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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

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Rajiv Gandhi Salai, Chennai – 600119.

PROCEEDINGS OF THE
"MARINE BIOLOGY RESEARCH SYMPOSIUM"
MBRS 2021
26 - 30 July 2021

IN ASSOCIATION WITH

ICAR-NATIONAL BUREAU OF FISH GENETIC RESOURCES

Lucknow

Organized by

CENTRE FOR CLIMATE CHANGE STUDIES

INTERNATIONAL RESEARCH CENTRE

SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY

PROCEEDINGS OF THE

"MARINE BIOLOGY RESEARCH SYMPOSIUM – MBRS 2021"
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&

ICAR - NATIONAL BUREAU OF FISH GENETIC RESOURCES, LUCKNOW

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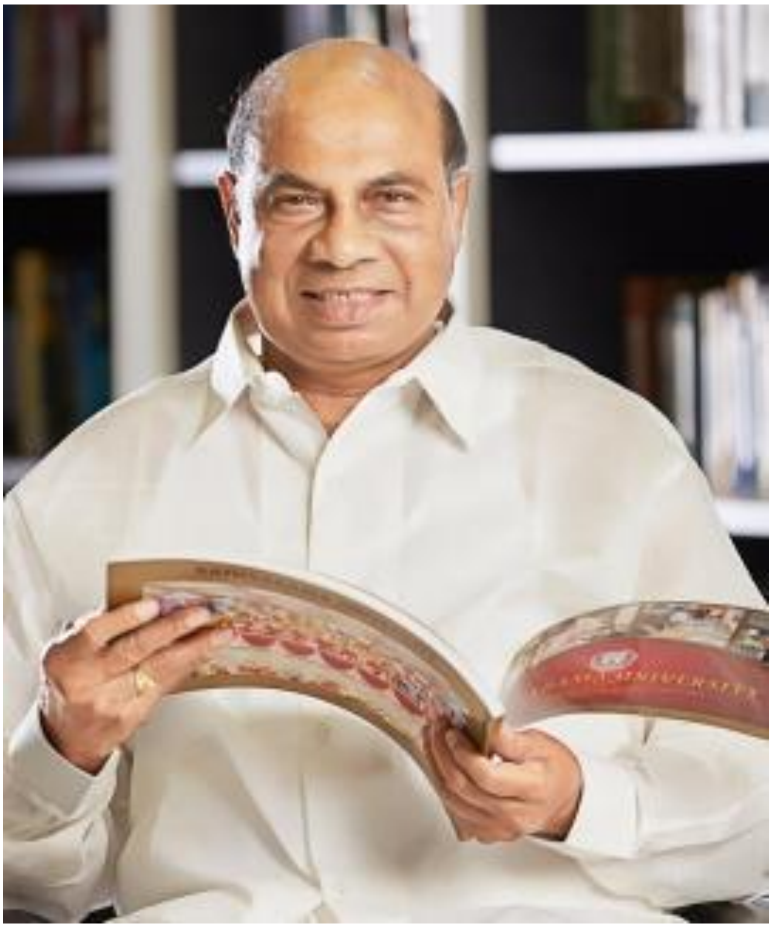

Centre for Climate Change Studies

presents

First National Virtual Event for
Marine Biology Enthusiasts

"MARINE BIOLOGY RESEARCH SYMPOSIUM

MBRS 2021"

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CHANCELLOR AND PRESIDENT MESSAGE

We feel enthralled on this gracious occasion to welcome you to the First National Virtual Event for the Marine Biology Enthusiasts "Marine Biology Research Symposium – MBRS 2021" organized by the Centre for Climate Change Studies from 26 to 30 July 2021 at Sathyabama Institute of Science and Technology, Chennai in association with ICAR-National Bureau of Fish Genetic Resources, Lucknow. The symposium provides ample opportunity to the marine biology researchers across the country to transmit the knowledge generated through their research. We are also glad to learn that many academicians, eminent scientists, students and other industry partners from India and all over the world have shown interest to participate in this symposium. We are sure this symposium will quench the knowledge of thirst of research activists and share their knowledge and valuable experience and time in the field of taxonomy, biodiversity and conservation, blue carbon, marine pollution, climate change, marine microbial and molecular ecology and coastal aquaculture.

Finally, we would like to thank all the authors, the reviewers, editors and the delegates for their contributions and participation. The symposium will not be a success without your expertise and active participation. On behalf of the organizing committee, we thank you for making this conference a great success.

Dr. MARIAZEENA JOHNSON
Chancellor

Dr. MARIE JOHNSON
President

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MESSAGE FROM VICE CHANCELLOR

I take the privilege to welcome the eminent scientists, researchers and the students for the First National Virtual Event "Marine Biology Research Symposium MBRS 2021" org organized by the Centre for Climate Change Studies from 26 to 30 July 2021 at Sathyabama Institute of Science and Technology, Chennai in association with ICAR-National Bureau of Fish Genetic Resources, Lucknow.

I expect it to be a great opportunity and an inspiring occasion for learning. I hope that the symposium will provide a better platform to interact and share their remarkable knowledge and experience with the eminent speakers on the cutting-edge themes of Marine Biology.

Dr. T. Sasipraba
Vice Chancellor,
Sathyabama Institute of Science and Technology.

Preface

On behalf of the MBRS 2021 organizing committee and Sathyabama Institute of Science and Technology, Chennai I cordially invite you for the First National Virtual Event "Marine Biology Research Symposium MBRS 2021" organized by the Centre for Climate Change Studies from 26 to 30 July 2021 at Sathyabama Institute of Science and Technology, Chennai in association with ICAR-National Bureau of Fish Genetic Resources, Lucknow.

So far, we have received 49 abstracts and 78 participants from various central, state government, and private research institutions and universities, NGO's and Industries from India and all over the world. Twenty-one full length articles have been received for peer review and publishing in the form of proceedings. Over the 5 days of symposium, abstracts have been distributed under 5 thematic sessions for both Oral and Poster presentations. The quality and the credibility of the symposium goes to the dedicated conveners (Dr. S. Prakash and Dr. Amit Kumar, Sathyabama and Dr. T. T. Ajith Kumar and Dr. P. R. Divya, Principal Scientist, ICAR-NBFGR for their unstinted effort and inviting eminent speakers all over the world.

I take this immense opportunity to express my heartfelt thanks and gratitude to the management of SATHYABAMA especially our Honorable Chancellor Dr. Mariazeena Johnson, our president Dr. Marie Johnson, and Vice President Ms. Maria Bernadette Tamilarasi Johnson without whose guidance and support this event could not reached this level.

I would like to extend my dutiful thanks to Dr. Kuldeep Lal, Director, ICAR-NBFGR, Lucknow for joining hands and supporting us for such a memorable event. I wish to convey my earnest wishes to our internal organizing committee of our university. Indeed, I am deeply moved by the selfless dedication and commitment of the Conveners whose hard work has contributed to the success of this conference.

Organizing Secretary,
Dr. T. Sasipraba,
Vice Chancellor
Sathyabama Institute of Science and Technology,
Chennai 600119.

भा.कृ.अनु.प.- राष्ट्रीय मत्स्य आनुवंशिक संसाधन ब्यूरो
ICAR-National Bureau of Fish Genetic Resources

Kuldeep K. Lal, PhD, ARS
Director
Member, Advisory Working Group on AqGR, FAO, Rome, Italy
Former Coordinator, Genetics & Biodiversity,
Network of Aquaculture Centres in Asia-Pacific (NACA), Bangkok (Thailand)

Preface

Ocean covers three-fourth of the total surface of the earth and it's a veiled treasure of unexplored resources of minerals, fuels, and biological species. In order to capture and sustain these resources, future generations will need to have a better understanding of the extraordinarily intricate nature of the world's oceans. Marine research is a multidisciplinary science including all fields from physics to biology, chemistry, and geology. The impacts of ocean warming and acidification on coastal and marine species and ecosystems also forms an important component of researchable issues. The importance of the ocean in global climate change mitigation cannot be underestimated. It absorbs a significant part of carbon and an overwhelming portion of the excess heat. The warmer atmosphere and increasing concentration of greenhouse gases nevertheless, exert enormous pressure on the ocean's ability to regulate the climate. Moreover, the impact of climate change on marine and terrestrial biodata also needs attention. Therefore, research programs and new initiatives all around the world are inviting young scientists to look into the deeper aspects of all these areas.

Against this backdrop, The Centre for Climate Change Studies, Sathyabama Institute of Science and Technology, Chennai and ICAR-National Bureau of Fish Genetic Resources, Lucknow is jointly organizing a First National Virtual Event called "Marine Biology Research Symposium — MBRS 2021" during 26th- 30th July 2021. The deliberations on the theme of the MBRS 2021 are spread over 4 days in the form of 5 technical sessions namely Taxonomy, Biodiversity and conservation (TBC), Blue Carbon and Coastal Ecosystems (BCCE); Marine Pollution and Climate Change (MPCC); Marine Microbial Ecology and Bioprospecting (MMEB) and Coastal and Ornamental Aquaculture (COA). The themetic areas will promote research in exploration, characterization fish genetic resources, for their conservation and sustainable utilization for posterity.

I would like to extend my special thanks to Dr Mariazeena Johnson Honorable Chancellor, Dr Marie Johnson, President, Ms Maria Bernadette Tamilarasi Johnson, Vice-President and S Sasiprabha, Vice Chancellor, whose guidance and unflinching support helped in bringing out this program. I wish all the success for the conduct of this program. I also congratulate the team from Sathyabhama for taking these efforts during this pandemic time and it will be honor for NBFGR to join with the proposed program

(Kuldeep K. Lal)

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Dr. Maria Bernadette Tamilarasi Johnson,

Vice President,

Sathyabama Institute of Science and Technology, Chennai, India.

PATRONS

Dr. T. Sasipraba

Vice Chancellor,

Sathyabama Institute of Science and Technology, Chennai, India

Dr. Kuldeep K. Lal

Director,

ICAR – National Bureau of Fish Genetic Resources, Lucknow

Conveners - Sathyabama

Dr. S. Prakash, Scientist

Dr. Amit Kumar, Scientist

Conveners – ICAR-NBFGR

Dr. T. T. Ajith Kumar, Principal Scientist

Dr. P. R. Divya, Senior Scientist

About Sathyabama Institute of Science and Technology

(Deemed to be University)

Sathyabama is a prestigious institution which excels in the fields of Engineering, Science and Technology for more than three successful decades. It offers multi-disciplinary academic programmes in various fields of Engineering, Science, Technology, law, Dental Science, Pharmacy, Nursing, Management, Arts and Science and Allied Health Sciences. It is established under Sec.3 of UGC Act, 1956 and is been Accredited with 'A' Grade by the National Accreditation and Assessment council. The Institution persistently seeks and adopts innovative methods to improve the quality of higher education and is responsive to the changes taking place in the field of education on a global scale. The Institution has a team of dynamic and outstanding faculty, innovative pedagogical practices, state of the art infrastructure and world class Research Facilities. This glorious Institution is functioning under the dynamic leadership of Dr. Mariazeena Johnson, Chancellor, Dr. Marie Johnson, President and Ms. Maria Bernadette Tamilarasi Johnson, Vice President.

Sathyabama has a good presence in rankings and ratings at National and International level. The Institution has been ranked in 39th position by the National Institutional Ranking Framework (NIRF), Government of India among the Universities in India for the year 2020 and ranked one among the top 50 Universities for five consecutive years. Sathyabama is ranked among the Top 5 Institutions in the Country for Innovation by ATAL ranking of Institution for Innovation Achievements, Govt. of India. Times Higher Education and QS has ranked Sathyabama among the top Institutions worldwide. Sathyabama Institute of Science & Technology has alliances with leading Universities and research establishments at National and International Level. It is a research-intensive University with world class laboratories and research facilities and is involved in research in the emerging areas of Science and Technology. Sathyabama has undertaken various sponsored and collaborative R&D projects funded by National and International Organizations. Sathyabama has written a special page in the history of space research on 22nd June 2016 with the launch of "SATHYABAMASAT" in association with ISRO.

Sathyabama has emerged as a leading Institution and achieved excellence in higher education to international standards owing to its research and academic excellence.

About ICAR-National Bureau of Fish Genetic Resources

The ICAR-National Bureau of Fish Genetic Resources established in 1983 during the VI five-year plan, is a research institute under the Indian Council of Agricultural Research (ICAR), Department of Agricultural Research and Education (DARE), in the Ministry of Agriculture and Farmers Welfare, Govt. of India to undertake research related to the conservation of fish germplasm resources of the country. Mandated with exploration, cataloguing, characterizing, and conserving the fish genetic resources of the country, the Bureau is headquartered at Lucknow, with the research centre at Kochi, Kerala and an Aquaculture Research and Training unit at Chinhat at Lucknow, Uttar Pradesh. Research Centre at Kochi, Kerala were established for carrying out research activities about characterization and conservation of marine and brackishwater fish germplasm, besides the endemic species of the Western Ghats. Another Unit for Aquaculture Research and Training is located at Chinhat, Lucknow with the focus to impart training to the farmers and the line department personnel on sustainable fish production and conservation. The Institute's vision is assessment and conservation of fish genetic resources for intellectual property protection, sustainable utilization, and posterity.

The institute has made pioneering efforts to emerge as the Centre of Excellence in cataloguing and conserving aquatic resources of India. Research achievements in the areas of Genomic resource development, identifying genetic stocks of prioritized commercially/culture important aquatic species, Development of databases on genetic resources, in situ conservation, Live germplasm resource centers, ex situ conservation, Sperm cryopreservation and cell line repository and Aquatic animal diseases diagnostics and surveillance are remarkable. Institute is also giving immense importance for capacity building in cutting-edge research areas on conservation.

The ICAR-National Bureau of Fish Genetic Resources has been certified as an ISO 9001:2008 organization. To facilitate the research, the major facilities are created, such as Automated DNA sequencing and genotyping system, Bacterial Identification System, GIS Remote Sensing, Real Time PCR, DNA and protein electrophoresis facility, Automated Nucleic Acid Extraction system, Fluorescent microscope, programmable bio-freezers and cryo-preservation facility. In order to accelerate the computational applications, the High-Performance Computing System is installed at the Institute under National Bioinformatics Grid of ICAR for fishery domain. The Department of Biotechnology (DBT) has identified Bureau as the National Fish Cell Line Repository. The institute has one of the largest and finely architecture Public Aquarium’s of the country, named 'Ganga Aquarium' and National Fish Museum is being established for holding germplasm collections, voucher specimens, tissue and cell lines repositories and gene banking. ICAR-NBFGR is also entrusted by the Council to develop strategies and programmes for registering genetic stocks and elite germplasm of potentially cultivable fish species, both from natural populations and domesticated sources in line with plants and animals.

About Centre for Climate Change Studies (CCCS)

The **Centre for Climate Change Studies (CCCS)** was established in the January 2014 at International Research Centre (IRC) with the primary mandate of investigating the impact of predicted climate change on marine organisms associated to various ecosystems like coral reefs, seagrass meadows, seaweeds, intertidal zones and mangrove ecosystems etc.

At present, in the CCCS, the following research activities are going-on: (i) Implications of climate change on natural life history traits of coral reef caridean shrimps; (ii) Response of micro-planktons to elevated temperature and decreased pH using multidisciplinary approach including proteomics, biochemical and physiological assays; (iii) Contribution of seaweeds towards sustainable future by playing a role in climate change mitigation and adaptation; (iv) Diversity and status of coral reef shrimps in Gulf of Mannar Biosphere Reserve, Tamil Nadu and Lakshadweep and (iv) Plant-insect interaction under climate change scenario. Besides, the Centre is also instrumental in spreading awareness about conservation of marine ecosystem to schools and teachers through citizen science program.

Researchers at CCCS have been actively working at Sathyabama Marine Research Station (SMRS), recently established at Rameswaram to encourage research on cutting-edge marine ecology and climate change to sustainably use, manage, and conserve natural ecosystems for the benefit of the coastal communities of Gulf of Mannar and Palk Bay regions.

About Marine Biology Research Symposium – MBRS 2021

The ongoing COVID-19 pandemic has brought a new social and academic distancing to researchers worldwide. Our Marine Biology research has been impacted in several ways from cancellation or postponement of laboratory experiments, field surveys and research expeditions. It makes sense for us to our research keep it front and center. Being a young researcher, we have a time-sensitive academic path, and the current pandemic may affect our research career. At the same time, the pandemic has challenged and demanded us to revise the research strategies to manage the current difficulties as well as to overcome similar bottlenecks in the future.

In view of the above, the First National Virtual Event ***"Marine Biology Research Symposium"*** mainly focuses in bringing budding Marine Biology enthusiasts and researchers all over India and rest of the world to share their research ideas, meet with subject experts, and discuss collaborations in the cutting-edge research themes. The main aim of this symposium is to provide platform to gain new experience, to interact with experts from diverse disciplines and to build the network of like-minded people for Marine Biology Research in India.

The agenda of the symposium were designated under FIVE thematic areas:

- Taxonomy, Biodiversity and Conservation (Code: TBC)
- Blue Carbon and Coastal Ecosystems (Code: BCCE)
- Marine Pollution and Climate Change (Code: MPCC)
- Marine Microbial Ecology & Bioprospecting (Code: MMEB)
- Coastal and Ornamental Aquaculture (Code: COA)

The symposium features eminent keynote speakers under the above areas followed by presentation by students, and researchers all over the country and rest of the world.

