70-89	Usually

90-98	Almost always
99-100	Always

CHAPTER 4: ANALYSIS AND CONCLUSIONS

4.1 RESULT AND DISCUSSIONS

In the present study, 40 Indian Mackerel (*R. kanagurta*) samples were collected from two distinct sites: Cacra Beach (Plate 3.1) and Betul Jetty (Plate 3.2) in the North and South districts of Goa, respectively. Among the samples examined, it was observed that 27 Mackerel specimens were afflicted with a combination of 7 microscopic and 1 macroscopic ectoparasite.

Upon microscopic examination of slides prepared from samples obtained from the skin, buccal cavity and gills, a diverse array of microscopic entities were discovered. Among these, various parasites were identified alongside a spectrum of planktonic species, including diatoms. Additionally, the scrapping yielded fibers and micro-plastics. This comprehensive range of findings indicates a complex ecosystem at play, suggesting potential environmental stressors and emphasizing the need for further investigation into the health implications for the organisms involved (Jones *et al*., 2018).

DESCRIPTIONS

MACROSCOPIC PARASITES

Norileca indica

Cymothoid found on the host *R. kanagurta* was identified to be belonging to genus Norileca with the help of study done by (Smit, 2014). Currently, nine marine fish species have been reported to be host of Norileca. *N. borealis* (Javed and Yasmeen 1999), *N. indica*, and *N. triangulata* (Richardson 1910) have all been reported from at least one scombrid fish, indicating the genus Norileca's affinity to infect scombrid fishes. Norileca possesses hook-like pereopods which allow it to cling to host tissue; the mouth part complex is made up of paired maxillule, maxilla, maxilliped, and mandibles that are modified for blood feeding.

Plate 4.1 ***N. indica***

Life cycle of *N. indica*, the adult female Norileca is known to carry developing marsupium embryos. With its oostegites, this pouch protects the young and keeps the embryos aerated (Varvarigos, 2003). The eggs hatch in the marsupium and go through their first moult into the sexually undifferentiated pullus stage. The first pullus (pullus I) is found only in the marsupium, where it moult into the second pullus (pullus II). Only after the young has left the brood pouch in search of a host sexual differentiation occur. With long setae on the appendage margins and well-developed eyes, these young and active isopods (now called manca) are well equipped for swimming (Brusca, 1978). Mancas look for a suitable host to attach to and, once found, will moult and lose their swimming setae, becoming immobile. Following the completion of permanent attachment, a subsequent moult occurs in which a seventh segment and pair of pereopods appear and the isopod is in a preadult form. The isopod is now known as a juvenile, and it will continue to function as a male until circumstances force it to transform into a female (Lincoln, 1971).

MICROSCOPIC PARASITES

Trichodina sp.

Approximately 400 species of *Trichodina* have been observed across different aquatic animals globally, inhabiting diverse settings such as freshwater, brackish water, and marine environments. These findings have been documented in various studies spanning several decades. These microorganisms have a round shape, usually ranging from 30 to 200 micrometers wide. They sport a circle of hair-like cilia, aiding in movement and food capture. They also have specialized mouth and attachment structures around their edges. Inside each cell sits a single nucleus, often positioned centrally. *Trichodina* primarily reproduces by splitting into two, although sexual reproduction may occur in specific conditions. They commonly inhabit fish skin, gills, and fins, potentially causing harm in large numbers. While presence of

Plate 4.2 *Trichodina sp*

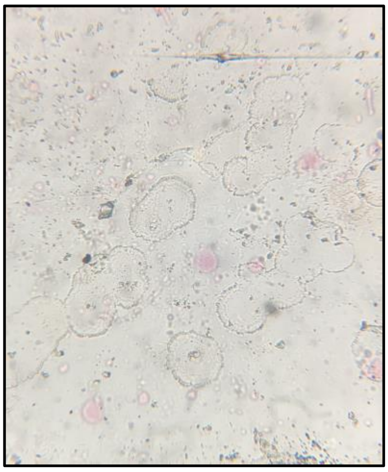


Plate 4.3 *Trichodina ciliata*

the parasite in small numbers on a fish generally do not cause much of a health problem, large numbers can cause moderate to serious pathology and ultimately, death of fish. Small fish and fry are more susceptible, and severe cases mortality can occur if undiagnosed (Stephen A, 2019).

Trichodina can form cysts, which are resilient and capable of surviving harsh conditions. Upon emerging from the cysts, free-swimming stages are released, facilitating transmission to new hosts and ensuring the continuation of the parasite's life cycle. Understanding these processes is crucial for effectively managing *Trichodina* infections in fish populations

Cyclopoida sp.

Cyclopoida are commonly found in freshwater habitats like lakes, rivers, and streams, although certain species can also inhabit marine environments. Their bodies are segmented, with the first antennae often adapted into grasping structures for feeding. Some *Cyclopoida* have evolved to live as parasites within various aquatic organisms, such as fish, amphibians, and invertebrates (Kabata, 1979). Unlike their free-living counterparts, parasitic *Cyclopoida* possess specialized mouthparts and appendages tailored for attachment to and feeding on their hosts' tissues or bodily fluids (Huys and Boxshall, 1991) These adaptations often include reduced body segmentation and eye development, reflecting their shift to a parasitic lifestyle. Parasitic

Plate 4.4 *Cyclopoida sps*

Cyclopoida exert significant influence on host-parasite dynamics, impacting the health and behavior of their hosts.