LIST OF KEYNOTE SPEAKERS

Dr. Peter Ng, Professor
National University of Singapore, Singapore
Topic: *"Systema Brachyurorom: 12 years of seismic changes and what more surprises can be expected"*

Dr. Biju Kumar, Professor
University of Kerala, Trivandrum
Topic: *"Research gaps in Taxonomy"*

Dr. S. Ajmal Khan, Honorary Professor
CAS in Marine Biology, Annamalai University.
Topic: *"Coastal and Marine Ecosystems"*

Dr. Kakoli Banerjee, Professor
Central University of Odisha
Topic: *"Scope and Potential of Coastal Blue Carbon"*

Dr. Haimanti Biswas, Principal Scientist
National Institute of Oceanography, Goa
Topic: *"Marine Pollution and its Impact on Marine Organisms"*

Dr. K. Sivakumar, Scientist F
Wildlife Institute of India
Topic: *"Marine Mammal Conservation"*

Dr. Sam Dupont, Professor
University of Gothenburg, Sweden
Topic: *"Impact of Ocean Acidification on Marine Organisms"*

Dr. Vindhya Mohindra, Principal Scientist and Head
ICAR-NBFGR, Lucknow
Topic: *"Marine Genomics and Fish Conservation"*

Dr. Joseph Selvin, Professor
Department of Microbiology, Pondicherry University
Topic: *"Marine Microbiology and Bioprospecting"*

Dr. C. Raghunathan, Director (i/c)
Zoological Survey of India, Kolkata
Topic: *"Marine Biodiversity"*

Dr. Ricardo Calado, Principal Investigator
CESAM, University of Aveiro, Portugal
Topic: *"Marine Ornamental Aquaculture"*

Dr. Divya, P. R., Senior Scientist
ICAR-NBFGR, Kochi
Topic: *"Intra-specific genetic diversity for management of marine genetic resources"*

Dr. Kailasam, Principal Scientist
Central Institute of Brackishwater Aquaculture
Topic: *"Brackish water finfish seed production and culture practices - a step towards sustainability"*

Dr. S. Prakash, Scientist
Centre for Climate Change Studies, Sathyabama
Topic: *"Physiological response of intertidal organism to OA"*

Dr. Amit Kumar, Scientist
Centre for Climate Change Studies, Sathyabama
Topic: *"Unveiling bacterial diversity in the hypersaline environment and their potential biotechnological applications"*

Dr. Azad, I.S., Professor
Kuwait Institute of Scientific Research
Topic: *"Endocrine Disrupting Chemicals (EDCs) in Domestic Wastes Influence Fish Health -An Overview"*

PROGRAM SCHEDULE

Day – 1: 26 July 2021

09.30 AM – 09.40 AM – Greetings and Welcome Address (Dr. S. Prakash)

09.40 AM – 09.50 AM – About the Conference (Dr. Amit Kumar)

09.50 AM – 10.00 AM – Presidential Addresses (Dr. T. Sasipraba, Vice Chancellor)

10.00 AM – 10.15 AM – Inaugural Address – Dr. Kripa, Member Secretary, Coastal Aquaculture Authority, Chennai

10.15 AM – 10.25 AM – Special address – Dr Kuldeep K. Lal, Director, NBFGR

10.25 AM – 10.30 AM – Vote of thanks – Dr. Divya, P. R., Principal Scientist, NBFGR

SESSION 1 – Taxonomy, Biodiversity and Conservation (Code: TBC)

10.30 AM – 11.30 AM - 1st invited Talk - Dr. Peter Ng, Professor, National University of Singapore - ***"Systema Brachyurorom: 12 years of seismic changes and what more surprises can be expected"***

11.30 AM – 11.45 AM – BREAK

11.45 AM – 12.30 PM – 2nd invited Talk – Dr. Biju Kumar, Professor, University of Kerala, Trivandrum – ***"Research gaps in Taxonomy***"

12.30 PM – 13.30 PM – **ORAL AND POSTER PRESENTATION** (Code: TBC – Judge: Dr. Biju Kumar, Moderator: S. Prakash).

13.30 PM – 14.00 PM – BREAK

14.00 PM – 15.30 PM - **ORAL AND POSTER PRESENTATION** (Code: TBC –Moderator: S. Prakash and Dr. Amit Kumar)

DAY – 2: 27 July 2021

SESSION 2 – Blue Carbon and Coastal Ecosystems (Code: BCCE)

9.30 AM – 10.15 PM – 3rd Invited Talk – Dr. C. Raghunathan, Director (i/c), Zoological Survey of India – ***"Marine Biodiversity"***

10.15 AM – 11.00 AM – 4th Invited Talk – Dr. Ajmal Khan, Honorary Professor, CAS in Marine Biology, Annamalai University – ***"Coastal and Marine Ecosystems"***

11.00 AM – 11.15 AM – BREAK

11.15 AM – 12.00 PM – 5th Invited Talk – Dr Kakoli Banerjee, Professor, Central University of Odisha – ***"Scope and potential of coastal blue carbon"***

12.00 PM – 13.30 PM – **ORAL AND POSTER PRESENTATION** – (Code: BCCE – Judges: Dr. S. Ajmal Khan and Dr. Kakoli Banerjee. Moderator: Dr. Amit Kumar)

DAY - 3: 28 July 2021

SESSION 3 – Marine Pollution and Climate Change (Code: MPCC)

9.30 AM – 10.15 AM – 6th Invited Talk – Dr. K. Sivakumar, Scientist F, Wildlife Institute of India – ***"Marine Mammal Conservation"***

10.15 AM – 11.00 AM – 7th Invited Talk – Dr. Haimanti Biswas, Principal Scientist, National Institute of Oceanography – ***"Climate Change and Marine Pollution"***

11.00 AM – 11.15 AM – BREAK

11:15 AM – 13.00 PM – **ORAL/POSTER PRESENTATION** – (Code: MPCC – Judges: Dr. K. Sivakumar and Dr. Haimanti Biswas. Moderator: S. Prakash)

13.00 PM – 13.30 PM – BREAK

13.30 PM – 14.30 PM - 8th Invited Talk – Dr. Sam Dupont, Professor, University of Gothenburg, Sweden – ***"Impact of ocean acidification on marine organisms"***

14.30 PM – 15.00 PM – Dr. S. Prakash, Scientist, Centre for Climate Change Studies – ***"Physiological response of intertidal organisms to ocean acidification"***

DAY – 4: 29 July 2021

SESSION 4 – Marine Molecular Ecology and Bioprospecting (Code: MMEB)

09.30 AM – 10:15 AM – 9th Invited Talk – Dr. Vindhya Mohindra, Principal Scientist, NBFGR – ***"Marine Genomics and Fish Conservation"***

10:15 AM – 11.00 AM – 10th Invited Talk – Dr. Joseph Selvin, Professor and Head, Pondicherry University – ***"Metagenomic approaches on the exploration marine microbes"***

11.00 AM – 11.15 AM - BREAK

11.15 AM – 13.00 PM – **ORAL AND POSTER PRESENTATION** (Judges: Dr. Vindhya Mohindra, Dr. Joseph Selvin, Moderator: Dr. Amit Kumar)

13.00 AM – 13.30 PM – BREAK

13.30 PM – 14.15 PM – 11th Invited Talk - Dr. Divya, P. R., Senior Scientist, ICAR-NBFGR – ***"Intra-specific genetic diversity for management of marine genetic resources"***

14.15 PM – 14.45 PM – Dr. Amit Kumar, Scientist, Centre for Climate Change Studies, Sathyabama – "***Unveiling bacterial diversity in the hypersaline environment and their potential biotechnological applications"***

DAY – 5: 30 July 2021

SESSION 5 – Coastal and Ornamental Aquaculture (Code: COA)

09.30 AM – 10.15 AM – 12th Invited Talk – Dr. M. Kailasam, Principal Scientist, Central Institute of Brackishwater Aquaculture - ***"Brackish water finfish seed production and culture practices - a step towards sustainability"***

10.15 AM – 11.00 AM – **ORAL AND POSTER PRESENTATION** (Judges: Dr. M. Kailasam and Dr. A. Kathirvelpandian, NBFGR, Moderator: Dr. S. Prakash)

11.00 AM – 11.15 AM - BREAK

11.15 AM – 13.00 PM – **ORAL AND POSTER PRESENTATION** (Judges: Dr. A. Kathirvelpandian, NBFGR, and Dr. T. Rajaswaminathan, NBFGR. Moderator: Dr. S. Prakash)

13.00 PM – 13.30 PM – BREAK

13.30 PM – 14.30 PM – Dr. R. Calado, Principal Investigator, CESAM, University of Aveiro, Portugal – ***"Marine Ornamental Aquaculture"***

14.30 PM – 15.15 PM – 14th Invited talk – Dr. Azad, I. S. Professor - Kuwait Institute of Scientific Research – ***"Endocrine Disrupting Chemicals (EDCs) in Domestic Wastes Influence Fish Health -An Overview"***

15.15 PM – 15.30 PM – Valedictory Session, Prize Distribution and Vote of Thanks.

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LIST OF FULL-LENGTH ARTICLES

SESSION 1: Taxonomy, Biodiversity and Conservation (Code: TBC)

TBC- 107- 0R

Gastropod Shell Utilization Pattern of *Clibanarius ransoni* Forest, 1953 in the Rocky Intertidal Zone of Saurashtra Coast, Gujarat state, India

Krupal J. Patel[1], Pooja R. Patel[2] and Jigneshkumar N. Trivedi[2,]*

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Abstract

The present work was aimed to study gastropod shell utilization pattern of *Clibanarius ransoni*. Specimens of *C. ransoni* were collected using hand picking method in the months of February, March and December, 2020 from the rocky shores of Veraval, Gujarat state, India. The specimens were categorized in three groups *viz* male, non-ovigerous female and ovigerous female. The specimens were weighed and their size (shield length) was measured. The gastropod shells occupied by *C. ransoni* individuals were identified up to species level. Various morphological characters of occupied shells such as shell length, shell aperture length and width, shell volume and shell dry weight were measured. Total 1200 individuals of *C. ransoni* were collected (546 males, 369 non-ovigerous females and 285 ovigerous females), occupying 28 different species of gastropod shells. Amongst, all the shell species, *Cerithium caeruleum* was highly occupied by the *C. ransoni* followed by *Lunella coronata*, *Turbo bruneus*, *Tenguella granulate* and *Pollia undosa*. Male and non-ovigerous female of *C. ransoni* utilized a wide range of shell species, while ovigerous female used only few shell species. Malesof*C. ransoni* were significantly larger in size than non-ovigerous female and ovigerous females. Significant correlations were observed between various morphological characters of *C. ransoni* and occupiedshells. According to studies, *C. caeruleum* occurs in high abundance as compared to other gastropod species in the study area. The present study revealedshell occupation pattern of *C. ransoni* is highly influenced by diversity, morphology and availability of gastropod shells in the study area.

Key words: Gastropod diversity, Shell availability, Shell occupation, Rocky shore, Gujarat

Introduction

Hermit crabs have adapted to occupy empty scavenged mollusc shells and pseudoshells to protect their non-calcified pleon (Schejter and Mantelatto, 2011; Schejter *et al*., 2017). Hermit crabs are known for occupying either empty shells or by removing the gastropod from the shell (Elwood and Neil, 1992). Empty gastropod shells provide 'portable refugia' to the inhibiting hermit crab into which they can retract when threatened (Bertness, 1982). The shell also provides them protection from various physical stress like temperature, osmotic stress and wave action (Reese, 1969). Hermit crabs require a series of shells in increasing size during its growth period, but before occupying a new shell, they perform evaluation process to assess the suitability of the shell which includes assessing the shell for its condition, species, size, aperture width and internal volume of the shell (Elwood & Neil, 1992; Biagi *et al*., 2006). Almost every aspect of the biology of hermit crab is governed by the shells of gastropod occupied by it including body morphology, reproduction and population dynamics (Bertness, 1981; Turra and Leite, 2002; Argüelles *et al*., 2010). For instance, a heavier and robust shell may provide better protection from predation and wave action (Hahn, 1998) but it also reduces reproductive success and increase energy consumption from locomotion (Argüelles *et al*., 2009). During its growth period, hermit crab constantly requires larger shells keeping them continually in search of suitable shells (Bertness, 1981).

Gujarat is the westernmost state of India with the coastline of ~1650 km which is divided into three major coastal regions *viz.* the Gulf of Kachchh, the Gulf of Khambhat and the Saurashtra coast (Trivedi *et al*., 2015). From the marine waters of Gujarat total 18 species (4 genera, 2 families) of hermit crabs are reported (Trivedi and Vachhrajani, 2017; Patel *et al*., 2020a). Majority of the studies are conducted on the taxonomy of hermit crabs and ecological studies are scanty. Ecological studies are mostly conducted on *C. zebra* (Dana, 1852) which includes the effect of abiotic and biotic factors on populations (Desai and Mansuri, 1989), intertidal distribution (Vaghela and Kundu, 2012), and shell utilization patterns (Trivedi and Vachhrajani, 2014). Recently studies have been conducted on the shell utilization pattern of *C. rhabdodactylus* (Patel *et al*., 2020c; Thacker *et al*., 2021) and *Diogenes custos* (Fabricius, 1798) (Patel *et al*., 2020b). *Clibanarius ransoni* is a hermit crab species found on intertidal regions of Tahiti (Forest, 1953), Vietnam (Fize and Serène, 1955), Indonesia (Rahayu and Forest,1993), Singapore and French Polynesia (Rahayu, 1996), Thailand (Rahayu and Komai, 2000),Taiwan (Mclaughlin *et al*., 2007) and India (Patel *et al*., 2020a).The ecological aspects of this species are not studied yet, hence, present study was carried out to understand the ecology of *C. ransoni* on rocky shores of the Saurashtra coast, Gujarat State.The aim of the study is to find out gastropod shell utilization and to analyse the relationship between the morphology of *C. ransoni* and different morphological parameters of gastropod shells utilized by the species.

Materials and Methods

Study area

The present study was conducted in the rocky intertidal zone of Veraval (20°54'37"N, 70°21'04"E) (Fig. 1) located on the Saurashtra coast. The width of the exposed rocky intertidal zone during low tide varies from 60 to 150 m. *Clibanarius ransoni* occurs in high abundance on the rocky shores of the study site where it occupies rock crevices and shallow tide pools found in the upper and middle intertidal zone (Patel *et al*., unpublished data).

Sampling method

Clibanarius ransoni specimens were collected randomly during low tide in the month month of February, March and December, 2020. Collected specimens were kept in an ice box and brought to the laboratory for further analysis. Hermit crabs were removed from their shells by

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gently twisting the crab against the direction of the shell spiral and only intact individuals were used for the study. The gender of each individual was identified using a stereo microscope (Metlab PST 901) and further categorized into male, non-ovigerous female and ovigerous female.

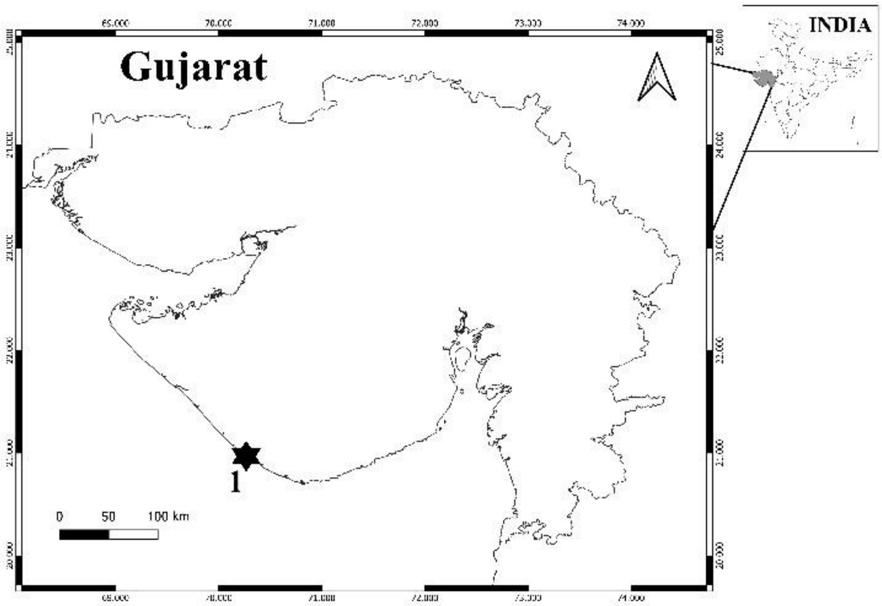

Fig. 1: Map of study area. 1. Veraval, Saurashtra coast, Gujarat, India.

Female individuals canbe identified by the presence of gonopores on the ventral part of the first segment of second pair of walking legs, while male individuals do not have such structure. Ovigerous females are the berried females carrying eggs. Two morphological characteristics, hermit crab weight (HW) (0.01 g) using a digital weighing scale and shield length (0.01 mm) (from the midpoint of the rostrum to the midpoint of the posterior margin of the shield) using vernier callipers were measured for the sampled hermit crabs. Hermit crabs were sorted into different size classes on the basis of their shield length (SL). The emptied gastropod shells were identified to species level using a monograph by Apte (2014). Gastropod shells were analyzed to quantify data on five different morphological characters such as, shell total length (SHL) shell aperture length (SAL); shell aperture width (SAW), shell dry weight (DW) and shell volume (SHV). For DW, the shells were dried in a laboratory oven at 60 °C for 24 h and weighed (Argüelles *et al*., 2010). For SHV, the empty shells were filled with water using a syringe (0.1 ml) to the edge of the aperture and the total volume of waterfilled is considered as the shell volume (mm^3).

The morphological variables of gastropod shell and hermit crabs were correlated using Regression analysis to find out the relationship between them (Sant'Anna *et al*., 2006). Variation in mean values of shield length of different sexes of hermit crab was analysed using a one-way ANOVA at 5% significance level. The shell species occupation rate was estimated as apercentage and the Chi square test (χ^2) was used to compare the occupancy rates of different shell species at a 5% significance level.

Results

A total of 1200 individuals of *C. ransoni* were collected during the study period out of which 546 specimens were males (45.5 %), 369 were non-ovigerous female (30.75 %) and 285 were ovigerous female (23.75 %). The average size of male individuals of *C. ransoni* was significantly larger than females (F=388.51, df= 1199, p<0.001) (Table 1).

Table 1: Carapace shield length values of *Clibanarius ransoni*. (SL= Shieldlength)

Sex	Minimum (SL)(mm)	Maximum (SL)(mm)	SL (mm)
Male	1.92	8.71	4.39 ± 1.22
Non-ovigerous female	1.42	6.64	3.45 ± 0.75
Ovigerous female	1.32	5.63	3.74 ± 0.49

Male individuals were recorded in all size classes (1.0 to 9.0 mm SL) with maximum number of individuals recorded from 4.0 to 5.0 mm SL size classes. The individuals of non-ovigerous females and ovigerous females were recorded from 2.0 to 5.0mm SL size classes with maximum number of individuals recorded from 3.0 to 4.0 mm SL size class (Fig. 2).

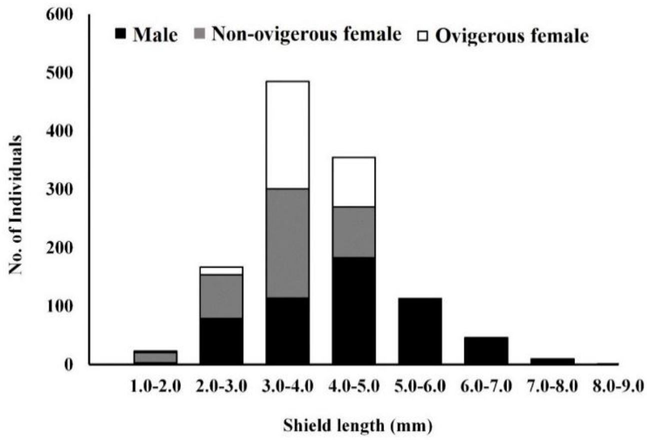

Fig. 2: Size frequency distribution of different individuals (males, non-ovigerous females andovigerous females) of *Clibanarius ransoni*.