Their life cycles typically involve intricate interactions among multiple host species, with different life stages exploiting diverse host environments. Despite their parasitic nature, *Cyclopoida* remain essential components of aquatic ecosystems, regulating host populations and facilitating the flow of energy and nutrients within aquatic food webs.

Decapoda Larvae

Decapods, a diverse group of crustaceans, are found in a variety of aquatic environments, including oceans, seas, rivers, and lakes. They have a distinct body structure consisting of a cephalothorax, abdomen, and tail fan, along with ten walking legs (Walter and Boxshall 2018). These creatures possess specialized appendages like enlarged claws, which serve purposes in defense, feeding, and mating (Martin and Davis 2001). They respire through gills located beneath their carapace and exhibit omnivorous or carnivorous feeding habits (Bliss 1982). Reproduction involves separate sexes and internal fertilization, with females carrying fertilized eggs until they hatch. During their early developmental stages, these larvae often form parasitic associations with diverse organisms, such as fish, mollusks, and even other crustaceans. Decapod larvae exhibit specific adaptations for parasitism, including specialized appendages for attachment and feeding, along with mechanisms to evade host immune responses.

Plate 4.5 *Decapoda sp*

Decapod larvae experience a multifaceted life cycle, beginning with egg fertilization, which can either be carried externally by females or incubated in specialized structures. Upon hatching, they enter the zoea stage, distinguished by their elongated bodies and specialized appendages for swimming and feeding. Remaining planktonic, zoea larvae molt several times as they grow. After multiple molts, they undergo metamorphosis into the megalopa stage, resembling miniature adult decapods with more distinct body segments and appendages. Eventually, they progress into juvenile and adult stages through additional molting and metamorphosis, settling into benthic habitats. Throughout this process, decapod larvae demonstrate adaptations tailored to their surroundings, facilitating dispersal, feeding, and predator avoidance. Variations in the life cycle arise due to habitat, reproductive strategies, and environmental conditions among different species.

Cercaria sp

Cercariae, the larval form of trematode parasites, are found in freshwater habitats like rivers, lakes, and ponds. These agile larvae swim using their distinctive forked tails, actively searching for their definitive host, usually a vertebrate (Lafferty and Kuris 2009). With specialized features for attachment and penetration, cercariae are essential for transmitting trematode parasites (Faltýnková *et*

Plate 4.6 *Cercariae sp*

al., 2007). Their existence in aquatic environments plays a vital role in the complex relationships between parasites and hosts, as well as nutrient circulation.

A developmental phase in the life cycle of trematode parasites, are often referred to as fluke larvae. These parasites undergo a complex life cycle, involving multiple hosts. *Cercariae* represent a crucial stage as the free-swimming larval form. After emerging from their intermediate host, typically a snail, cercariae actively navigate through water to find their definitive host, often a vertebrate such as a bird or mammal. During this phase, cercariae may infect the definitive host by penetrating its skin or mucous membranes. Once inside, they undergo further development, maturing into adult flukes capable of reproduction.

Argulus Sp

Argulus, also known as fish lice, are small crustaceans that inhabit freshwater ecosystems like lakes and rivers. These disc-shaped parasites, ranging from millimeters to centimeters in size, have a tough outer shell and specialized attachment organs such as hooks and suckers. They feed on the blood, tissue fluids, and mucous of fish hosts using piercing mouthparts (Boxshall and Defaye 2008). In terms of reproduction, female *Argulus* lay eggs that hatch into larvae, which undergo several developmental stages before

Plate 4.7 *Argulus sp*

reaching maturity (Nakagawa, M. *et al.*, 2009). Despite their ecological importance, Argulus infestations can pose risks to fish health, causing skin irritation, tissue damage, and mortality in affected populations.

The life cycle of *Argulus*, also known as fish lice, involves several distinct phases. It commences with the laying of eggs by female Argulus, which hatch into nauplii larvae. These larvae undergo molting to transition into the parasitic stage, attaching to and feeding on hosts like small crustaceans. Upon maturity, they detach and revert to the water as adults capable of reproduction. Female adults then lay eggs, concluding the cycle. Variations in this process may arise due to environmental conditions and host availability.

Lecithocladium sp

Lecithocladium, a genus of trematode parasites, is commonly encountered in aquatic habitats, where it parasitizes diverse fish and mollusk species. These parasites possess elongated bodies equipped with anterior suckers for host attachment and reproductive organs responsible for egg production (Bray and Gibson 1989).

Plate 4.8 ***Lecithocladium sp***

Their life cycle typically involves multiple hosts, including mollusks as intermediate hosts and fish as definitive hosts. Eggs laid by adult parasites hatch into miracidia larvae, which infect snails and undergo subsequent developmental stages. Cercariae larvae emerge from snails, encyst on surfaces, and are consumed by fish, where they mature into adults.

. MACROSCOPIC EXAMINATION

An attempt was made to study the isopod at various body parts such as gill pouches, skin, and buccal cavity. Among the 27 Mackerel samples infested the infestation was in/and, 27 samples were in the branchial pouches, 5 buccal cavity and 1 sample being affected on the skin and branchial pouch (Table 4.1 & Table 4.2)

High prevalence of N. indica was in the Branchial pouches and less on the skin of the fish. The high prevalence of *N.indica* in the branchial pouches may be because of the exchange diffusion of oxygen and release of carbon dioxide occurring in this region and as it is associated with the blood vessels and it being closer to the digestive tract Puspitasari (2014).