In the present study, the individuals of *C. ransoni* were found occupying 28 species of gastropod shells, amongst them five species of gastropod shells were highly occupied by *C. ransoni*. *Cerithium caeruleum* (51.58 %) was the highly occupied gastropod species followed by *Lunella coronata* (10 %), *Turbo bruneus* (6.66 %), *Tenguella granulata* (4.83%) and *Pollia undosa* (4.25 %). The remaining gastropod species (termed as "others") contributed 22.68 % of total gastropod shell occupation while their occupation percentage varied from 0.08 % to 2.33 % (Table 2). The variation in percentage occupation of these six species of gastropod varied significantly ($\square^2$= 15.72, p<0.0001). Percentage occupation of these six highly occupied gastropod shell species also varied significantly between different sexes of *C. ransoni* (male, $\square^2$ =8.33, p <0.01; non-ovigerous female, $\square^2$ =17.01, p <0.0001; ovigerous female, $\square^2$= 40.41, p <0.0001).

Table 2: Gastropod shell utilization by *Clibanarius ransoni* (N= total individuals; M = Male; F = Non-ovigerous female; OF= Ovigerous female).

Gastropod species	N	%	M	%	F	%	O	%
Cerithium caeruleum G.B. Sowerby II, 1855	619	51.58	153	28.02	237	64.22	229	80.35
Lunella coronata (Gmelin,1791)	120	10	109	19.96	11	2.98	0	0
Turbo bruneus (Röding, 1798)	80	6.66	68	12.45	11	2.98	1	0.35
Tenguella granulata (Duclos, 1832)	58	4.83	13	2.38	17	4.60	28	9.82
Pollia undosa (Linnaeus, 1758)	51	4.25	38	6.95	12	3.25	1	0.35
Others	**218**	**22.68**	**165**	**30.24**	**81**	**21.97**	**26**	**9.13**
Anachis terpsichore (G. B. Sowerby II, 1822)	10	0.83	0	0	10	2.71	0	0
Astralium stellare (Gmelin, 1791)	34	2.83	19	3.47	13	3.52	2	0.70
Cantharus spiralis (Gray, 1839)	10	0.83	8	1.46	1	0.27	1	0.35
Cerithideopsilla cingulata (Gmelin,1971)	7	0.58	2	0.36	5	1.35	0	0
Ergalatax contracta (Reeve, 1846)	5	0.41	0	0	2	0.54	3	1.05
Chicoreus bruneus (Link, 1807)	28	2.33	28	5.12	0	0	0	0
Chicoreus maurus (Broderip, 1833)	15	1.25	13	2.38	0	0	2	0.70
Nassarius pullus (Linnaeus,1758)	1	0.08	0	0	1	0.27	0	0
Euchelus asper (Gmelin, 1791)	21	1.75	13	2.38	8	2.16	0	0
Gyrineum natator (Röding, 1798)	9	0.75	8	1.46	1	0.27	0	0
Indothais lacera (Born,1778)	6	0.5	3	0.54	2	0.54	1	0.35
Indothais sacellum (Gmelin, 1791)	22	1.83	12	2.19	4	1.08	6	2.10
Morula uva (Röding, 1798)	9	0.75	4	0.73	4	1.08	1	0.35
Monodata australis (Lamarck, 1822)	7	0.58	6	1.09	1	0.27	0	0
Nerita oryzarum Recluz, 1841	7	0.58	7	1.28	0	0	0	0
Nassarius reeveanus (Dunker, 1847)	2	0.16	1	0.18	1	0.27	0	0
Natica picta (Recluz,1844)	4	0.33	1	0.18	3	0.81	0	0
Orania subnodulosa (Melvill,1893)	8	0.66	3	0.54	2	0.54	3	1.05
Pollia rubiginosa (Reeve, 1846)	13	1.08	2	0.36	8	2.16	3	1.05
Purpura panama (Röding, 1798)	28	2.33	25	4.57	3	0.81	0	0
Semiricinula tissoti (Petit de la Saussaye, 1852)	19	1.58	3	0.54	12	3.25	4	1.40
Tibia insulaechorab Röding, 1798	2	0.16	2	0.36	0	0	0	0
Chicoreus virgineus (Röding, 1798)	5	0.41	5	0.91	0	0	0	0
TOTAL	**1200**		**546**		**369**		**285**	

Cerithium caeruleum shells were utilized by *C. ransoni* individuals recorded in size classes ranging from 1.0 to 7.0 mm SL with maximum utilization recorded in size classes 3.0–4.0 mm SL. *Lunella coronata* and *T. bruneus* shells were also commonly utilized by *C. ransoni* individuals recorded in size classes ranging from 2.0 to 8.0 mm SL with maximum utilization recorded in size classes 4.0–5.0 mm and 2.0–3.0 mm SL, respectively. *Tenguella granulate* and *P. undosa* shells were also commonly utilized by larger *C. ransoni* individuals recorded in size classes ranging from 2.0 to 6.0 mm SL with maximum utilization recorded in size classes 3.0–4.0 mm and 4.0–5.0 mm SL, respectively. Gastropod species belonging to "others" gastropod species were widely utilized by the specimens belonging to all size classes (Fig. 3).

Regression analysis carried out between different morphological variables of *C. ransoni* and gastropod shells showed significant relationships. *C. ransoni* shield length showed significant relationship with all morphological parameters of gastropod shell. Maximum values of relationship were observed for shell aperture length, dry weight and volume (Fig. 4).

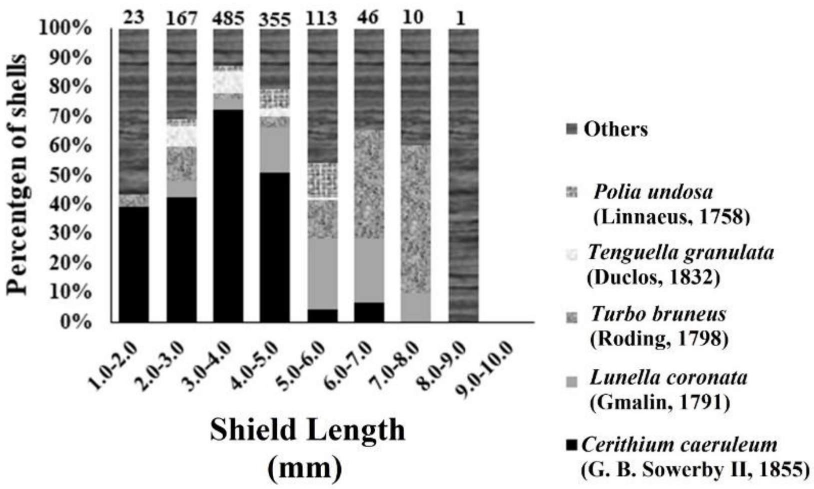

Figure 3: Use of gastropod shell species by individuals of *Clibanariusransoni*of different size classes. (Numbers above the bar indicates number of individuals)

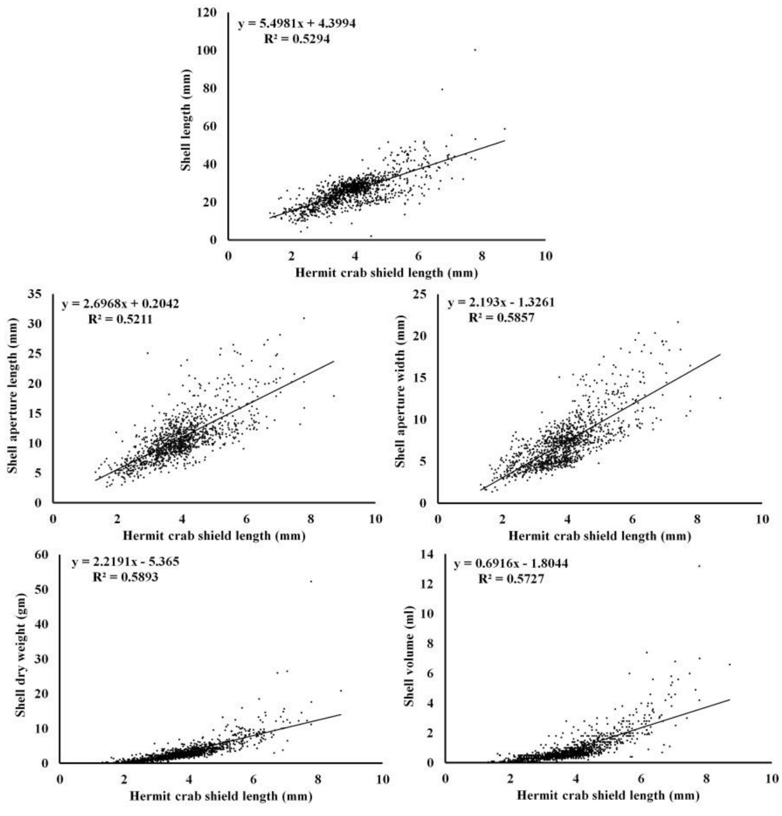

Fig. 4: Regression analysis between different morphological factors of gastropod shells and *Clibanarius ransoni* shield length (mm)

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Clibanarius ransoni wet weight showed significant relationship with shell length, shell dry weight and shell volume. *Clibanarius ransoni* wet weight showed maximum values of relationship with shell dry weight and volume (Fig. 5).

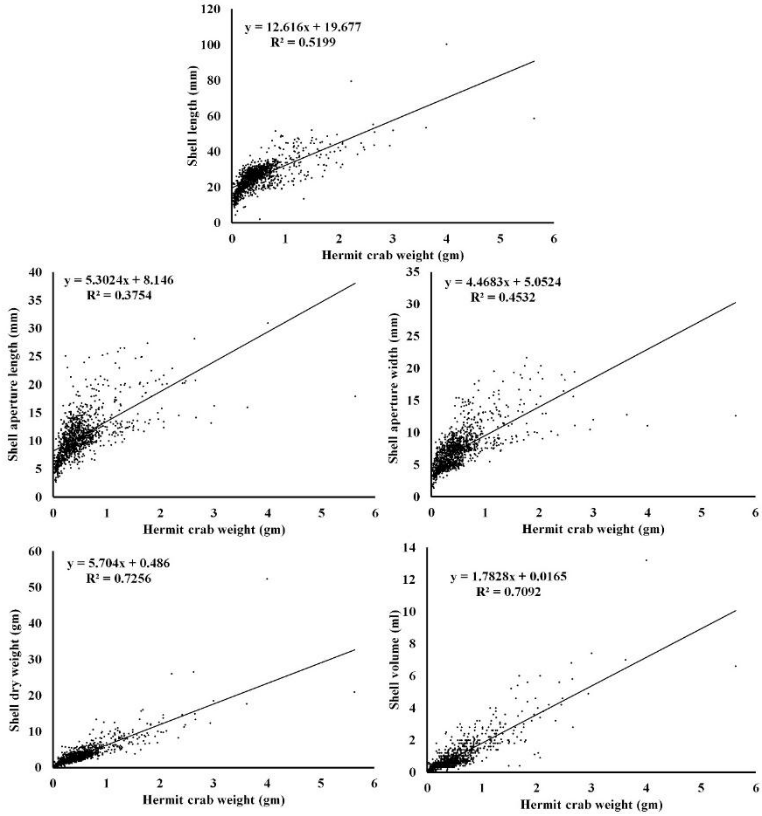

Fig. 5: Regression analysis between different morphological factors of gastropod shells and *Clibanarius ransoni* weight (gm).

Discussion

Hermit crabs are ecologically very important and easily recognizable invertebrates inhabiting intertidal and sub-tidal habitats (Schembri, 1982). They show unique adaptation by occupying empty gastropod shells primarily for the purpose of protection of their non-calcified abdomen from various factors like predation (Elwood *et al.*, 1995), mechanical damage by wave action (Reese, 1969) and desiccation (Bertness and Cunningham 1981). In present study, 28 species of gastropod shell were found to be occupied by *C. ransoni* which is quite higher as compared to gastropod species occupied by other species like *C. vittatus* (13 species) (Sant'anna *et al*., 2006), *C. virescens* (17 species) (Wait and Schoeman, 2012), *C. erythropus* (11 species) (Fatma *et al*., 2015) and *C. zebra* (23 species) (Trivedi and Vachhrajani, 2014). It was also observed that male individuals have occupied 25 species of gastropod shells and non-ovigerous female individuals occupied 23 species however ovigerous females have occupied only 14 species of gastropod shells. Similar results were observed for the ovigerous females of *C. vittatus* (Sant'Anna *et al*., 2006), *Isocheles sawayai* (Fantucci *et al*., 2008) and *C. zebra* (Trivedi and Vachhrajani, 2014) suggesting that ovigerous females are selective for specific shells which are having larger internal volume that is suitable for the accommodation and incubation of eggs (Abram, 1978; Bertness, 1981).

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The morphology of hermit crab (SL and HW), have shown strong relationship with the different morphological parameters of gastropod shells occupied by them. In the present study regression analysis was carried out between morphological parameters of hermit crab and gastropod shell, where the SL of *C. ransoni* showed high correlation with SAW, DW and SHV. Also, the HW of *C. ransoni* individuals showed significantly high correlation with DW and SHV. Similar results were also observed for other hermit crab species like *C. erythropus* (Botelho and Costa, 2000; Caruso and Chemello, 2009), *Paguristes tortugae* (Mantelatto and Dominciano, 2002), *Pagurus exilis* (Mantelatto *et al*., 2007) and *C. latens* and *C. signatus* (Ismail, 2010). Studies suggest that heavy and robust shell occupied by the hermit crab protects it from wave action and predatory attack (Reese, 1969), while shell volume is an important factor for the ovigerous females in order to accommodate its body as well as egg mass (Lancaster, 1988). The aperture width of gastropod is an important morphological character as the shell aperture is the only way for the enter and exit of the hermit crab from the shell (Sant'Anna *et al*., 2006; Ismail, 2010; Fatma *et al*., 2015). Therefore, it should be large enough to facilitate movement of the residential hermit crab to capture food and to get protection from predators.

In the present study it was found that the males were larger in body size (Table 1) as compared to non-ovigerous females and ovigerous females. Similar results were observed for other hermit crab species like, *C. symmetricus* (Rodrigues and Martinelli-Lemos, 2016) *C. virescens* (Imazu and Asakura, 1994), *Calcinus laevimanus*, *C. latens* and *Clibanarius humilis* (Nardone and Gherardi, 1997). It is generally observed that males occupy larger and robust shells as they utilize most of their energy in physical growth as a result, they can attain larger size which require larger shells. On the other hand, female occupies smaller shells as they have to spend a major part of their energy for the purpose of reproduction and egg development (Sant'Anna *et al.*, 2006; Mantelatto *et al.*, 2010) and hence they could not attain larger size as that of males. Ovigerous females are found to occupy larger and voluminous shells as compared to non-ovigerous females since they require more space for the accommodation and protection of egg mass from predators and desiccation (Fotheringham, 1976; Abrams, 1978; Mantelatto and Garcia, 2000).

It was observed that *Cerithium caeruleum* was the most preferred gastropod species by the individuals of *C. ransoni*, possibly due to high abundance of *C. caeruleum* (25 individual / 0.25m^2) in intertidal region of thestudy area (Patel *et al*., unpublished data). Similar pattern of shell preference has been observed for *C. antillensis* utilizing *Tegula viridula* (Floeter *et al*., 2000), *C. zebra* utilizing *C. scabridum* shell (Trivedi and Vachhrajani, 2014), *C. rhabdodactylus* utilizing *C. caeruleum* (Patel *et al*., 2020c) and *Diogenes custos* utilizing *Pollia undosa* shells (Patel *et al*., 2020b). It has been observed that the shell utilization preference of hermit crabs is affected by the availability and abundance of gastropod shells in habitat (Kellogg, 1976; Scully, 1979). It was also observed that the shells of *C. caeruleum* were occupied by almost all size class of *C. ransoni* suggesting high availability of the shell species in the study area. It was also observed that the smaller individuals of *C. ransoni* largely preferred *C. caeruleum* shells but as the size of the species increases, their preference shifts to the shells of *L. coronata*, *T. bruneus*, *T. granulata*, *P. undosa* and "other" gastropod shells. Such pattern of shell utilization suggests that there is high competition for optimum shells amongst the larger individuals of *C. ransoni*. The larger and stronger shells provide various benefits including protection from predators, desiccation, cannibalism, intra or inter specific fights and also protect the egg mass of ovigerous females (Lawal-Are *et al.*, 2010). Along with that, the shell utilization pattern by different sexes can also be strongly affected by various factors including individual size, reproductive status, growth and energy expenditure of individuals (Fotheringham, 1976; Bertness, 1981).

The current study provides first understanding to the ecological aspect of *C. ransoni* inhabiting rocky shores of the Saurashtra coast of Gujarat State. It has been observed that *C. ransoni* occupies wide variety of gastropod shells available in the habitat. The shell utilization pattern was highly dependent on the relationship between the morphology of hermit crab (SL and HW) and of the shell (SAW, DW and SHV). Difference in shell use pattern of different sexes was also observed which could be due to difference in their growth rates and reproductive success. The studies also suggests that the availability ofgastropod shell in the habitat have marked impact on the shell use pattern b the hermit crab species. Further studies on the intertidal distribution, population ecology and seasonal variation in the shell utilization patterns are required to provide detailed information about the ecology of *C. ransoni*.

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References

Abrams, P. (1978). Shell selection and utilization in a terrestrial hermit crab, *Coenobita compressus* (H. Milne Edwards). *Oecologia*, 34(2), 239–253.

Apte, D. (2014). *Sea Shells of India*. Bombay Natural History Society, Mumbai, India. 197 pp.

Argüelles, A., Álvarez, F., and Alcaraz, G. (2009). Shell architecture and its relation to shell occupation by the hermit crab *Clibanarius antillensis* under different wave action conditions. *Scientia Marina*, 73(4), 717–723.

Argüelles-Ticó, A., Álvarez, F. and Alcaraz, G. (2010). Shell utilization by the hermit crab *Clibanarius antillensis* Stimpson 1862 (Crustacea: Anomura) in intertidal rocky pools at Montepio, Veracruz, Mexico. *Tropical Zoology*, 23(1), 63–73.

Bertness, M. D. and Cunningham, C. (1981). Crab shell-crushing predation and gastropod architectural defence. *Journal of experimental marine biology and Ecology*, 50(2–3), 213–230.

Bertness, M. D. (1982). Shell utilization, predation pressure, and thermal stress in Panamanian hermit crabs: an interoceanic comparison. *Journal of Experimental Marine Biology and Ecology*, 64(2), 159–187.

Bertness, M.D. (1981). The influence of shell-type on hermit crab growth rate and clutch size (Decapoda, Anomura). *Crustaceana*, 197–205.

Biagi, R., Meireles, A. L., Scelzo, M. A. and Mantelatto, F. L. (2006). Comparative study of shell choice by the southern endemic hermit crab *Loxopagurus loxochelis* from Brazil and Argentina. *Revista Chilena de Historia Natural*, 79(4), 481–487.

Botelho, A. Z. and Costa, A. C. (2000). Shell occupancy of the intertidal hermit crab *Clibanarius erythropus* (Decapoda, Diogenidae) on Sao Miguel (Azores). *Hydrobilologia*, 440,111–117.

Caruso, T., and Chemello, R. (2009). The size and shape of shells used by hermit crabs: a multivariate analysis of *Clibanarius erythropus*. *Acta Oecologica*, 35(3), 349–354.