Low occurrence of ectoparasite on the skin is due to the fish having very fine scales so it is suspected that parasites have difficulty attaching to the scales, this coincides with the study done by (Telleng 2010; Yusni1 and Handayani 2022). *N. indica* was also seen affecting the oral cavity of the R. kanagurta (Table 4.1 & 4.2). Similar observations were stated by Pattipeiluhu and Gill (1998), where *N. indica* been recovered from the buccal cavity of D. russelli from coastal waters of Indonesia.

The presence of N. indica in the oral cavity of Indian mackerel could be due to its habitat preferences and feeding habits, which could facilitate its colonization in this area. Moreover, environmental factors like water temperature and salinity might contribute to creating optimal conditions for the growth and persistence of N. indica within the fish's oral cavity. This coincides with the study by Fernandes et al. (2019) who investigated the prevalence and distribution of N. indica in Indian mackerel from coastal waters of India, providing insights into the factors influencing its occurrence in fish oral cavities.

Table 4.1 Comparison of infestation site of Isopods at Mackerel at Cacra Beach

Month	Fish infected	oral cavity	gill	skin	months
November	3	0	3	0	3
December	1	0	2	0	1
Janaury	3	1	3	0	3
February	4	1	7	0	4

Table 4.2 Comparison of infestation site of Isopods at mackerel at Cutbona Jetty

Month	Fish infected	oral cavity	gill	skin	Months
November	4	1	3	0	4
December	3	1	4	0	3
Janaury	5	1	6	1	5
February	4	0	5	0	4

The prevalence N. indica in *R.kanagurta* exhibit monthly variation ranging from 60-80% (Cacra Beach) (Table 4.3 & Figure 4.1) and 80-100% (Betul Jetty) (Table 4.4 & figure 4.2) with minimum prevalence recorded in the month of November and maximum recorded in the month of February. According to Carvalho-Souza et al., 2009 high prevalence of infestation coincides with high abundance of hosts. The present study showed difference from the previous research done on prevalence of isopod infestation in the Indian mackerel. Seasonal variations can be one of the causes of the variations in the data (Table 4.5& Figure 4.3, table 4.6 & figure 4.4)

As the earlier studies suggest, the number of parasites often increase with host age or size of the fish (Dogiel et al., 1958; Poulin, 2000). These patterns are explained by the fact that larger hosts can ingest bigger quantities of food and display larger surface for parasites attachment (Guégan et al. 1992; Poulin 2000; Valtonen et al. 2010). On comparing the size and length the fishes with weight ranging from 90-120g showed maximum infestations (Table 4.7 & Figure 4.5, Table 4.8 & figure 4.6) and fishes with the weight above 120g showed minimum infestation rates. The fishes with the body length above 21 cm showed higher rates of infestation (Table 4.9 & Figure 4.7, Table 4.10 & Figure 4.8), hence supporting the observations between host- size and the parasite. One of the most important factors in host-parasite interactions is host specificity, which reflects host ecology, chorology, and phylogeny (Cressey et al.1983).

Table 4.3 Monthly prevalence of Isopods in the Mackerel at Cacra Beach

Month	Number of fishes examined	Number of fishes infected (with Isopods)	Percentage of fishes infected/Prevalence
November	5	3	60%
December	5	1	20%
Janaury	5	3	60%
February	5	4	80%
Total	20	11	55%

Fig 4.1 Monthly prevalence of Isopods in the mackerel at Cacra Beach

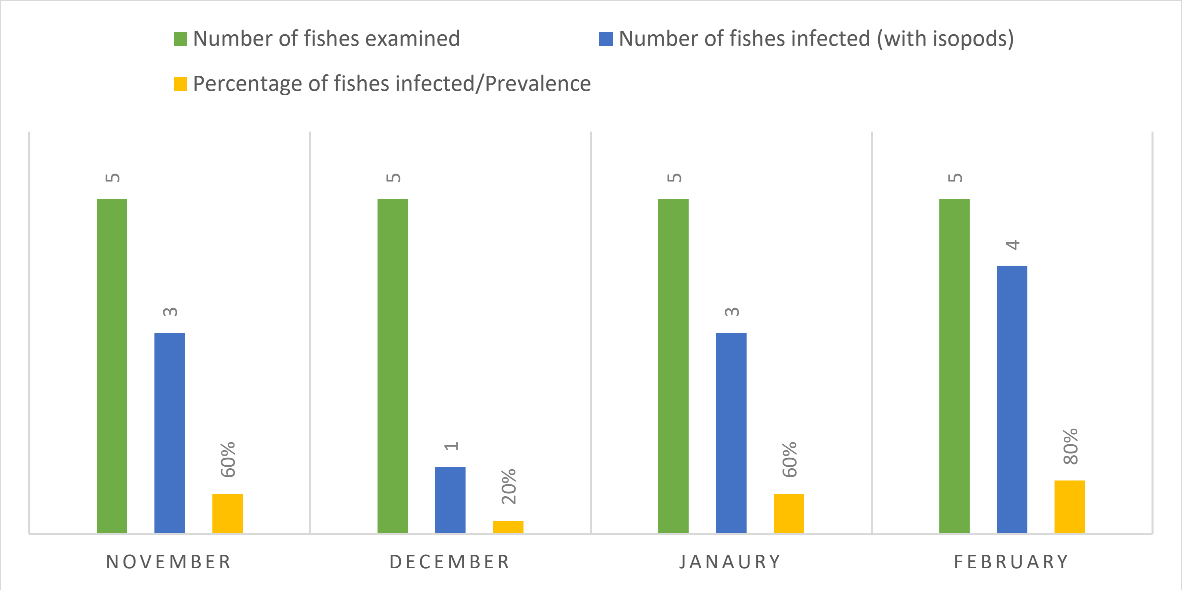


Table 4.4 Monthly prevalence of Isopods in the Mackerel at Cutbona Jetty

Month	Number of fishes examined	Number of fishes infected (with Isopods)	Percentage of fishes infected/Prevalence
November	5	4	80%
December	5	3	60%
Janaury	5	5	100%
February	5	4	80%
Total	20	16	80%

Fig 4.2 Monthly prevalence of Isopods in the mackerel at Cutbona Jetty

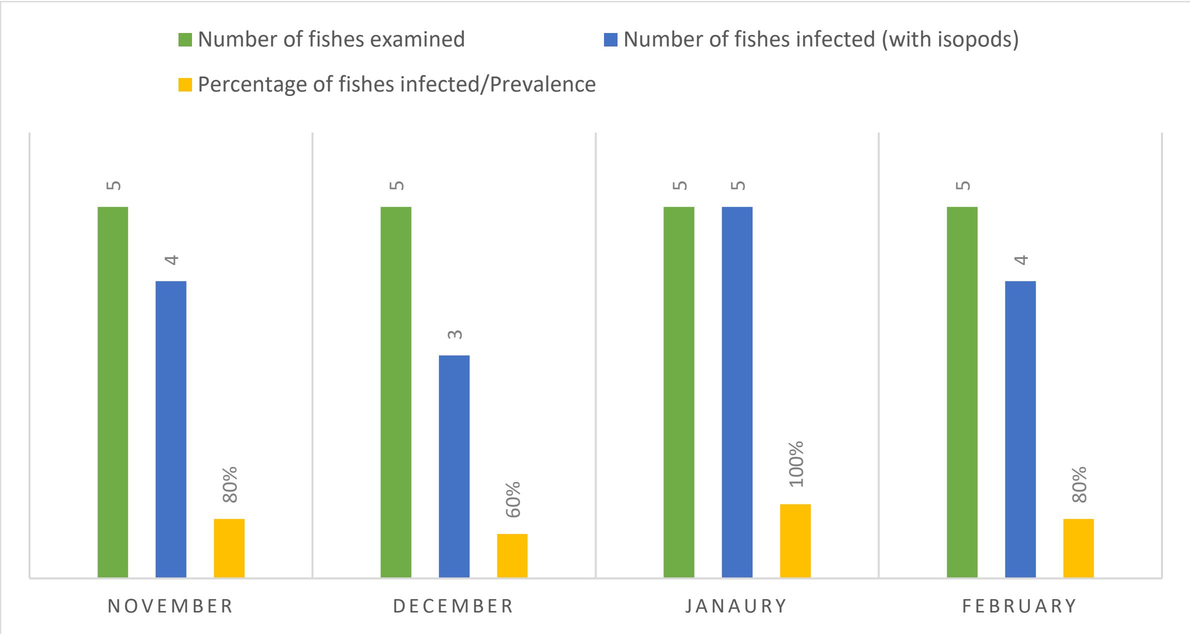


Table 4.5 Relation of temperature with intensity of parasites at Cacra Beach

Months	Temperature	Intensity of parasites
November	31	3
December	33	2
Janaury	34	4
February	35	8

Fig 4.3 Temperature vs intensity of Isopods at Cacra Beach

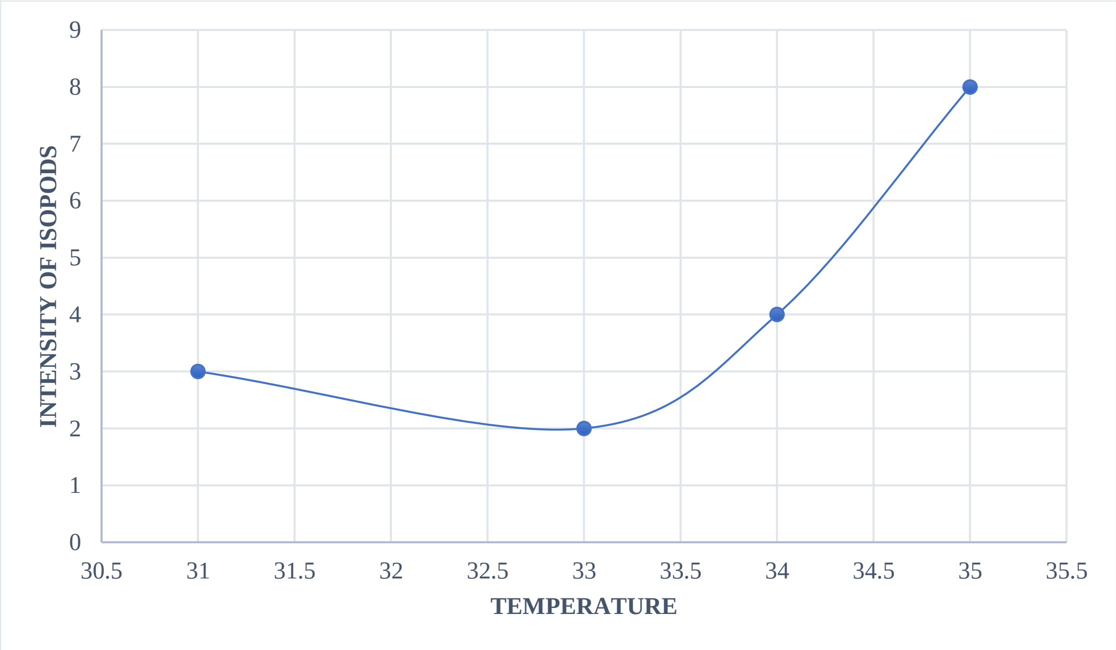


Table 4.6 Relation of temperature with intensity of parasites at Cutbona Jetty

Months	Temperature	Intensity of parasites
November	29	4
December	31	4
Janaury	33	7
February	36	5