Desai, A. Y. and Mansuri, A. P. (1989). Salinity and desiccation tolerance of hermit crab of Veraval, West coast of India. *Indian Journal of Current Biosciences*, 8, 129–132.

Elwood, R. W. and Neil S. J. (1992). *Assessments and Decisions: a study of information gathering by hermit crabs*. London: Chapman & Hall, 203 pp.

Elwood, R. W., Marks, N. and Dick, J. T. A. (1995). Consequences of shell-species preferences for female reproductive success in the hermit crab *Pagurus bernhardus. Marine Biology*, 123(3), 431–434.

Fantucci, M. Z., Biagi, R. and Mantelatto, F. L. (2008). Shell occupation by the endemic western Atlantic hermit crab *Isochelessawayai*(Diogenidae) from Caraguatatuba, Brazil. *Brazilian Journal of Biology*, 68(4), 859–867.

Fatma El-Zahraa A. Abd El-Aziz, Khaleid F. Abd El-Wakeil, Ahmad H. Obuid-Allah, and Faraj O. R. (2015) Occupancy of gastropod shells by the hermit crab *Clibanarius erythropus* (Crustacea, Anomura) inhabiting the Mediterranean Sea coast of Libya. *International Journal of Advanced Research,* 3, 68–76.

Fize, A. andSerène, R. J. (1955). Les Pagures du Vietnam. *Institut Océanographique Nhatrang*, Note, 45, ix, 1–228.

Floeter, S. R., Nalesso, R. C., Rodrigues, M. M. P., and Turra, A. (2000). Patterns of shell utilization and selection in two sympatric hermit crabs (Anomura: Diogenidae) in south-eastern Brazil. *Journal of the Marine Biological Association of the United Kingdom*, 80(6), 1053–1059.

Forest, J. (1953). Crustacés Décapodes Marcheurs des îles de Tahiti et des Tuamotu. - I. Paguridea. *Bulletin du Muséum national d'Histoire naturelle, Paris*, 25, 441–450

Fotheringham, N. (1976). Hermit crab shells as a limiting resource (Decapoda, Paguridae). *Crustaceana*, 31(2), 193–199.

Hahn, D. R. (1998). Hermit crab shell use patterns: response to previous shell experience and to water flow. *Journal of Experimental Marine Biology and Ecology*, 228, 35−51.

Imazu, M., and Asakura, A. (1994). Distribution, reproduction and shell utilization patterns in three species of intertidal hermit crabs on a rocky shore on the Pacific coast of Japan. *Journal of Experimental Marine Biology and Ecology*, 184(1), 41–65.

Ismail, T. G. E. K. (2010). Distribution and shell selection by two hermit crabs in different habitats on Egyptian Red Sea Coast. *Acta Oecologica*, 36(3), 314– 324.

Kellogg, C.W. (1976). Gastropod shells: a potentially limiting resource for hermit crabs. *Journal of experimental marine Biology and Ecology*, 22(1), 101–111.

Lancester, I. (1988). Optimization in the life history of the hermit crab *Pagurus benhardus* (L). *Ph.D Thesis. University of Plymouth,* 192 pp.

Lawal-Are, A., Uwadiae, R. E. and Owolabi, O. R. (2010). Shell selection of the hermit crab *Clibanarius africanus* (Aurivillus,1898) (Decapoda: Diogenidae) in the Lagos lagoon: Aspects of behavioural and bio-ecology of benthos. *World Rural Observations*, 2, 70–78.

Mantelatto, F. L. M. and Dominciano, L. C. C. (2002). Pattern of shell utilization by the hermit crab *Paguristes tortugae* (Diogenidae) from Anchieta Island, Southern Brazil. *Scientia Marina*, 66(3), 265–272.

Mantelatto, F. L., Biagi, R. and Scelzo, A. L. M. M. A. (2007). Shell preference of the hermit crab *Pagurus exilis* (Anomura: Paguridae) from Brazil and Argentina: a comparative study. *Revista de Biología Tropical*, 55(1), 153–162.

Mantelatto, F. L., Fernandes-Góes, L. C., Fantucci, M. Z., Biagi, R., Pardo, L. M., and de Góes, J. M. (2010). A comparative study of population traits between two South American populations of the striped-legged hermit crab *Clibanarius vittatus. Acta Oecologica*, 36(1), 10–15.

Mantelatto, F.L.M. and Garcia, R.B. (2000). Shell utilization pattern of the hermit crab *Calcinus tibicen* (Diogenidae) from southern Brazil. *Journal of Crustacean Biology*,20(3), 460–467.

McLaughlin, P.A., Rahayu, D.L., Komai, T. and Chan T. Y. (2007). *A Catalogue of the Hermit Crabs (Paguroidea) of Taiwan. Keelung*. National Taiwan Ocean University, 365 pp.

Nardone, F., and Gherardi, F. (1997). The question of coexistence in hermit crabs: population ecology of a tropical intertidal assemblage. *Crustaceana*, 70(5), 608–629.

Patel, D. M., Patel, K. J., Patel, P. R., and Trivedi, J. N. (2020b). Shell utilization pattern by the hermit crab *Diogenes custos* (Fabricius, 1798) along Gulf of Kachchh, Gujarat, India. *Journal of Biological Studies*, 3(2), 79–95.

Patel, P. R., Patel, K. J., Vachhrajani K. D., and Trivedi, J. N. (2020c). Shell utilization pattern of the Hermit crab *Clibanarius rhabdodactylus* Forest, 1953 on rocky shores of the Saurashtra coast, Gujarat State, India. *Journal of Animal Diversity*, 2(4): 33–43.

Patel, P., Patel, K. and Trivedi, J. (2020a). First record of Hermit crab *Clibanarius ransoni* Forest, 1953 (Crustacea: Anomura: Diogenidae) from India. *Journal of Biological Studies*, *3*(1), 19–23.

Rahayu, D.L. and Forest, J. (1993). Le genre *Clibanarius* (Crustacea, Decapoda, Diogenidae) en Indonésie, avec la description de six espèces nouvelles. *Bulletin du Muséum national d'Histoire naturelle, Paris*, 14, 745–779.

Rahayu, D.L. and Komai, T. (2000). Shallow-water hermit crabs (Crustacea: Decapoda: Anomura: Diogenidae and Paguridae) of Phuket, Thailand. Phuket. *Marine Biological Centre Research Bulletin*, 63, 21–44.

Rahayu, D.L. (1996). Notes on littoral hermit crabs (excluding Coenobitidae) (Crustacea: Decapoda: Anomura) mainly from Singapore and peninsular Malaysia. *The Raffles Bulletin of Zoology*, 44, 335–355.

Reese, E. S. (1969). Behavioral adaptations of intertidal hermit crabs. *American Zoologist*,9,343–355.

Rodrigues, A. C. M. and Martinelli-Lemos, J. M. (2016). Gastropod shell utilisation pattern by the hermit crab *Clibanarius symmetricus* (Anomura: Diogenidae) in an Equatorial Amazon estuary. *Journal of Natural History*, 50(41–42), 2657–2671.

Sant'Anna, B. S., Zangrande, C. M., Reigada, A. L. and Pinheiro, M. A. (2006). Shell utilization pattern of the hermit crab *Clibanarius vittatus* (Crustacea, Anomura) in an estuary at São Vicente, State of São Paulo, Brazil. Iheringia. *Série Zoologia*, 96(2), 261–266.

Schejter L, Mantelatto FL. (2011). Shelter association between the hermit crab *Sympagurus dimorphus* and the zoanthid *Epizoanthus paguricola* in the southwestern Atlantic Ocean. Acta Zoologica, 92(2), 141–149.

Schejter, L., Scelzo, M. A., and Mantelatto, F. L. (2017). Reproductive features of the deep water hermit crab *Sympagurus dimorphus* (Anomura: Parapaguridae) inhabiting pseudoshells in the SW Atlantic Ocean. *Journal of Natural History*, 1–14.

Schembri, P. J. (1982). Feeding behaviour of fifteen species of hermit crabs (Crustacea: Decapoda: Anomura) from the Otago region, southeastern New Zealand. *Journal of Natural History*, 16(6), 859–878.

Scully, E.P. (1979). The effects of gastropod shell availability and habitat characteristics on shell utilization by the intertidal hermit crab *Pagurus longicarpus* Say. *Journal of Experimental Marine Biology and Ecology*,37(2), 139–152.

Thacker, D. R., Patel, K. J., Patel, P. R., and Trivedi, J. N. (2021). Gastropod shell occupation pattern of hermit crab *Clibanarius rhabdodactylus* Forest, 1953 in the infralittoral zone of Gulf of Kachchh, Gujarat, India. *Uttar Pradesh Journal of Zoology*, 42(5), 20–31.

Trivedi, D.J. Trivedi, J.N., Soni, G.M., Purohit, B.D., and Vachhrajani, K.D. (2015). Crustacean fauna of Gujarat state of India: A review. *Electronic Journal of Environmental*, 8, 23–31.

Trivedi, J. N. and Vachhrajani, K. D. (2014). Pattern of shell utilization in the hermit crab *Clibanarius zebra* (Dana, 1852) along the Saurashtra coast, Gujarat, India. *Tropical zoology*, 27(4), 129–139.

Trivedi, J. N. and Vachhrajani, K. D. (2017). An annotated checklist of hermit crabs (Crustacea, Decapoda, Anomura) of Indian waters with three new records. *Journal of Asia-Pacific Biodiversity*, 10(2), 175–182.

Turra, A., and Leite, F.P. (2002). Shell utilization patterns of a tropical intertidal hermit crab assemblage. *Journal of the Marine Biological Association of the United Kingdom*, 82(1), 97–107.

Vaghela, A. and Kundu, R. (2012). Spatiotemporal variations of hermit crab (Crustacea: Decapoda) inhabiting rocky shore along Saurashtra coast, western coast of India. *Indian Journal of Geo-Marine Sciences*, 41(2), 146–151.

Wait, M. and Schoeman, D. S. (2012). Shell use, population structure, and reproduction of the hermit crab, *Clibanarius virescens* (Kraus, 1843) at Cape Recife, South Africa. *Journal of Crustacean Biology*,32(2), 203–214.

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New occurrence of *Metapenaeopsis gaillardi* Crosnier, 1991 from Lakshadweep waters, India with morphological notes on *Metapenaeopsis commensalis* Borradaile, 1899 (Decapoda: Penaeidae)

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Abstract

The velvet shrimp under genus *Metapenaeopsis* Bouvier, 1905 is a highly diverse group, falls under the family Penaeidae. In the exploratory survey conducted at Bangaram Island, Lakshadweep, India during February 2020, few specimens of *Metapenaeopsis* were collected from the intertidal regions at the depth of 1-2 m. Further analysis revealed that *Metapenaeopsis gaillardia* Crosnier, 1991 and *M. commensalis* Borradaile, 1899 are available in Lakshadweep islands, wherein, *M. gaillardi* finds as a new distributional record to Lakshadweep Sea. Mitochondrial COI gene sequences were generated for both the species and compared with other congener species. The collected Indian material, *M. gaillardi* is most similar to the characters of the holotype specimen such as rostral dentation, carapace orientation, and thelycal plate structures, however, exhibited a high genetic divergence with Taiwan material (8.6%). Similarly, in *M. commensalis*, a large intraspecific divergence is found between present Indian material and Taiwan material (3.9%), while the collected specimens are morphologically more similar to the holotype and syntype of the Kavaratti island of Lakshadweep. However, minute differences were noted in the present materials *i.e* rostrum slightly exceeded the second antennular peduncle for both sexes, without longitudinal hairy depression on either side of the dorsal region at the fourth abdominal segment, the sixth abdominal segment about 1.6 times as long as maximum broad. The detailed morphological characteristics and colouration of the Indian materials of both species are described and illustrated. The findings of the present study will be helpful in the assessment of the crustacean resources at Lakshadweep.

Keywords: Velvet shrimps, Lakshadweep, *Metapenaeopsis*, Taxonomy, Mitochondrial COI

Introduction

Genus *Metapenaeopsis* Bouvier, 1905 is a highly diverse group from the family Penaeidae Rafinesque, 1815 and commonly known as velvet shrimps (Holthius, 1980). These species are commercially and ecologically important to many regions of the world (De Young 2006; Chen *et al.*, 2014; Purushothaman, 2018). Genus *Metapenaeopsis* contains 71 species and 7 subspecies, which are widely distributed in shallow, inshore, and offshore waters globally (Perez Farfante and Kensley, 1997; De Grave & Fransen, 2011). *Metapenaeopsis* have an asymmetrical petasma in male animals which is a unique character and it is used to differentiate from the other penaeid species. Species of *Metapenaeopsis* are majorly classified based on the shape of genitalia shape, presence and absence of stridulating organ, and asymmetrical petasma with or without lobulated structure in distal part (Dall *et al.*, 1990; Crosnier, 1991). The morphological characters of stridulations and distal part of the petasma were greatly confusing in the taxonomical studies of these species.

Fifteen species of *Metapenaeopsis* were inhabited in Indian waters (Radhakrishnan et al., 2012; Samuel et al., 2016). Where, *Metapenaeopsis andamanensis* (Wood-Mason, 1891 [in Wood-Mason & Alcock, 1891-1893]), *Metapenaeopsis coniger* (Wood-Mason, 1891 [in Wood-Mason & Alcock, 1891-1893]) are widely distributed in deepwater regions of Andaman, southwest and southeast coast of India (100 to 450 m); *Metapenaeopsis philippii* (Spence Bate, 1881) also noticed in deepwater regions of southwest coast only (Geogre, 1969; Purushothman, 2018). *Metapenaeopsis ceylonica* Starobogatov, 1972, *Metapenaeopsis gallensis* (Pearson, 1905), *Metapenaeopsis novaeguineae* (Haswell, 1879), and *Metapenaeopsis toloensis* Hall, 1962 were reported in shallow depth at the southeast coast of India; *Metapenaeopsis barbata* (De Haan, 1844 [in De Haan, 1833-1850]) commonly occurs in south and northeast coast of India. *Metapenaeopsis hilarula* (de Man, 1911), *Metapenaeopsis mogiensis* Rathbun, 1902, *Metapenaeopsis stridulans* (Alcock, 1905) were frequently reported from the east and west coast and Andaman waters and contributing to the commercial landing of these regions; *Metapenaeopsis palmensis* (Haswell, 1879) was reported only from Andaman and Nicobar islands. *Metapenaeopsis commensalis* Borradaile, 1899 was noticed long back from intertidal regions of Minicoy, Kalpeni, and Kavaratti Island of Lakshadweep (Thomas, 1971) in the name of *Metapenaeopsis borradaili*. *Metapenaeopsis gaillardi* Crosnier, 1991 was observed only from Mandapam and Gulf of Mannar regions (Crosnier, 1991). Afterward, no update on *M. commensalis* and *M. gaillardi*. Recently, *Metapenaeopsis difficilis* Crosnier, 1991 was reported as a new record to Andaman waters (Padate et al., 2020).

Recently, the specimens of *Metapenaeopsis gaillardi* and *M. commensalis* were collected from intertidal regions of Bangaram and Agatti Islands, Lakshadweep, India at the depth of 1-2 m. Among them, *M. gaillardi* finds as a new distributional record to Lakshadweep Sea. *M. gaillardi* differs mostly from other species of this genus by having very low and broad dorsal carina on the third abdominal segment and absences of long median spine on the anterior border of thelycal plate. Earlier, *M. commensalis* was confused with *M. borradaili* (Thomas, 1971, Crosnier, 1991) which was discussed in detail. Additionally, we have generated the mitochondrial COI gene sequences for both species. The pairwise genetic distances were estimated and compared with other congener species.

Materials and methods

Sampling and Morphology

The specimens of *Metapenaeopsis gaillardi* and *M. commensalis* were collected from intertidal regions of Bangaram and Agatti Islands, Lakshadweep, India at the depth of 1-2 m. the specimens were collected by hand net and snorkeling method. Live colourations of this species are captured images with a camera (Canon G5). Then, the specimens are preserved in 95% ethanol for further morphological and molecular examinations. Rostrum, pereopods, and telson teeth are examined using a stereo-zoom microscope (0.5-8X) with Nikon SMZ1270.

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The morphological examination was carried out using the available literature of Thomas (1971) and Crosnier (1991). The examined materials are deposited in the Peninsular and Marine Fish Genetic Resources (PMFGR) Centre and National Fish Museum and Repository of the ICAR-National Bureau of Fish Genetic Resources, Lucknow, India. The carapace length (CL) was used as a standard length for the species which was measured from postorbital margin to posterior margin of the carapace dorsally.

Genetic analyses

Mitochondrial gene Cytochrome c oxidase subunit I sequences of the samples were produced by isolating genomic DNA from the pereopods and peleopods using salting-out protocol (NBFGR, 2013). The COI maker was amplified using invertebrate universal primers (Folmer et al., 1994). The PCR amplification and sequencing process have followed the methods given in Akash et al. (2020). The obtained sequences were deposited into the GenBank. COI sequences of 23 species of *Metapenaeopsis* were retrieved from GenBank which were included in the analysis (Table 1). The Bioedit V.7.0.5.2 (Hall 1999) was used for aligning, trimming, and edit of the dataset. MEGA X (Kumar et al., 2018) was used to estimate the pair-wise genetic distances and construct the Maximum likelihood (ML) tree using the General Time Reversible model with 1000 bootstraps (Felsenstein, 1985; Rodriguez et al. 1990).

Results

Systematic account

Order **Decapoda Latreille, 1802**

Suborder **Dendrobranchiata Spence Bate, 1888**

Family **Penaeidae Rafinesque, 1815**

Genus ***Metapenaeopsis* Bouvier, 1905**

***Metapenaeopsis commensalis* Borradaile, 1899 (Fig. 1)**

Metapenaeopsis commensalis — Borradaile, 1898: 1001, pl. 63, fig. 1-1b. — Starobogatov, 1972: 404. — Joseph Poupin, 1998: 4 (List). — Radhakrishnan et al., 2012: 54 (List).

Penaeopsis borradailei — de Man, 1911: 8 (list), 73; 1913: pl. 8, fig. 24-24b; 1920: 104; 1924: 15, fig. 7-7a.

Ceratopenaeus borradailei — Kishinouye, 1929: 283.

Metapenaeopsis borradailei — Dall, 1957: 174, fig. 13 A-E. — Racek & Dall, 1965: 20 (Key). —Starobogatov, 1972: 405, pl.10, fig. 125 a-b. — Motoh, 1977: 6, 10. — Loveit, 1981: 46 (Key), fig. 89. — Devaney & Bruce, 1987: 221, 228.

Metapenaeopsis borradaili — Thomas, 1971: 213, fig.1 A-G. — Burukovsky, 1974: 37 (ed. 1983: 49) (Key), fig. 49 a-b. — George, 1979: 32, fig. 4d. — Rao et al., 1989: 73 (List).