Fig 4.4 Temperature vs intensity of Isopods at Betul Jetty

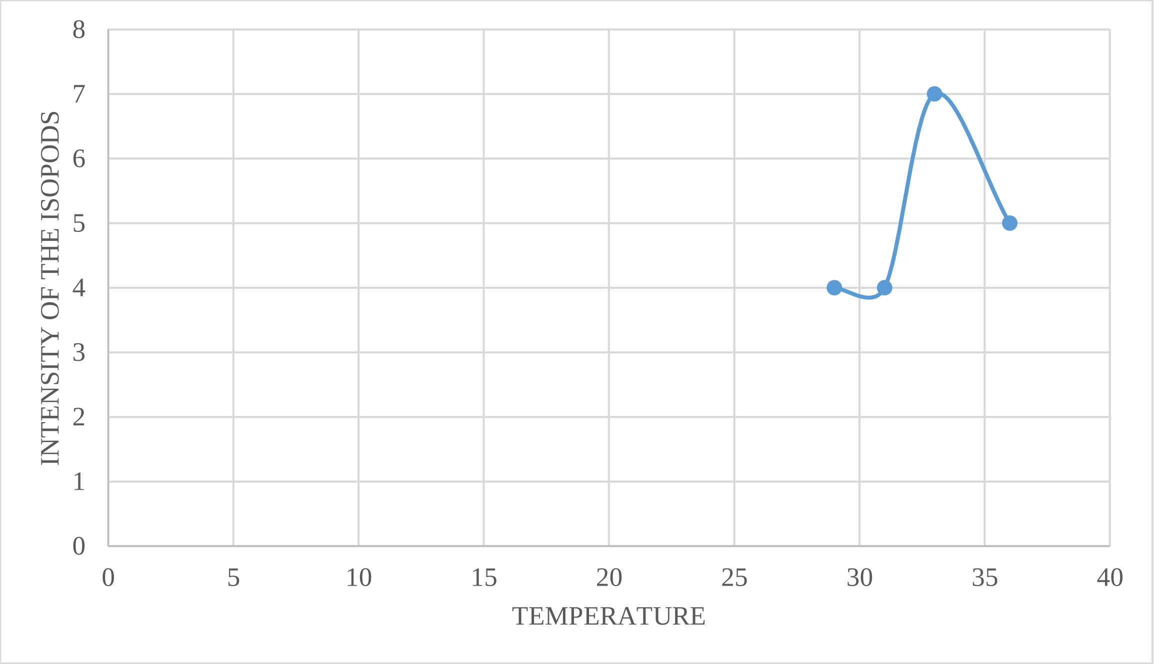


Table 4.7 Comparison of infested fish weight at Cacra Beach

Weight range (gms)	Samples infected
50-70	4
70-90	1
90-120	5
120-150	1

Fig 4.5 Comparison of infested fish weight at Cacra Beach

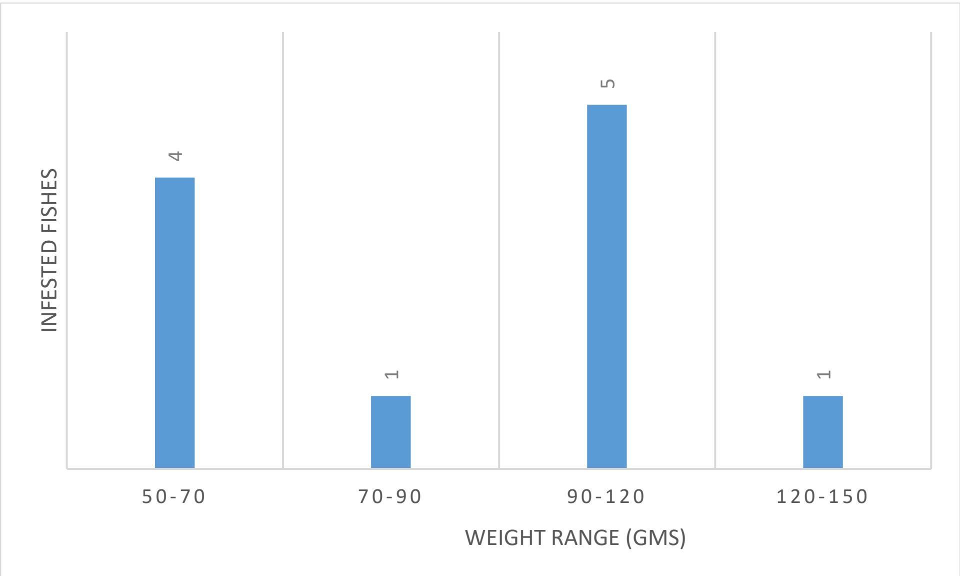


Table 4.8 Comparison of infested fish weight at Cutbona Jetty

Weight range	Fishes infected
50-70	0
70-90	7
90-120	10
120-150	0

Fig 4.6 Comparison of infested fish weight at Cutbona Jetty

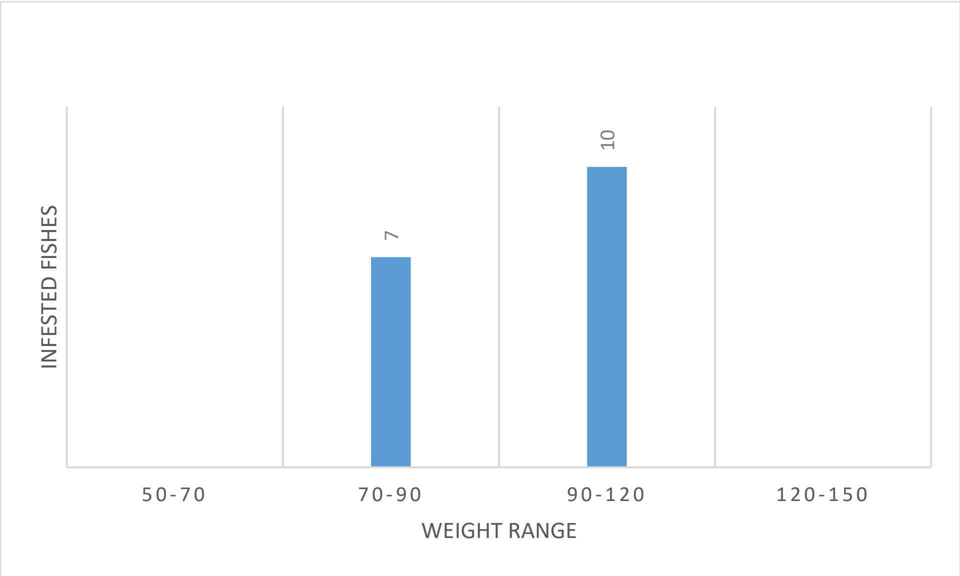


Table 4.9 Comparison of infested fish length at Cacra Beach

Length range (cm)	Samples infected
16-17	1
17-18	0
18-19	3
19-20	1

Fig 4.7 Comparison of infested fish length at Cacra Beach

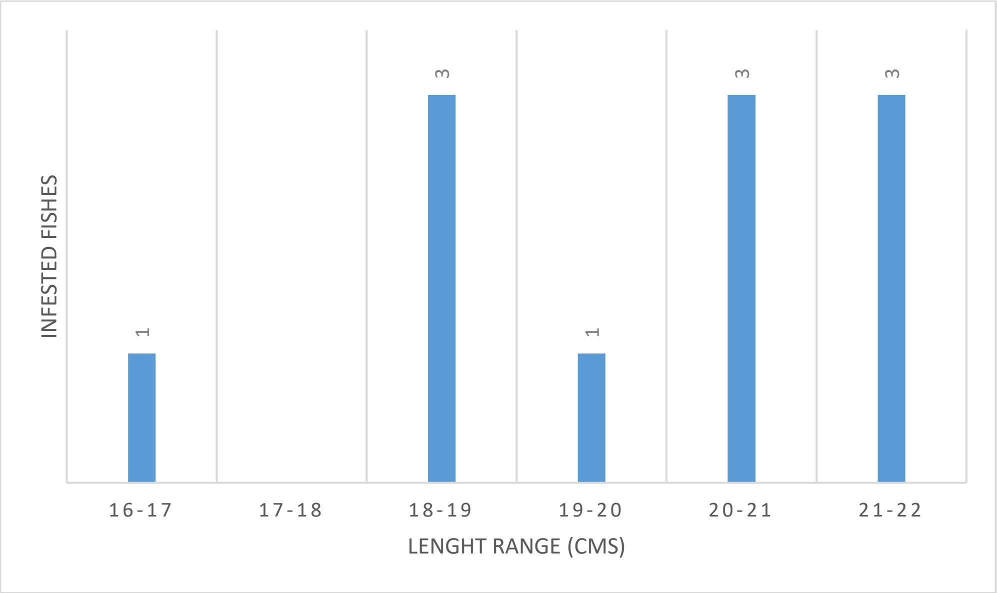
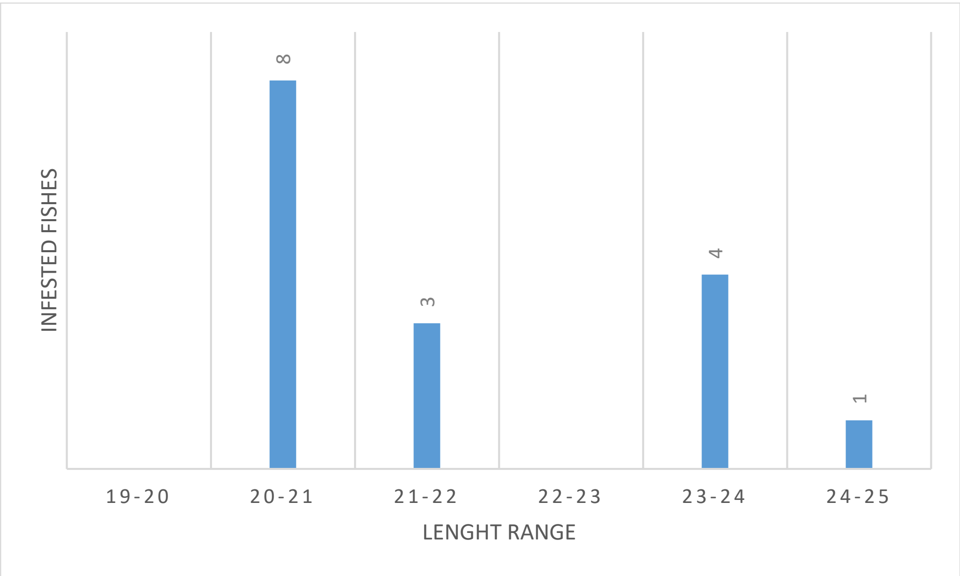