Material examined. Bangaram, Lakshadweep, India, Intertidal region, 1-2 m, February 2020, 2 females CL 9.1 and 9.7 mm (NBFGR: DBTLD200, NBFGR: DBTLD216); 1 male CL 5.7 mm (NBFGR: DBTLD218). Agatii, Lakshadweep, India, Intertidal region, 1-2 m, February 2020, 2 male CL 6.7 and 7.0 mm (NBFGR: DBTLD45; NBFGR: DBTLD217).

Diagnosis: Rostrum (Fig. 1A, B) moderately long, almost straight or slightly directed upwards, extending middle of third antennular peduncle; dorsally armed with 9-10 teeth including an epigastric, ventrally fringed with long setae.

Carapace (Fig. 1B) pubescent, about 1.1-1.3 times as long as rostrum; orbital tooth small; antennal spine long and well developed; hepatic spine prominent, situated slightly lower level of antennal spine; cervical sulcus deep, not reaching the dorsum of carapace, hepatic sulcus sinuous, almost reaching the lower end of the carapace, both sulcus fringed with long spinose setae; pterygostomial spine well-formed.

Abdominal (Fig. 1C, D) first to fourth segment smooth, and without carinated; fifth and sixth segments strongly carinated with hairy form setae present on either side of dorsal carina; sixth segment about 1.5-1.55 times as long as width, dorsal carina posterior end with spinule. Telson triangular, pubescent, almost equal length to sixth abdominal segment, bearing four pairs of lateral spines; proximal spine small and situated half-length of telson, second pair slender, two times longer than proximal one, placed at 0.63 of telson length, third pair slender, about 4.5 times as long as proximal, posterior pair shorter, about 0.55 times of the third pair.

The third maxilliped slightly exceeding the middle of second antennular segment, exopod slender, exceeding the distal end of meral segment. The first pereopod reaching the distal end of the carphocerite second pereopod exceeding the middle of first antennular segment; the third pereopod longer, reaching the distal end of first antennular segment; fourth and fifth pereopods similar, not exceeding carpocerite. Sternal plate with a pair of long spines in between the second pair of pereopod.

Thelycum: Anterior thelycal plate situated between the fourth pair of pereopods, bearing a long median spine, curved anteriorly. Transverse plate with a pair of well-developed lobes, somewhat rounded, slightly swollen, situated between the fifth pereopods (Fig. 1E, F).

Petasma: Asymmetrical and complex structure (Fig 1G, H), one valve present in the right side, petaloid shaped, joined at mid of ventral side which covers an apical portion of petasma. The distoventral portion is well developed. In ventral view, distoventral left lobe formed like leaflets, folded, distal margin finely crenulated; distoventral right lobe with coiled form.

Colouration of life: Carapace and abdomens are partially transparent with irregular light brown and white spots scattered widely. The rostrum is semi-transparent. The antennular peduncle with brown and white bands. Telson and uropods have slightly deep brown and white bands. Peleopods and pereopods are semi-transparent with light brownish and white spots dorsally.

Geographic and bathymetric distributions: This species are widely distributed in Indo-Pacific regions: 0 to 21 m depth in Ellice Islands, New Caledonia (Loyalty Islands), Torres Strait (Murray Island), Indonesia, Philippines, Taiwan (off South coast), Australia (Off northwest coast), Laccadive Islands and Maldives (Thomas, 1971; Crosnier, 1991).

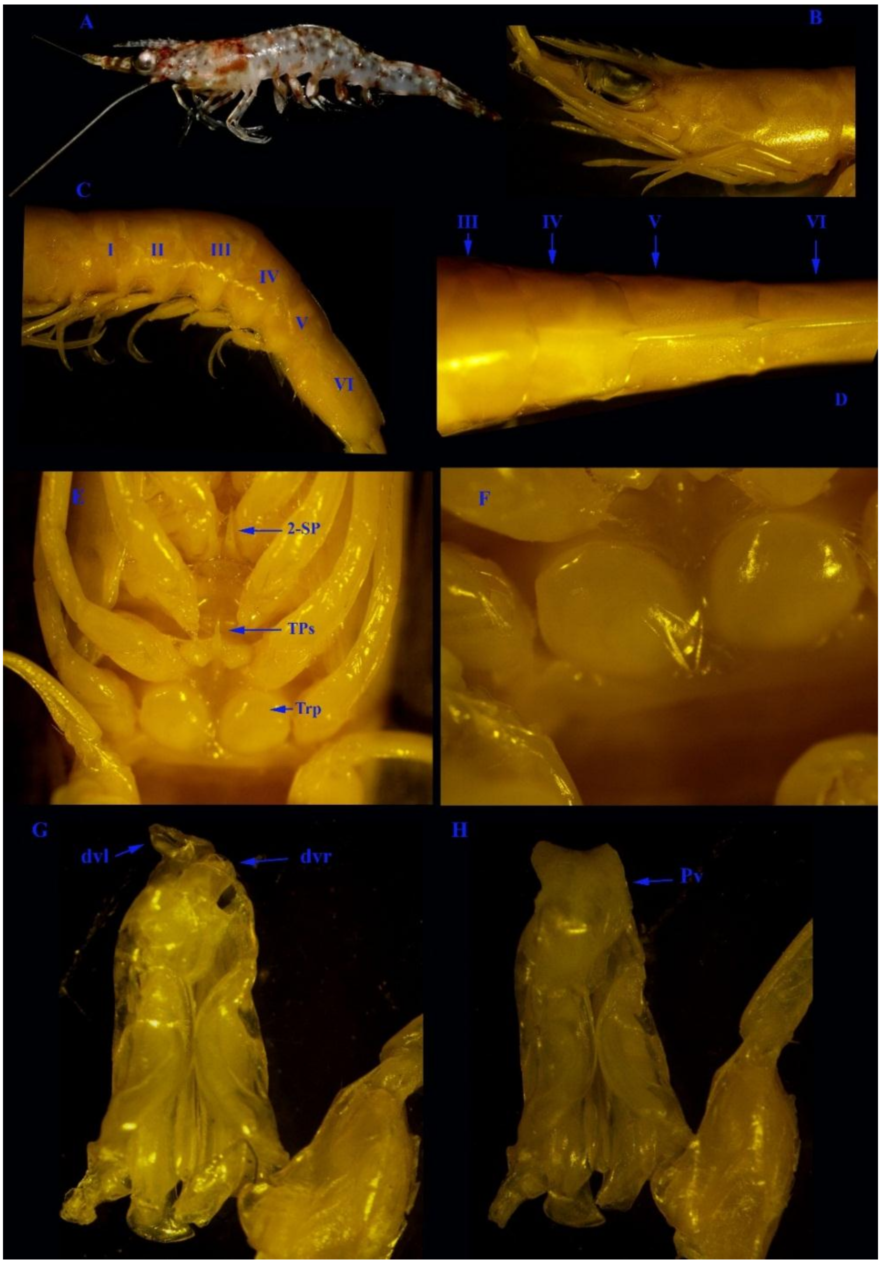

Fig.1. *Metapenaeopsis commensalis* Borradaile, 1899 collected from Intertidal region of Bangaram Island, Lakshadweep, India. A, Live colourations of male specimen; B, Lateral view of carapace; C, Lateral view of abdominal segments; D, Dorsal view of abdominal segments; E, Ventral view of sternal plate and thelycum, 2-SP- Second sternal spines, TPs- Thelycal plate anterior spine, Trp- Transverse plate; F, closer view of transverse plate of thelycum; G, Ventral view of petasma without valve, dvl-distoventral left lobe, dvr- distoventral left lobe; H, Ventral view of petasma with valve.

Remarks. *Metapenaeopsis commensalis* is a type of small-sized velvet shrimps (CL ranged from 4.8-7.8 mm for males and 5.3-11.8 mm for females) which commonly occurs in the intertidal depth of coral environments and is distributed across the Indo-West Pacific regions (Thomas, 1971, Motoh, 1977; Crosnier 1991). Initially, this species was described under the name of *commensalis* based on the female specimens from Rotuma Island (Borradaile, 1898).

Later, De man (1911) was collected male and female specimens of *M. commensalis* from the Sunda Islands and reported in the name of *borradailei*. Subsequently, Thomas (1971) also reported and re-described the morphology of *M. commensalis* with the name of *borradaili* based on the collections of 30 specimens from Minicoy Island (Lakshadweep). Later, Crosnier (1991) has erroneously revised and provided the illustrative keys for Indo-Pacific velvet shrimps. He has deeply reclassified the morphology of *borradailei* and *borradaili,* accounted as synonymous of *M. commensalis.* In the present study, few of the small-sized *Metapenaeopsis* specimens were collected from Bangaram and Agatti Islands (Lakshadweep), which well agreed with descriptions of the holotype (Borradaile, 1898), syntypes (Thomas, 1971), and illustrative keys of *M. commensalis* (Crosnier, 1991).

The present Indian materials were identified by following morphological characters: rostrum dorsally armed with 7 to 9 teeth and an epigastric tooth; carapace about 1.1-1.3 times as long as a rostrum, hepatic sulcus sinuous, reaching lower margin of the carapace, sternal plate with a pair of long spines in between the second pair of pereopods; third abdominal segment without dorsal carina; sixth abdominal segment about 1.5-1.55 times as long as width, dorsal carina extended posteriorly with a small spinule; Anterior thelycal plate with a strong spine, transverse plate with two large round bulges; petasma with single valved lobe, asymmetrical, and distoventral right lobe with coiled form (Thomas, 1971; Crosnier, 1991). Particularly, *M. commensalis* have special features with the thelycum (thelycal plate with strong spine) and patasma (Single valve) which are strongly differentiated from the other species of *Metapenaeopsis*.

Metapenaeopsis gaillardi **Crosnier, 1991 (Fig. 2)**

Metapenaeus velutinus — Rathbun, 1906: 903 in part (st. 3874). Non Dana, 1852.

Metapenaeus mogiensis — Rathbun, 1906: 904, pl. 20, fig. 3. Non Rathbun, 1902.

Penaeopsis sp. (nom conditionnel hilarulus) — de Man, 1911: 70 (in part, st. 179).

Penaeopsis sp. — de Man, 1924: 14, fig. 6, 6a.

Metapenaeopsis gaillardi — Angel et al., 2005: 210 (List). — Radhakrishnan et al., 2012: 54 (List).

Material examined: Bangaram, Lakshadweep, India, Intertidal region, 1-2 m, February 2020, 2 females CL 6.7 and 6.6 mm (NBFGR: DBTLD48A, NBFGR: DBTLD48B).

Diagnosis: Rostrum (Fig. 2A, B) moderately long and slender, slightly directed upwards, the overreaching distal end of second antennular peduncle; bearing 8 dorsal teeth and an epigastric tooth, situated at 0.7 of carapace, ventral margin without tooth and fringed some long setae.

Carapace (Fig. 2B, E) pubescent, about 1.1 times as long as rostrum; antennal spine well developed; hepatic spine sharp, placed a slightly lower level of antennal spine; hepatic sulcus fabulous not reaching the lower end of the carapace; pterygostomial spine small and well-formed.

Abdominal (Fig. 2C, D) first and second segment smooth, and without carinated; third segment with carinated dorsally which wide, smooth, and sometimes divided into three; fourth segment with carina which moderately wide and smooth; fifth and sixth segment strongly carinated with hairy form setae present on either side of dorsal carina; sixth segment broad, about 1.4 times as long as width, posterior end of dorsal carina with minute spinule. Telson slender and pubescent, equal length to sixth abdominal segment, with three pairs of lateral spines.

The third maxilliped slightly exceeding the distal end of third antennular segment, exopod slender, exceeding the distal end of the ischium segment. First pereopod short, not exceeding the distal end of carpocerite; the second pereopod reaching near to the distal end of the first antennular segment; third pereopod slender, and near to the distal end of the third antennular segment; fourth and fifth pereopods shorter, and reaching just near to the distal end of cornea.

Thelycum: Thelycale plate broad (Fig. 2F, G), anterolaterally rounded, with a median tooth in anterior side; intermediate zone hollowed, with a pair of a spoon like lobes, middle regions with a groove which are situated between the fourth pereopods; transverse plate broad, anterior margin look like broad U shaped; posterior plate with a wide and low mid lobe which terminating a small median tooth with few long setae on either side, lateral lobes are asymmetrical, slightly taller than mid lobe.

Colouration of life: Carapace and abdomens are semi-transparent with irregular white spots and light pink patches scattered over the body. The rostrum is semi-transparent with white spots on laterally. The antennular peduncle and antennal flagellum are whitish with light pinkish bands. Telson and uropods have whitish with pink band on terminally. Pereopods are semi-transparent and light pinkish.

Geographic and bathymetric distributions: This species is distributed scattered in Indo-Pacific waters. Western Pacific: 12 to 51 m from Indonesia, New Caledonia, and Hawaii (Crosnier, 1991; Angel et al., 2005). Indian Ocean: 0 to 3.5 m from Sri Lanka, Southern India, Kenya (Crosnier, 1991; Radhakrishnan et al., 2012) and Lakshadweep (Present study).

Remarks: Metapenaeopsis *gaillardi* is a small-sized velvet shrimp which are widely distributed in the Indo-Pacific region (Crosnier 1991). Earlier, the species was described from 11 females (CL 5.6 –17.0 mm) and 9 males (CL 5.7 –11.1 mm), which collected from depths of 0–51 m in various waters such as Kenya, Southern India, Sri Lanka, Indonesia, New Caledonia and Hawaii (Crosnier 1991). The present observation is the new report from the Lakshadweep Sea, which indicates the species distributional range was extended to the westward of the Indian waters. Additionally, we have described the colouration of species in detail which was not noticed in the holotype specimen of the species by Crosnier (1991).

The present Indian materials well agreed with the morphological characters and illustrative figures of holotype specimen (Crosnier 1991) which follows rostrum dorsally armed with 7 to 9, not including epigastric tooth; sternal plate with a pair of long spines in between the second pair of pereopods and a pair of low, triangular lobes between the third pair of pereopods; thelycal plate with a small spine in mid of anterior margin, intermediate zone with a pair of a spoon like lobes; third abdominal segment with carinated dorsally which low and smooth, fifth and sixth segment strongly carinated with hairy form setae dorsally; third maxilliped with small exopod; telson sub-equal to sixth abdominal segment, with three pairs of lateral spines. However, slight variations were observed with present Indian materials, as follows hepatic sulcus fabulous not reaching the lower end of the carapace; the carina of third abdominal segment wide, smooth and divided into three sub-segments; sixth segment broad, about 1.4 times as long as width, which may be intra-specific variations of the species. Overall, the species are confirmations were done based on the morphological features of thelycal plate and sternal structure, particularly, a pair of spoon lobes in the intermediate zone and a small spine in mid of anterior margin of the thelycum (Crosnier 1991).

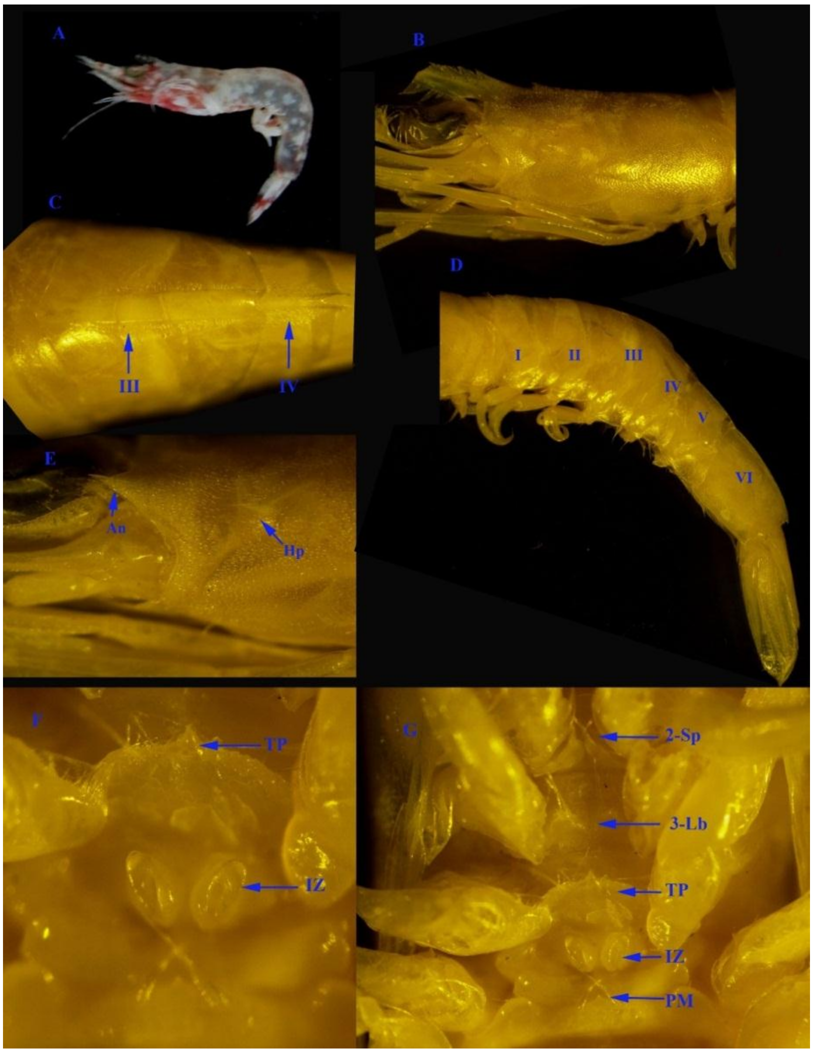

Fig. 2. *Metapenaeopsis gaillardi* Crosnier, 1991 collected from Intertidal region of Bangaram Island, Lakshadweep, India. A, Live colourations of female specimen; B, Lateral view of carapace; C, Dorsal view of abdominal segments with carina; D, Lateral view of abdominal segments; E, Closer view of anterior carapace, An- Antennal spine, Hp- Hepatic spine; F, closer view of thelycum, TP- anterior part of thelycal plate, IZ- Intermediate zone with a pair of spoon like lobes; G, Ventral view of sternal plate and thelycum, 2-Sp- Second sternal spines, 3-Lb- third sternal lobes, TPs-Thelycal plate anterior tooth, IZ- Intermediate zone, PM- Posterior mid plate with a small tooth.

Metapenaeopsis gaillardi is closely similar to *M. quadrilobata* by the morphological characters of rostral length and dorsal teeth patterns, appearances of the hepatic tooth, and shape of the dorsal carina of the third abdominal segment. however, the *M. quadrilobata* is strongly differed by the structures of thelycal plates: latero-anterior margin triangle,

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intermediate zone with a pair of ear-shaped lobes, transverse plate divided into two parts with symmetrical form (wherein *M. gaillardi, the* latero-anterior margin of thelycal plates rounded, intermediate zone with a pair of the spoon like lobes, transverse plate broad with U or V-shaped structures) (Crosnier 1991). Unfortunately, we did not observe the male specimens of *M. gaillardi* from the Lakshadweep waters.