Table 4.10 Comparison of infested fish length at CutbonaJetty

Length range	Samples infected
16-17	1
17-18	0
18-19	3
19-20	1

Fig 4.8 Comparison of infested fish length at Cutbona Jetty



A total of 20 samples were examined from Cacra Beach, among these 11 showed infestation by the Isopods out of 20 samples examined from Cutbona Jetty, 16 fishes showed the infestation (Table 4.11) it is worth to mention here that the samples obtain at Cacra Beach were collected by shore siene, where much of the catch at Cutbona Jetty was obtained by Mechanized Gear, thus suggesting that the degree of infestation of ectoparasites is high among the individuals collected from the mechanized boats. The infestation was mostly seen in gill region than other parts of the body, suggesting that gills are primary sites where the infestation is high. Overall, the intensity was 1.54% and 1.25% at Carca Beach (Table 4.12) and Cutbona Jetty (Table 4.13) respectively.

Table 4.11 Fish sample Infested by Isopods at both Study sites

Sample	Cacra Beach	Cutbona jetty
1	-	+
2	+	-
3	-	+
4	+	+
5	+	+
6	+	+
7	-	-
8	-	-
9	-	+
10	-	+
11	-	+
12	+	+
13	-	+
14	+	+
15	+	+
16	-	+
17	+	-
18	+	+
19	+	+
20	+	+
Total	11	16

Table 4.12 Monthly Intensity of Isopods in the Mackerel at Cacra Beach

Month	Total number of infested fish samples	Total number of infesting parasites	Intensity
November	3	3	1%
December	1	2	2%
Janaury	3	4	1.33%
February	4	8	2%
Total	11	17	1.54%

Fig 4.9 Monthly Intensity of Isopods in the Mackerel at Cacra Beach

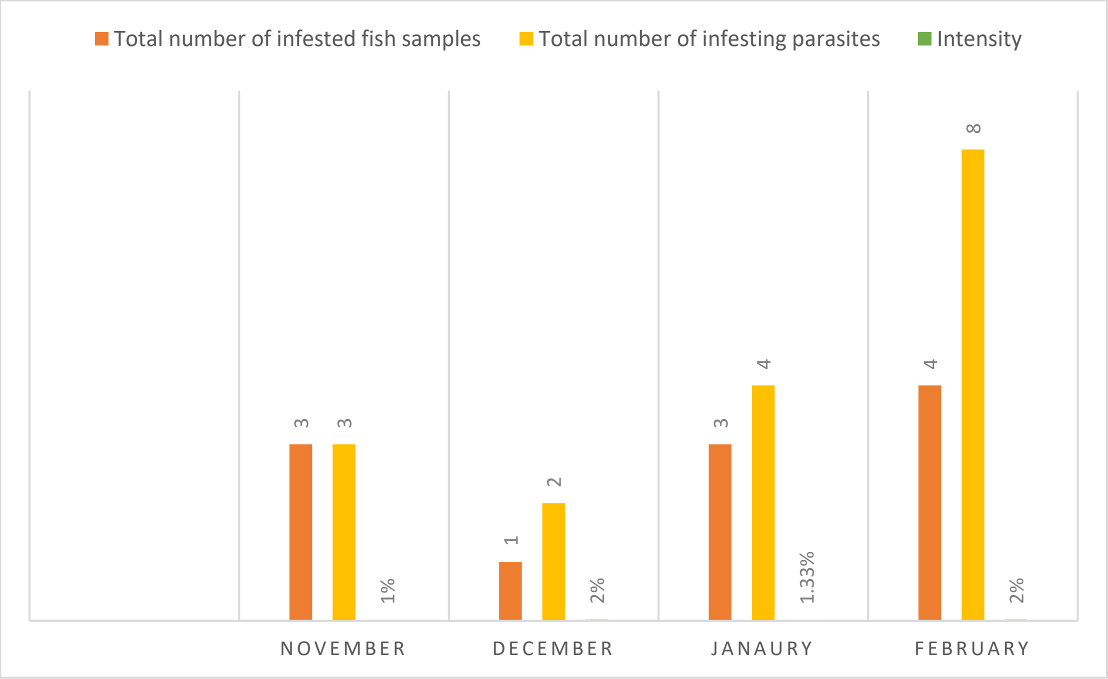
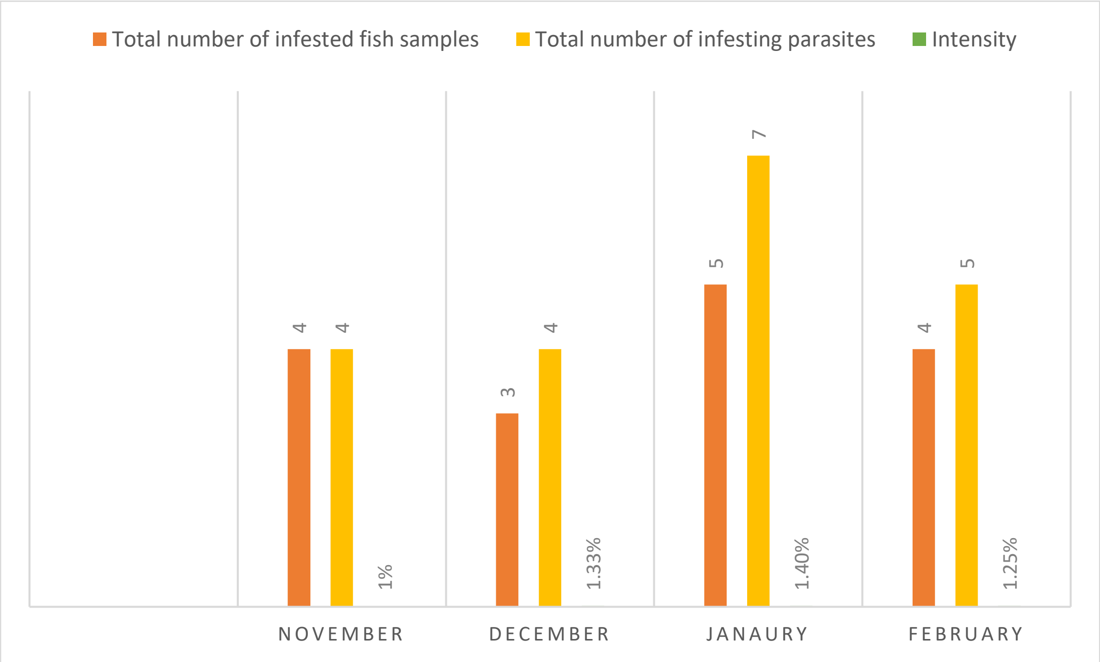


Table 4.13Monthly Intensity of Isopods in the Mackerel at Cutbona Jetty

Month	Total number of infested fish samples	Total number of infesting parasites	Intensity
November	4	4	1%
December	3	4	1.33%
Janaury	5	7	1.4%
February	4	5	1.25%
Total	16	20	1.25%

Fig 4.10 Monthly Intensity of isopods in the mackerel at Cutbona Jetty



MICROSCOPIC EXAMINATION

On the monthly examinations of microscopic ectoparasite it was seen that *Trichodina sp.* was most diverse among other observations in addition, *Trichodina sp.* was most abundant, Possible reason for *Trichodina sp.* being the diverse and abundant due to environmental factors conducive to their proliferation. These ciliates thrive in habitats with elevated organic content, subpar water quality, and moderate temperatures conditions commonly found where Indian mackerel reside. Another possible reason could be the ability of *Trichodina* to form resilient cysts capable of enduring harsh conditions could enhance its prevalence and endurance within fish populations. Moreover, the presence of appropriate host species like Indian mackerel, offering ideal conditions for *Trichodina* infestation, could also significantly influence its abundance, this can be supported with a study conducted by Oğuz *et al*. (2017) investigated the prevalence of *Trichodina sp* on various fish species in Turkish waters, highlighting environmental factors such as water temperature and quality as determinants of *Trichodina* abundance, followed by *Cyclopoida sp.* and the least abundant being Lecithocladium *sp*., *Argulus sp.* and *Cercaria sp* (Table 4.14).

The abundance of the parasites was at peak in the month of November and the population being declined towards the months of January (Table 4.14), this coincides with the study by (Majumder *et al*, 2015) where they reported that temperature variation affects the parasite species on fishes.

Apart from above observation, *Leptodora kindtii*, *Planktoniella spp*, few unidentified species, fibres and microplastic was also observed.

Table 4.14 Monthly occurrence of microscopic parasites in the Indian Mackerel (*R.kanagurta)*

	Parasites observed						
Months	Trichodina sp	Trichodina Ciliata	Cyclopoida sp.	Decapod Larvae	Lecithocladium sp	Cercaria sp	Argulus sp
November	+	–	+	+	+	–	+
December	+	–	+	–	–	–	–
January	–	–	–	–	–	–	–
February	+	+	–	–	–	+	–

PLATE 4.9

A- *Leptodora kindtii*

B- *planktoniella sol*

C- Microplastic

PLATE 4.10

A

B

C

4.2 CONCLUSIONS

A comprehensive examination of 40 fish samples revealed ectoparasitic infestations in 27 specimens, encompassing both microscopic and macroscopic varieties. Among these, various parasites a spectrum of planktonic species, including diatoms were observed. Additionally, the scrapping yielded fibers and micro-plastics.

Among the microscopic ectoparasites identified were *Trichodina sp., Trichodina ciliata, Cyclopoida sp., decapod larvae, Lecithocladium sp., Cercaria sp., and Argulus sp.*, with *Trichodina sp.* being the most prevalent. Notably, macroscopic ectoparsite *N. indica* emerged as the dominant ectoparasite in the branchial pouches compared to other anatomical regions of the fish.

Analysis of size and length correlations indicated that fish weighing between 90-120g and measuring above 21 cm exhibited the highest infestation rates.

The prevalence of isopods in mackerel varied between 55% at site 1 and 80% at site 2, with intensities recorded at 1.54% and 1.25% respectively. Interestingly, prevalence demonstrated seasonal fluctuations, with the lowest rates observed in November and the highest in February.

Noteworthy differences were observed between sampling sites, with fish samples from Site 2 (Betul Jetty) exhibiting a higher incidence of infestation compared to Site 1 (Cacra Beach).

These findings shed light on the complex ecological interactions between ectoparasites and their host fish, providing valuable insights for fisheries management and conservation strategies

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