Metapenaeopsis gaillardi was collected with *M. commensalis* from Bangaram Island, Lakshadweep, India. The morphological character such as rostral patterns and carapace appearances of M. gaillardi looks close to *M. commensalis*. However, the *M. gaillardi* is distinguished from the *M. commensalis* by the presence of wide dorsal carina of the third abdominal segment, thelycal plate with a small median tooth, transverse plate broad, U shaped and haptic groove or sulcus not reached the lower margin of the carapace (where in *M. commensalis,* haptic groove extended the lower margin of the carapace, without carina on the third abdominal segment, thelycal plate with a strong median spine, and transverse plate with two large round bulges) (Thomas, 1971; Crosnier, 1991).

In Molecular analyses, 25 COI sequences of species of *Metapenaeopsis* were retrieved from GenBank and they can be used for our molecular analyses (Cheng et al., 2015; Purushothaman et al., 2019; Venera-Pontón et al., 2020; Karuppasamy et al., 2020). Amongst them one sequence from *M. commensalis* (KR150448), and one from *M. gaillardi* (KR150452). It should be noted that the sequences from Tong et al. (2000) were showed improper COI barcoding similarity and therefore those sequences were excluded from our analyses. The present study was generated >600 bp of COI sequences for Indian specimens of *M. commensalis* and *M. gaillardi* (Table 1). The genetic comparisons between the present Indian materials and Taiwan materials of *M. commensalis* and *M. gaillardi* showed interesting results. The present Indian specimens of *M. commensalis* have 95.6 % sequences similarities with a specimen of Taiwan material, where 4.0 % of sequence divergences was observed. Similar way, the present Indian specimens of *M. gaillardi* have 94 % of sequences similarities with the specimen of Taiwan material, where 6.2 % of sequence divergences were noted. Similar results were observed in the phylogenetic analysis and both the species were found a monophyletic clade with other Indo-Pacific species (Fig 3).

Both the species showed a high level of intraspecific genetic divergences, and similar kinds of high intraspecific genetic divergences were noticed in other shrimps such *Plesionika semilaevis* and *P. quasigrandis* (Chan et al., 2020). However, the observed intraspecific divergences are still lower than the 10% divergences, because more than 10% of divergences were generally considered for the standard interspecific species variations in crustaceans groups (Zhang et al., 2019; Chan et al., 2020). Accordingly, the morphological characters such as thelycal plate and patasma structure significantly with reports pf Crosnier (1991) and Cheng et al. (2015). Another hand, the estimated interspecific genetic divergences for Indo-Pacific *Metapenaeopsis* is ranged from 3.3 to 20.4 % except for sequences of *M. provocatoria longirostris*, and *M. quinquedentata*, where showed a very low level of interspecific divergences (0.05%).

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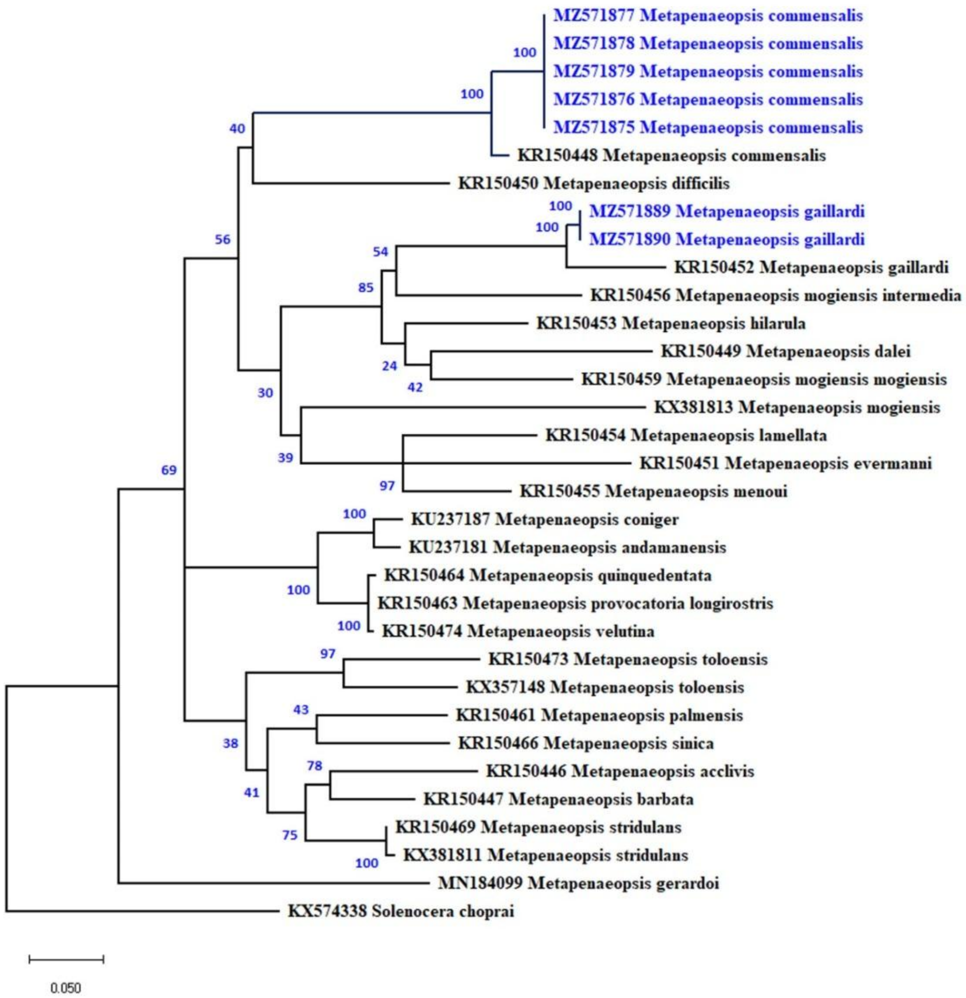

Fig. 3. The phylogenetic tree constructed for *Metapenaeopsis* species using Mitochondrial gene Cytochrome Oxidase I sequences by the Maximum Likelihood method and General Time Reversible model with the highest log likelihood (-5225.87).

A similar result was observed by Cheng et al., 2015, therefore we suggest that detailed integrative studies are required to reveal the confusions on those species identifications. Additionally, the colourations of the *M. commensalis* and *M. gaillardi* were described in the present study, which are the first reports for these species, it could be more useful for future studies. Moreover, the present reports on the *Metapenaeopsis* species will also strengthen the knowledge of crustacean fauna of the Lakshadweep waters.

Table 1: Details of present Indian specimens and GenBank sequences incorporated for molecular analyses.

S. No.	Species name	Voucher No	Accession No	References
1	*Metapenaeopsis commensalis*	NBFGR:DBTLD45	MZ571875	Present study
2	*Metapenaeopsis commensalis*	NBFGR:DBTLD200	MZ571876	Present study
3	*Metapenaeopsis commensalis*	NBFGR:DBTLD216	MZ571877	Present study
4	*Metapenaeopsis commensalis*	NBFGR:DBTLD217	MZ571878	Present study

5	*Metapenaeopsis commensalis*	NBFGR:DBTLD218	MZ571879	Present study
6	*Metapenaeopsis gaillardi*	NBFGR:DBTLD48A	MZ571889	Present study
7	*Metapenaeopsis gaillardi*	NBFGR:DBTLD48B	MZ571890	Present study
8	*Metapenaeopsis acclivis*	TW-METAP1	KR150446	Cheng et al., 2015
9	*Metapenaeopsis barbata*	GT-HN-METAP2	KR150447	Cheng et al., 2015
10	*Metapenaeopsis commensalis*	TW-METAP3	KR150448	Cheng et al., 2015
11	*Metapenaeopsis dalei*	YS-METAP4	KR150449	Cheng et al., 2015
12	*Metapenaeopsis difficilis*	PH-METAP5	KR150450	Cheng et al., 2015
13	*Metapenaeopsis evermanni*	TW-METAP6	KR150451	Cheng et al., 2015
14	*Metapenaeopsis gaillardi*	TW-METAP7	KR150452	Cheng et al., 2015
15	*Metapenaeopsis hilarula*	PH-METAP8	KR150453	Cheng et al., 2015
16	*Metapenaeopsis lamellata*	PH-TW-METAP9	KR150454	Cheng et al., 2015
17	*Metapenaeopsis menoui*	PA-METAP10	KR150455	Cheng et al., 2015
18	*Metapenaeopsis mogiensis intermedia*	TW-METAP11	KR150456	Cheng et al., 2015
19	*Metapenaeopsis mogiensismogiensis*	SY-HN-METAP14	KR150459	Cheng et al., 2015
20	*Metapenaeopsis palmensis*	DG-TW-METAP16	KR150461	Cheng et al., 2015
21	*Metapenaeopsis provocatoria longirostris*	DG-TW-METAP18	KR150463	Cheng et al., 2015
22	*Metapenaeopsis quinquedentata*	PH-METAP19	KR150464	Cheng et al., 2015
23	*Metapenaeopsis sinica*	GT-HN-METAP21	KR150466	Cheng et al., 2015
24	*Metapenaeopsis stridulans*	SI-METAP24	KR150469	Cheng et al., 2015
25	*Metapenaeopsis toloensis*	GT-HN-METAP28	KR150473	Cheng et al., 2015
26	*Metapenaeopsis velutina*	MPR-METAP29	KR150474	Cheng et al., 2015
27	*Metapenaeopsis gerardoi*	ULLZ13357	MN184099	Venera-Pontón et al., 2020
28	*Metapenaeopsis coniger*	CMFRI:CFD:M6	KU237187	Purushothaman et al., 2019
29	*Metapenaeopsis andamanensis*	CMFRI:CFD:M12	KU237181	Purushothaman et al., 2019
30	*Metapenaeopsis mogiensis*	PCMUZ MMC 01	KX381813	Karuppasamy et al., 2020
31	*Metapenaeopsis toloensis*	PCMUZ MTC 01	KX357148	Karuppasamy et al., 2020
32	*Metapenaeopsis stridulans*	PCMUZ MSC 01	KX381811	Karuppasamy et al., 2020
33	*Solenocera choprai*	CMFRI:CFD:SSP3	KX574338	Purushothaman et al., 2019

References

Akash S., Purushothaman P., Manu Madhavan, Charan Ravi, Jafer Hisham T, Sudhakar M., Ajith Kumar T.T., And Lal K Kudeep. 2020. *Urocaridella arabianensis* n sp., A new Palaemonid shrimp (Crustacea, Decapoda, Palaemonidae) from Lakshadweep Islands, India with taxonomic comparison on the genus *Urocaridella* Borradaile, 1915. *Zootaxa*, 4816(1), 49-66.

Angel, M.V., Bousfield, E.L., Brunei, P., Brusca, R.C., Cadien, D., Cohen, A.C., Conlan, K., Eldredge, L.G., Felder, D.L., Goy, J.W. and Haney, T. 2005. *Common and Scientific Names of Aquatic Invertebrates from the United States and Canada*.

Bate, C.S. 1881. On the Penaeidae. *The Annals and Magazine of Natural History*, series 5. 8: 169-196, pls. 11-12.

Bate, C.S. 1888. *Report on the Crustacea Macrura collected by H.M.S. Challenger during the years 1873-1876*. Report on the Scientific Results of the Voyage of H.M.S. Challenger, Zoology, 24, 942 p.

Borradaile, L.A. 1898. On some crustaceans from the South Pacific. Part 3. *Proceedings of the Zoological Society of London* 1898: 1000-1015.

Bouvier, E.L. 1905. Sur les Pénéides et les Sténopies receuillis par les expeditions françaises et monégasques dans l'Atlantique oriental. [On the Penaeids and Stenopodids collected by the French and Monaco expeditions in the Eastern Atlantic]. *Comptes Rendus Acad sci.* 140: 980 – 983 (French).

Burukovsky, R.N. 1974. Opredelitel krevetok, langustov i omarov. Moskva, pischevaja promichlennost. 124 p., fig. 1-189. Traduit en anglais, 1983, Key to Shrimps and Lobsters. Russian Translations sériés (Ed. Balkema, Rotterdam), 5: xi + 174 p., fig. 1-189.

Chan, T. Y., Hsu, C. Y., Kumar, A. B., & Chang, S. C. (2020). On the" Plesionika martia"(A. Milne-Edwards, 1883) species group in Indian waters. Zootaxa, 4729(1), zootaxa-4729.

Chen, H.S., Chen, C.Y. & Chen, M.H. 2014. Life history tactics of southern velvet shrimp *Metapenaeopsis palmensis* (Crustacea, Decapoda) in the waters off southwestern Taiwan. *Hydrobiologia*, 741: 177–191.

Cheng, J., Sha, Z. L., & Liu, R. Y. 2015. DNA barcoding of genus Metapenaeopsis (Decapoda: Penaeidae) and molecular phylogeny inferred from mitochondrial and nuclear DNA sequences. *Biochemical Systematics and Ecology*, 61 : 376-384.

Crosnier A. 1991. Crustacea Decapoda: les *Metapenaeopsis* indo-ouest-pacifiques sans appareil stridulant (Penaeidae). Deuxie`me partie. In Crosnier A. (ed.) Re´sultats des Campagnes MUSORSTOM, Volume 9. *Me´moires du Muse´um National d'Histoire Naturelle, Paris* 152, 155–297.

Dall, W. 1957. A revision of the Australian species of Penaeinae (Crustacea Decapoda: Penaeidae). *Australian Journal of Marine and Freshwater Research* 8(2): 136-230, fig. 1-29.

Dall, W., Hill B.J., Rothlisberg P.C. & Sharples D.J. 1990. *Advances in Marine Biology: The Biology of the Penaeoidae. Academic Press Limited, London:* 489.

De Grave, S. & Fransen, C. H. J. M. 2011. Carideorum Catalogus: The recent species of the Dendrobranchiate, Stenopodidean, Procarididean and Caridean shrimps (Crustacea: Decapoda). *Zoologiche Mededelingen* 85: 195–588.

De Haan, W. (1833-1850). Crustacea. In: von Siebold, P.F., Fauna Japonica sive Descriptio Animalium, quae in Itinere per Japoniam, Jussu et Auspiciis Superiorum, qui Summum in India Batava Imperium Tenent, Suspecto, Annis 1823-1830 Collegit, Notis, Observationibus et Adumbrationibus Illustravit. i-xxxi, ix-xvi, 1-243, Plates A-J, L-Q, 1-55. Lugduni-Batavorum.

de Man, J.G. 1911. Family Penaeidae. The Decapoda of the Siboga Expédition. *Siboga Expedition Monograph.* 39a: 1-131.

de Man, J.G. 1913. Family Penaeidae. The Decapoda of the Siboga Expédition. Part I. Siboga Expedition *Monograph, supplementary* 39a, pl. 1-10.

de Man, J.G. 1920. Diagnoses of some new species of Penaeidae and Alpheidae with remarks on two known species of the genus *Penaeopsis* A. M. Edw. from the Indian Archipelago. *Zoologische mededeelingen, Leiden*, 5 (3): 103-109.

de Man, J.G. 1924. On a collection of Macrurous Decapod Crustacea, chiefly Penaeidae and Alpheidae from the Indian Archipelago. *Archiv fur Naturgeschichte*, 90, A, 2: 1-16, fig.1-7.

De Young, C. (ed.). 2006. Review of the state of world marine capture fisheries management: Indian Ocean. *FAO Fisheries Technical Paper*, 488:.1–458.

Devaney, D.M. & Bruce, A.J. 1987. Crustacea Decapoda (Penaeidea, Stenopodidea, Caridea, and Palinura) of Enewetak Atoll. In: *The Natural History of Enewetak Atoll. Vol. 2. Biogeography and Systematics. Chapitre* 22: 221 - 233.

Felsenstein, J. 1985. '*Confidence limits on phylogenies: An approach using the bootstrap', Evolution,* Vol. 39, pp. 783–791.

Folmer, O., Black, M., Hoeh, W., Lutz, R., & Vrijenhoek, R. 1994. DNA primers for amplification of mitochondrial Cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Molecular marine biology and biotechnology* 3: 294–299.

George, M.J. 1969. Svstematics-Taxonomic consideration and general distribution. CMFRI Bulletin, 14, 5-49.

George, M.J. 1979. *Taxonomy of Indian prawns (penaeidae, crustacea & decapoda). Contributions to marine sciences dedicated to Dr. CV Kurian*, pp.21-59.

Hall, D.N.F. 1962. Observations on the taxonomy and biology of some Indo-west Pacific Penaeidae (Crustacea, Decapoda).— *Colonial Office Fisheries Publications* 17: 1-229.

Hall, T.A. 1999. BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *In Nucleic acids symposium series* 41, 95-98. [London]: Information Retrieval Ltd., c1979-c2000.

Haswell, W.A. 1879. On the Australian species of *Penaeus*, in the Macleay Museum, Sydney.— *The Proceedings of the Linnean Society of New South Wales* 4: 38-44.

Holthuis, L.B. 1980. *FAO Species Catalogue. In: Shrimps and Prawns of the World: An Annotated Catalogue of Species of Interest to Fisheries, vol. 1. FAO Fisheries Synopsis,* p. 162.

Karuppasamy, P. K., Logeshwaran, V., Priyadarshini, R. S. S., & Ramamoorthy, N. (2020). Molecular and Systematic Identification of Food Marine Shrimps Using mtCOI Marker from Southeast Coast of India. *Thalassas: An International Journal of Marine Sciences*, 1-9.

Kishinouye, K. 1929. Penaeid Crustaceans with Asymmetrical Pétasma. *Proceedings of the Imperial Academy of Japan,* 5: 280 - 283 , fig. n.n.

Kumar, S., Stecher, G., Li, M., Knyaz, C., & Tamura, K. 2018. MEGA X: molecular evolutionary genetics analysis across computing platforms. *Molecular biology and evolution* 35(6): 1547-1549.

Latreille, P.A. 1802. Histoire naturelle, générale et particulière des Crustacés et des Insectes. Ouvrage faisant suite à l'histoire naturelle générale et particulière, composée par Leclerc de Buffon, et rédigée par C.S. Sonnini, membre de plusieurs Sociétés savantes, Vol. 3. F. Dufart, Paris.

Lovett, D.L. 1981. A Guide to the Shrimps, Prawns, Lobsters, and Crabs of Malaysia and Singapore. *Occ. Publ. Fac. Fish. mar. Sci. Univ. Pertanian Malaysia*, (2) : i-iv + 1-156, fig. 1-337.

Motoh, H. 1977. An annotated list of scientific and english common names of commercially important penaeid prawns and shrimps. Tech. Rep. Aquacult. *Depl. South East Asian Dev. Cent. Manila*, (2): 1-14.

NBFGR, 2013. *DNA Barcoding and Molecular Taxonomy: Training manual*. National Bureau of Fish Genetic Resources (NBFGR) Unit, Kochi, India. pp 57.

Pearson, J. 1905. Report on the Macrura collected by Professor Herdman at Ceylon in 1902. In: W.A. Herdman, Report to the Government of Ceylon on the Pearl Oyster Fisheries in the Gulf of Manaar, 4, Supplementary *Report* 20(24): 65-92.

Pérez Farfante, I. & Kensley, B. 1997. Penaeoid and sergestoid shrimps and prawns of the world, keys and diagnoses for the species and genera. *Memoires Museum National d' Histoire Naturalle Zoologie Tome* 175–235.

Purushothaman, P. 2018. *Integrative taxonomy of deepsea shrimp Aristeus alcocki Ramadan, 1938 (Family: Aristeidae) resources along the southern coast of India*. Doctoral dissertation, ICAR-Central Marine Fisheries Research Institute, Kochi, India. pp 171.

Purushothaman, P., Chakraborty, R. D., Kuberan, G., & Maheswarudu, G. 2019. Integrative taxonomy of commercially important deep water penaeoid shrimps from India. *Journal of genetics*, 98(1), 1-13.

Racek, A.A. & Dall, W. 1965. Littoral Penaeinae (Crustacea Decapoda) from northern Australia, New Guinea, and adjacent waters. *Verh. K. Akad. Wet. (B Natuurk.),* 56(3) : 1-119, fig. 1-16, pl. 1-13.

Radhakrishnan E.V., V.D. Deshmukh, G. Maheswarudu, J. Josileen, A.P. Dineshbabu, K.K. Philipose, P.T. Sarada, S. Lakshmi Pillai, K.N. Saleela, Rekhadevi, Chakraborty, Gyanaranjan Dash, Sajeev, C., Tirumilu, K., Sridhara, P., Muniyappa, B., Sawant, Y., Narayan, A.D., Vaidya, G., Dias Johny, R., Verma, J.B., Baby, P.K., Unnikrishnan, C., Ramachandran, N.P., Vairamani, A., Palanichamy, A., Radhakrishnan, M., & Raju, B. 2012. Prawn fauna (Crustacea: Decapoda) of India — an annotated checklist of the penaeoid, sergestoid, stenopodid and caridean prawns. *Journal of Marine Biological Association of India* 54(1): 50–72. http://mbai.org.in/ php/journaldload.php?id=2242&bkid=106

Rafinesque, C.S. 1815. *Analyse de la nature ou tableau de l'univers et de corps organisés*. Privately published, Palermo, 224 pp.

Rao, G. S., Suseelan, C., & Kathirvel, M. 1989. Crustacean resources of the Lakshadweep Islands. CMFRI Bulletin, 43, 72-76.

Rathbun, M.J. 1902. Japanese stalk-eyed crustaceans. Proceedings of the United States National Museum. 26: 23-55., available online at https://www.biodiversitylibrary.org/page/7612066

Rathbun, M.J. 1906. The Brachyura and Macrura of the Hawaiian Islands. *Bull. U. S. Fish Commn,* 23 (3): 827-930, fig. 1-79, pl. 1-24.

Rodriguez, F.J.L.O.J., Oliver, J.L., Marin, A., & Medina, J.R. 1990. The general stochastic model of nucleotide substitution. *Journal of theoretical biology,* 142(4), 485-501.

Samuel, V.K.D., Sreeraj, C.R., Krishnan, P., Parthiban, C., Sekar, V., Chamundeeswari, K., Immanuel, T., Shesdev, P., Purvaja, R. & Ramesh, R. 2016. An updated checklist of shrimps on the Indian coast. *Journal of Threatened Taxa*, 8, 8977–8988. https://doi.org/10.11609/jott.2628.8.7.8977-8988.

Starobogatov, Y.I. 1972. Peneidy (Sem. Penaeidae - Crustacea Decapoda) Tonkingskogo Zaliva. Penaeidae (Crustacea Decapoda) of Tonkin Gulf. In : Fauna Tonkingskogo zaliva i usloviya ee suchchestvovaniya issledovaniya fauny Morey. (Isdatelstvo «Nauka», Leningrad), 10 (18) : 359-415, pl. 1-11 (en russe).

Thomas, M.M. 1971. *Metapenaeopsis borradaili* (de Man) a Penaeid Prawn (Decapoda, Penaeidae) new to the Indian Océan. *Journal of the Marine Biological Association of India*, 12 (1 & 2), 1970 (1971): 213-216, fig. 1.

Tong, J.G., Chan, T. Y., & Chu, K. H. 2000. A preliminary phylogenetic analysis of Metapenaeopsis (Decapoda: Penaeidae) based on mitochondrial DNA sequences of selected species from the Indo-West Pacific. *Journal of Crustacean Biology*, 20(3), 541-549.

Venera-Pontón, D. E., Driskell, A. C., De Grave, S., Felder, D. L., Scioli, J. A., & Collin, R. (2020). Documenting decapod biodiversity in the Caribbean from DNA barcodes generated during field training in taxonomy. *Biodiversity Data Journal*, 8.

Wood-Mason, J. Alcock, A. (1891-1893). Natural history notes from H.M. Indian Marine Survey Steamer 'Investigator,' Commander R.F. Hoskyn, R.N., commanding.—Series II., No. 1. On the results of deep-sea dredging during the season 1890–91. *Annals and Magazine of Natural History, ser.* 6. 8(43), 16–34; 8(44), 119–138, pls. VII–VIII; 8(46), 268–286; 8(47), 353–362; 8(48), 427–452, pl. XVII; 9(52), 265–275, pls. XIV-XV; 6(53), 358–370; 11(62), 161–172, pls. X-XI.

Zheng, X. Z., Chen, W. J., & Guo, Z. L. 2019. The genus Macrobrachium (Crustacea, Caridea, Palaemonidae) with the description of a new species from the Zaomu Mountain Forest Park, Guangdong Province, China. *ZooKeys*, 866, 65.

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An annotated checklist of marine brachyuran crabs (Crustacea, Decapoda, Brachyura) from Goa, west coast of India with ten new records

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Abstract

An annotated checklist of marine brachyuran crabs occurring in coastal areas of Goa is compiled based on published accessible literature and specimens collected based on the survey carried out from the coastal areas of Chapora, Mandovi and Sal estuaries between 2016-2020. A total of 103 species belonging to 66 genera and 25 families are recorded so far. Out of the 25 families recorded, family Portunidae showed the highest species diversity (21 species, 7 genera) followed by Sesarmidae (15 species, 8 genera), Xanthidae (9 species, 7 genera). In the present study, we report ten new species: *Portunus reticulatus* (Herbst, 1799), *Metopograpsus latifrons* (White, 1847), *Clistocoeloma lanatum* (Alcock, 1900), *Neosarmatium malabaricum* (Henderson, 1893), *Parasesarma bengalense* (Davie 2003), *Perisesarma dussumieri* (H. Milne Edwards, 1853), *Pseudosesarma glabrum* Ng, Rani and Bijoy Nandan, 2017, *Macrophthalmus (Macrophthalmus) brevis* (Herbst, 1804), *Macrophthalmus (Macrophthalmus) parvimanus* Guérin, 1834 and *Tubuca alcocki* Shih, Chan and Ng, 2018, which are first time reported from the present study area.

Keywords: Brachyuran crabs, Checklist, Goa, West coast of India

Introduction

Goa, the smallest state of India has a coastline of 151 km and is traversed by nine tidal rivers (Kumar *et al*., 2006; Fernandes *et al*., 2018). The infraorder Brachyura (true crabs) is the most species-rich decapoda group, with 93 families and over 7000 species worldwide and 62 families and over 910 species in India (Ng *et al.*, 2008; Trivedi *et al*., 2018). Although the marine brachyuran crab fauna of India has been studied since the mid-1700s (Trivedi *et al.*, 2018), the first publication from Goa was only in the early 1900s by Kemp (1917, 1919a, 1919b) who reported seven species from three families. Later, with the establishment of the National Institute of Oceanography (NIO) in Goa, studies on the edible crab fauna and benthic macrofauna were carried out by Ansari and Harkantra (1975) and Parulekar *et al*. (1980). However, the major and most significant contribution was by the scientists from the Zoological Survey of India (ZSI) who carried out preliminary surveys in the early 2000s, data of which was published subsequently in later years as Dev Roy and Nandi (2005); Dev Roy

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and Bhadra (2008); Dev Roy (2008) and Dev Roy (2013). Guinot (1985) and Galil (2009) in their revisionary work on the genus *Parapanope* De Man, 1985 and *Philyra* Leach, 1817 respectively also contributed one species each to the brachyuran fauna of the state. Recently published studies provide a much better insight on the distribution of brachyuran crabs from Goa (Padate *et al*., 2010; Padate, 2010; Joshi *et al*., 2011; Padate *et al*., 2013; Hegde *et al*., 2013; Hegde, 2013; Velip and Rivonker, 2014; Kaullysing *et al*., 2015; Padate *et al*., 2015; Vijaylaxmi *et al*., 2016; Velip, 2017; Komarpant *et al*., 2018; Vijaylaxmi, 2020; Bhat and Trivedi, 2021; Bhat *et al*., in press). Considering the significant amount of publications in this field in the last 20 years, the present study aims to prepare a comprehensive checklist of the marine brachyuran crab fauna of Goa which will provide baseline information for future research.

Materials and Methods

The present study is a compilation of the information gathered by authors based on the review of all the accessible published documents regarding brachyuran crab diversity of the Goa state. Several field visits were carried out by the first author to Chapora and Mandovi estuary and Sal estuary in the North and South Goa district respectively from 2016 to 2020. All the collected specimens were washed properly, identified, photographed, preserved in 90% ethanol and deposited in the Zoological Reference Collection (LFSc.ZRC), Department of Life Sciences, Hemchandracharya North Gujarat University, Patan, Gujarat and in the collection of School of Earth, Ocean and Atmospheric Sciences, Goa University, Goa state.

Results and Discussion

A total of 103 species belonging to 66 genera and 25 families are recorded so far from the Goa state (Table 1). Out of the 25 families recorded, family Portunidae showed the highest species diversity (21 species, 7 genera) followed by Sesarmidae (15 species, 8 genera), Xanthidae (9 species, 7 genera), Leucosiidae (8 species, 6 genera), Ocypodidae (6 species, 4 genera) Hymenosomatidae (6 species, 3 genera), Pilumnidae (4 species, 4 genera), Epialtidae (4 species, 3 genera), Dotillidae (3 species, 3 genera), Matutidae and Grapsidae (3 species, 2 genera), Macrophthalmidae (3 species, 1 genus). Families like Oziidae, Majidae and Varunidae were represented by 2 species and 2 genera each. Families like Calappidae, Hexapodidae were represented by 2 species and 1 genus each. Eight families like Dromiidae, Raninidae, Carpiliidae, Dorippidae, Euryplacidae, Galenidae, Gecarcinidae and Plagusiidae were represented by 1 species, 1 genus each.

According to the published literature, seven species have their type locality in Goa state namely *Elamena xavieri* Kemp, 1917, *Neorhynchoplax alcocki* (Kemp, 1917), *Neorhynchoplax demeloi* (Kemp, 1917), *Neorhynchoplax octagonalis* (Kemp, 1917) *Scopimera proxima* Kemp, 1919, *Charybdis (Charybdis) goaensis* Padate, Rivonker, Anil, Sawant and Krishnamurthy, 2010 and *Hexapus bidentatus* Velip and Rivonker, 2014. Among these, *Charybdis (Charybdis) goaensis* and *Hexapus bidentatus* are endemic locally. Three species *Carupella banlaensis* Tien, 1969, *Sarmatium crassum* Dana 1851 and *Epigodromia gilesii* (Alcock, 1899), which in India have been reported only from Goa state.

In the present study ten species namely *Portunus reticulatus* (Herbst, 1799), *Metopograpsus latifrons* (White, 1847), *Clistocoeloma lanatum* (Alcock, 1900), *Neosarmatium malabaricum* (Henderson, 1893), *Parasesarma bengalense* (Davie 2003), *Perisesarma dussumieri* (H. Milne Edwards, 1853), *Pseudosesarma glabrum* Ng, Rani and Bijoy Nandan, 2017, *Macrophthalmus (Macrophthalmus) brevis* (Herbst, 1804), *Macrophthalmus (Macrophthalmus) parvimanus* Guérin, 1834 and *Tubuca alcocki* Shih, Chan and Ng, 2018 are reported for the first time from the coastal waters of Goa (Table 1., Figure 1, 2). The observations revealed that Goa state with a comparatively small coastline support rich marine brachyuran crab fauna and have potential for a more diversified brachyuran community as some of the habitats are unexplored.

Table 1: Checklist of marine brachyuran crabs reported from Goa. (Modified from Trivedi *et al.* (2018))

Family and species list	**References**
Order **Decapoda Latreille, 1802**	
Infraorder **Brachyura Latreille, 1802**	
Section **Podotremata Guinot, 1977**	
Family **Dromiidae De Haan, 1833**	
Epigodromia gilesii (Alcock, 1899)	Alcock, 1901; Dev Roy, 2013, 2015
Family **Raninidae De Haan, 1839**	
Notopus dorsipes (Linnaeus, 1758)	Dev Roy, 2008
Section **Eubrachyura, Saint Laurent, 1980**	
Subsection **Heterotremata, Guinot, 1977**	
Family **Calappidae De Haan, 1833**	
Calappa guerini Brito-Capello, 1871	Parulekar *et al.*, 1980; Padate, 2010; Hegde, 2013; Velip 2017
Calappa hepatica (Linnaeus, 1758)	Parulekar *et al.*,. 1980
Family **Matutidae De Haan, 1835**	
Ashtoret lunaris (Forskål, 1775)	Parulekar *et al.*, 1980; Padate, 2010; Hegde, 2013; Velip, 2017
Ashtoret miersii (Henderson, 1887)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Matuta victor (Fabricius, 1781)	Alcock, 1896; Dev Roy and Bhadra 2008
Family **Carpiliidae Ortmann, 1893**	
Carpilius maculatus (Linnaeus, 1758)	Dev Roy, 2008
Family **Dorippidae MacLeay, 1838**	
Dorippoides facchino (Herbst, 1785)	Parulekar *et al.*, 1980; Padate, 2010; Hegde, 2013; Velip, 2017
Family **Oziidae Dana, 1851**	
Epixanthus frontalis (H. Milne Edwards, 1834)	Dev Roy and Bhadra, 2008; Dev Roy, 2013; Kaullysing, *et al.*, 2015; Vijaylaxmi, 2020
Lydia annulipes (H. Milne Edwards, 1834)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Family **Euryplacidae, Stimpson, 1871**	

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Trissoplax dentata (Stimpson, 1871)	Velip, 2017
Family **Leucosiidae Samouelle, 1819**	
Euclosiana unidentata (De Haan, 1841)	Alcock, 1896; Dev Roy, 2013, 2015
Leucosia corallicola Alcock, 1896	Alcock, 1896; Dev Roy, 2013
Nursilia dentata Bell, 1855	Dev Roy, 2008
Philyra corallicola Alcock, 1896	Dev Roy, 2008
Philyra globus (Fabricius,1775) (Following Galil (2009), *Philyra globulosa* H. Milne Edwards, 1837, is a junior synonym)	Hegde *et al.*, 2013
Philyra scabriuscula (Fabricius, 1798)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Ryphila cancellus (Herbst, 1783)	Galil 2009
Seulocia pubescens (Miers, 1877)	Padate, 2010; Dev Roy, 2013; Hegde, 2013; Velip, 2017
Family **Hymenosomatidae MacLeay, 1838**	
Elamena truncata (Stimpson, 1858)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Elamena xavieri Kemp, 1917	Kemp, 1917; Dev Roy and Bhadra, 2008
Elamenopsis alcocki (Kemp, 1917)	Dev Roy and Bhadra, 2008
Neorhynchoplax alcocki (Kemp, 1917)	Kemp, 1917; Chopra and Das, 1930
Neorhynchoplax demeloi (Kemp, 1917)	Kemp, 1917; Dev Roy and Bhadra, 2008
Neorhynchoplax octagonalis (Kemp, 1917)	Kemp, 1917; Dev Roy and Bhadra, 2008; Dev Roy, 2013
Family **Epialtidae MacLeay, 1838**	
Acanthonyx euryseroche Griffin and Tranter, 1986	Joshi *et al.*, 2011; Dev Roy, 2013
Acanthonyx limbatus A. Milne-Edwards, 1862	Joshi *et al.*, 2011; Dev Roy, 2013
Doclea rissoni Leach, 1815	Padate, 2010
Rochinia riversandersoni (Alcock, 1895)	Alcock, 1900; Dev Roy, 2013
Family **Majidae Samouelle, 1819**	
Micippa thalia (Herbst, 1803)	Alcock, 1895; Dev Roy, 2013
Schizophrys aspera (H. Milne Edwards, 1831)	Hegde *et al.*, 2013; Velip, 2017
Family **Portunidae Rafinesque, 1815**	
Carupella banlaensis Tien, 1969	Vijaylaxmi *et al.*, 2016
Charybdis (Charybdis) affinis Dana, 1852	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Charybdis (Charybdis) annulata Fabricius, 1798	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Charybdis (Charybdis) callianassa (Herbst, 1798)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Charybdis (Charybdis) feriata (Linnaeus, 1758)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Charybdis (Charybdis) goaensis Padate, Rivonker, Anil, Sawant and Krishnamurthy, 2010	Padate *et al.*, 2010; Hegde *et al.*, 2013
Charybdis (Charybdis) lucifera (Fabricius, 1798)	Dev Roy and Bhadra, 2008; Dev Roy, 2013

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Charybdis (Charybdis) riversandersoni Alcock, 1899	Alcock, 1899; Dev Roy, 2013
Charybdis (Charybdis) variegata (Fabricius, 1798	Hegde *et al.*, 2013
Charybdis (Goniohellenus) hoplites (Wood-Mason, 1877)	Alcock, 1899; Dev Roy, 2013
Charybdis (Goniohellenus) vadorum Alcock, 1899	Padate, 2010; Hegde, 2013; Velip, 2017
Cycloachelous granulatus (H. Milne Edwards, 1834)	Alcock, 1899; Dev Roy, 2008
Lupocyclus philippinensis Semper, in Nauck, 1880	Alcock, 1899
Portunus reticulatus (Herbst, 1799) (Fig. 1A, B)	Present Study One male and one female were collected from Siolim fish market; four juvenile males and four juvenile females were collected from Chapora estuary.
Portunus sanguinolentus (Herbst, 1783)	Parulekar *et al.*, 1980; Dev Roy and Bhadra, 2008; Padate, 2010; Dev Roy, 2013; Hegde, 2013; Velip, 2017; Vijaylaxmi, 2020
Portunus segnis (Forskål, 1775)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Scylla olivacea (Herbst, 1796)	Hegde *et al.*, 2013; Padate *et al.*, 2013
Scylla serrata (Forskål, 1775)	Parulekar *et al.*, 1980; Dev Roy and Bhadra, 2008; Padate, 2010; Dev Roy, 2013; Hegde, 2013; Velip, 2017; Vijaylaxmi, 2020
Scylla tranquebarica (Fabricius, 1798)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Thalamita crenata (Latreille, 1829)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Thalamita oculea Alcock, 1899	Alcock, 1899
Family **Xanthidae MacLeay, 1838**	
Actiomera lophopa (Alcock, 1898)	Dev Roy, 2008
Atergatis integerrimus (Lamarck, 1818)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Atergatis laevigatus A. Milne-Edwards, 1865	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Atergatis roseus (Rüppell, 1830)	Dev Roy, 2008
Demania baccalipes (Alcock, 1898)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Epiactaea margaritifera (Odhner, 1925)	Deb, 1989
Leptodius exaratus (H. Milne Edwards, 1834)	Dev Roy and Bhadra, 2008; Dev Roy, 2013; Lee *et al.*, 2013
Lophozozymus incisus (H. Milne Edwards, 1834)	Alcock, 1898
Odhnea echinus (Alcock, 1898)	Alcock ,1898; Deb, 1989
Family **Galenidae Alcock, 1898**	
Parapanope hextii (Alcock, 1898)	Dev Roy and Bhadra, 2008; Dev Roy, 2013; Guinot, 1985

Family **Pilumnidae Samouelle, 1819**	
Benthopanope indica (De Man, 1887)	Dev Roy and Bhadra 2008; Dev Roy 2013
Eurycarcinus orientalis A. Milne-Edwards, 1867	Dev Roy and Bhadra 2008; Dev Roy 2013
Heteropanope glabra Stimpson, 1858	Kaullysing *et al.*, 2015
Xenophthalmodes moebii Richters, 1880	Alcock, 1900; Dev Roy, 2013
Family **Hexapodidae Miers, 1886**	
Hexapus bidentatus Velip and Rivonker, 2014	Velip and Rivonker, 2014
Hexapus sexpes (Fabricius, 1798)	Hegde *et al*., 2013
Section **Eubrachyura, Saint Laurent, 1980**	
Subsection **Thoracotremata Guinot, 1977**	
Family **Gecarcinidae MacLeay, 1838**	
Cardisoma carnifex (Herbst, 1796)	Dev Roy and Nandi, 2005; Dev Roy, 2013
Family **Grapsidae MacLeay, 1838**	
Grapsus albolineatus Latreille, in Milbert, 1812	Alcock, 1900; Dev Roy, 2013
Metopograpsus latifrons (White, 1847) (Fig. 1C, D)	Present study Ten males and nine females collected from mangroves of Chapora and Mandovi estuary.
Metopograpsus messor (Forskål, 1775)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Family **Sesarmidae Dana, 1851**	
Clistocoeloma lanatum (Alcock, 1900) (Fig. 1E, F)	Present study One male and one female collected from mangroves of Divar island, Mandovi estuary.
Clistocoeloma merguiense De Man, 1888	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Episesarma mederi (H. Milne Edwards, 1854))	Dev Roy, 2013
Episesarma versicolor (Tweedie, 1940)	Bhat and Trivedi, 2021
Nanosesarma andersonii (De Man, 1888)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Nanosesarma minutum (De Man, 1887)	Vijaylaxmi, 2020
Nanosesarma batavicum (Moreira, 1903)	Vijaylaxmi, 2020
Neosarmatium malabaricum (Henderson, 1893) (Fig. 1G, H)	Present Study Three males and one female collected from mangroves around Dhauji ferry terminal, Mandovi estuary.
Parasesarma bengalense (Davie 2003) (Fig. 1I, J)	Present study Six males and six females collected from mangroves of Chapora and Sal estuary.
Parasesarma plicatum (Latreille, 1803)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Parasesarma bidens (De Haan, 1835) (Dev Roy and Bhadra (2008); Dev Roy (2013) recorded this species as *Perisesarma bidens* (De Haan, 1835) but a recent revision of the genus *Perisesarma*, De Man, 1895 now places this	Dev Roy and Bhadra, 2008; Dev Roy, 2013

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taxon under the genus *Parasesarma*, De Man, 1895 cf. Shahdadi and Schubart, 2018)	
Perisesarma dussumieri (H. Milne Edwards, 1853) (Fig. 2A, B)	Present study One male collected from mangroves of Divar island, Mandovi estuary.
Pseudosesarma edwardsii (De Man, 1887)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Pseudosesarma glabrum Ng, Rani and Bijoy Nandan, 2017 (Fig. 2C, D)	Present Study Three males and 3 females collected from embankments adjacent to mangroves from Chapora estuary.
Sarmatium crassum Dana, 1851	Bhat *et al.*, in press
Family **Varunidae H. Milne Edwards, 1853**	
Pseudograpsus intermedius Chhapgar, 1955	Vijaylaxmi, 2020
Varuna litterata (Fabricius, 1798)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Family **Plagusiidae Dana, 1851**	
Plagusia immaculata Lamarck,1818	Dev Roy, 2013
Family **Dotillidae Stimpson, 1858**	
Dotilla myctiroides H. Milne Edwards, 1852	Kemp, 1919a; Dev Roy, 2013; Padate *et al.*, 2015
Ilyoplax gangetica (Kemp, 1919)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Scopimera proxima Kemp, 1919	Kemp, 1919a; Dev Roy, 2013
Family **Macrophthalmidae Dana, 1851**	
Macrophthalmus (Macrophthalmus) brevis (Herbst, 1804) (Fig. 2E, F)	Present Study Three males and two females collected from open sand flats, Sal estuary.
Macrophthalmus (Macrophthalmus) parvimanus Guérin, 1834 (Fig. 2G, H)	Present Study Two males collected from open sand flats, Sal estuary.
Macrophthalmus (Mareotis) pacificus Dana, 1851	Kemp, 1919b; Dev Roy and Bhadra, 2008; Dev Roy, 2013
Family **Ocypodidae Rafinesque, 1815**	
Austruca annulipes (H. Milne Edwards, 1837)	Vijaylaxmi, 2020
Austruca lactea (De Haan, 1835)	Dev Roy and Bhadra, 2008; Dev Roy, 2013
Gelasimus vocans (Linnaeus, 1758)	Vijaylaxmi, 2020
Ocypode ceratophthalmus (Pallas, 1772)	Dev Roy and Bhadra, 2008; Dev Roy, 2013; Komarpant *et al.*, 2018
Tubuca alcocki Shih, Chan and Ng, 2018 (Fig. 2I, J)	Present Study Four males collected from mangroves of Chapora and Sal estuary
Tubuca dussumieri (H. Milne Edwards, 1852)	Dev Roy and Nandi, 2005; Dev Roy, 2013

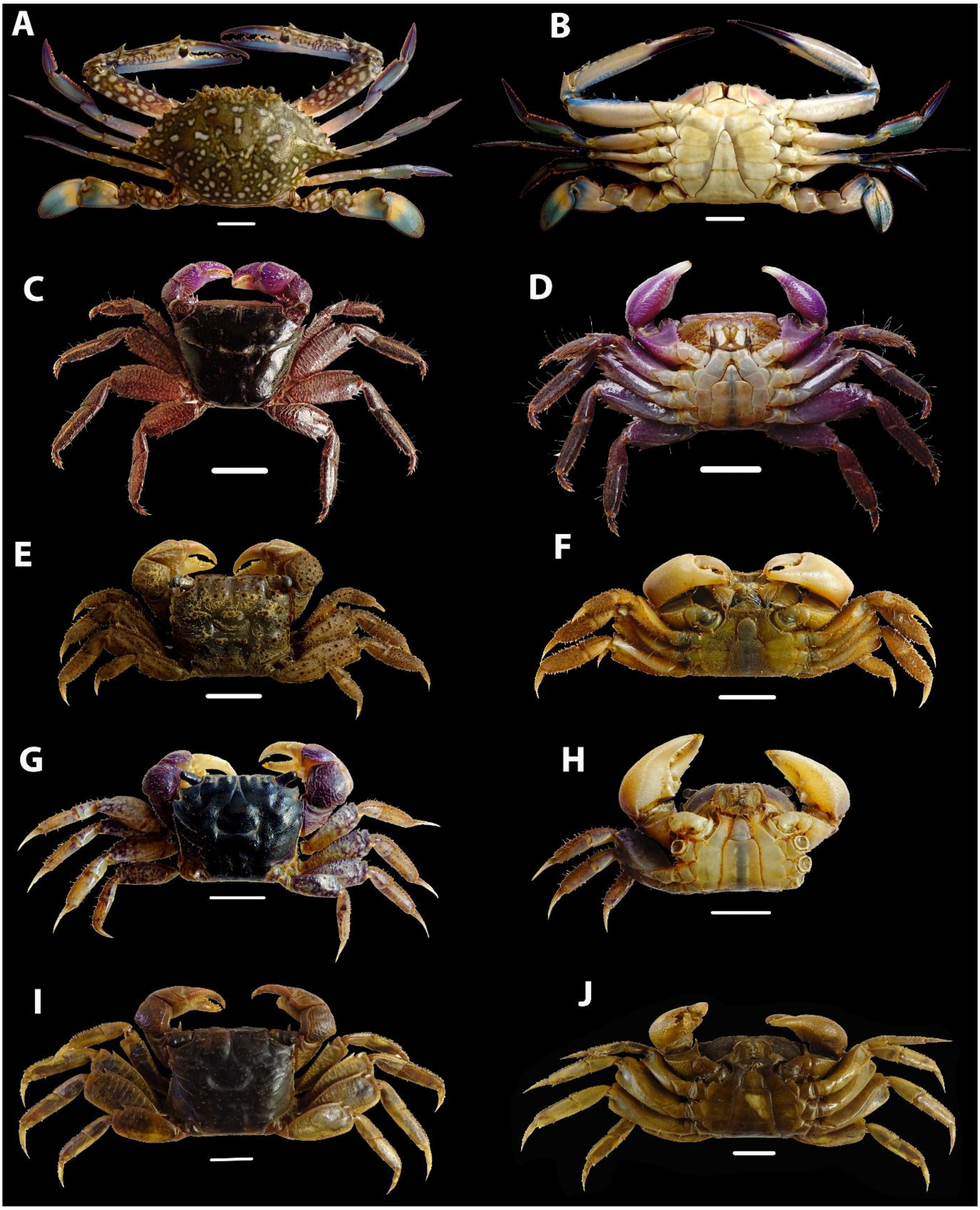

Fig. 1. *Portunus reticulatus* (Herbst, 1799), male, A. Dorsal habitus, B. Ventral habitus; *Metopograpsus latifrons* (White 1847), male, C. Dorsal habitus, D. Ventral habitus; *Clistocoeloma lanatum* Alcock, 1900, male, (Preserved colouration), E. Dorsal habitus, F. Ventral habitus; *Neosarmatium malabaricum* (Henderson, 1893), male,G. Dorsal habitus, H. Ventral habitus; *Parasesarma bengalense* (Davie, 2003), male, (Preserved colouration), .I. Dorsal habitus, J. Ventral habitus. Scale: A, B 20mm; C, D, G-J 10 mm; E, F 5mm.

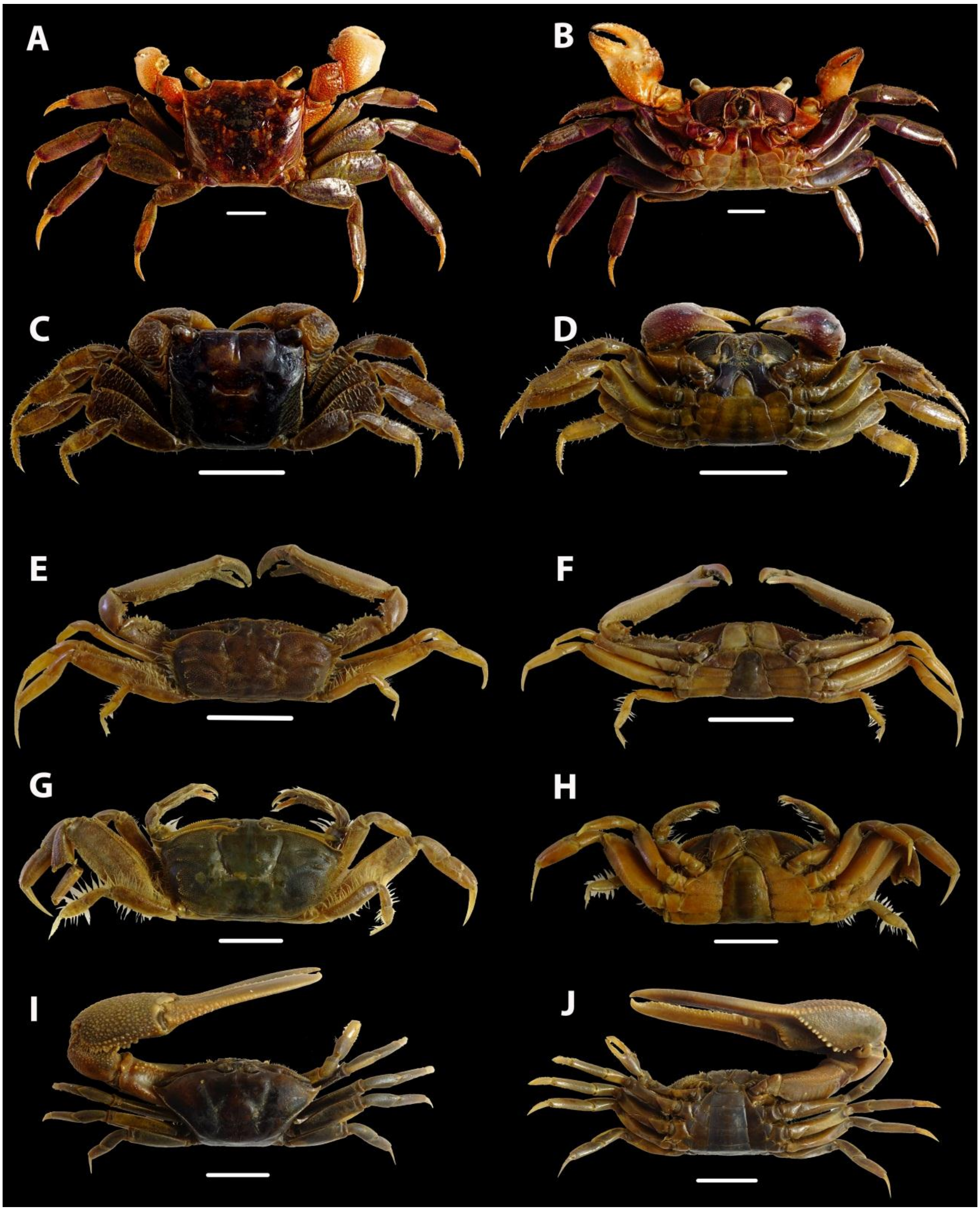

Fig. 2. *Perisesarma dussumieri* (H. Milne Edwards, 1853) male, A. Dorsal habitus, B. Ventral habitus; *Pseudosesarma glabrum* Ng, Rani and Bijoy Nandan, 2017, male, (Preserved colouration), C. Dorsal habitus, D. Ventral habitus; *Macrophthalmus (Macrophthalmus) brevis* (Herbst, 1804) male, (Preserved colouration), E. Dorsal habitus, F. Ventral habitus; *Macrophthalmus (Macrophthalmus) parvimanus* Guérin, 1834, male, (Preserved colouration), G. Dorsal habitus, H. Ventral habitus; *Tubuca alcocki* (Shih Chan, and Ng 2018), male, (Preserved colouration), .I. Dorsal habitus, J. Ventral habitus. Scale: A-J 10 mm.

References

Alcock, A. 1895. Materials for a carcinological fauna of India. No. 1. The Brachyura Oxyrhyncha. *Journal of the Asiatic Society of Bengal, Calcutta*, 64 Part 2 (2), 157–291.

Alcock, A. 1896. Materials for a carcinological fauna of India. No. 2. The Brachyura Oxystoma. *Journal of the Asiatic Society of Bengal, Calcutta*, 65, 134–296

Alcock, A. 1898. Materials for a carcinological fauna of India. No. 3. The Brachyura Cyclometopa. Part I. The family Xanthidae. *Journal of the Asiatic Society of Bengal, Calcutta*, 67 Part 2 (1), 67–233.

Alcock, A. 1899. Materials for a carcinological fauna of India. No. 4. The Brachyura Cyclometopa. Part II. A revision of the Cyclometopa with an account of the families Portunidæ, Cancridæ and Corystidæ. *Journal of the Asiatic Society of Bengal, Calcutta*, *68*, 1–104.

Alcock, A. 1900. Materials for a carcinological fauna of India. No. 6. The Brachyura Catametopa or Grapsoidea. *Journal of the Asiatic Society of Bengal, Calcutta*, 69(3), 279–486.

Alcock, A. 1901. Catalogue of the Indian Decapod Crustacea in the collection of the Indian Museum Part I. Brachyura. Fasciculus I. Introduction and Drmides or Dromiacea (Brachyura Primigenia). *Indian Museum, Calcutta*, 1–80.

Ansari, Z. A. and Harkantra, S. N. 1975. Crab resources of Goa. *Seafood Export J*., 8(3), 21-24.

Bhat, M., and Trivedi, J. N. 2021. New record of the Sesarmid crab *Episesarma versicolor* (Tweedie, 1940) (Crustacea: Decapoda: Sesarmidae) from the west coast of India. *Journal of Biological Studies*, 3(4), 165–170.

Bhat, M., Rivonker, C.U, Patel, K and Trivedi, J. N. in press. First confirmed record of *Sarmatium crassum* Dana, 1851 (Crustacea: Decapoda: Sesarmidae) from India. *Nauplius.*

Chopra, B., and Das, K. 1930. Further notes on Crustacea Decapoda in the Indian Museum. I. On two new speies of Hymenosomatid crabs, with notes on some other species. *Records of Indian Museum*, *32*, 413–429.

Deb, M. 1989. Contribution to the study of Xanthidae. Ataeinae (Decapoda: Crustacea) of India. *Records of the Zoological Survey of India*, Occasional paper, 117, 1–59

Dev Roy, M. K. 2008. An annotated checklist of mangrove and coral reef inhabiting brachyuran crabs of India. *Records of the Zoological Survey of India*, Occasional Paper, 289, 1-212.

Dev Roy, M. K. 2013. Diversity and distribution of marine brachyuran crab communities inhabiting west coast of India. *In* C. Venkataraman, K., Sivaperuman, C. and Raghunathan (Eds.), *Ecology and Conservation of Tropical Marine Faunal Communities*, *Part 1* Springer, Berlin and Heidelberg, 147–169.

Dev Roy, M. K., and Bhadra, S. 2008. Marine and estuarine crabs (Crustacea : Decapoda : Brachyura). *In:* Director ZSI, Kolkata (Ed.), Fauna of Goa, *State Fauna Series*. *Zoological Survey of India*, 16, 109–154.

Dev Roy, M. K. and Nandi, N.C. 2005. On the brachyuran crabs of Salim Ali Bird Sanctuary, Goa. *Journal of Environment and Sociobiology*, 2 (1 &2), 123.

Fernandes, L. L., Kessarkar, P. M., Suja, S., Ray, D., and Bhat, M. 2018. Seasonal variations in the water quality of six tropical micro- and mesotidal estuaries along the central west coast of India. *Marine and Freshwater Research*, 69(9), 1418–1431.

Galil, B. S. 2009. An examination of the genus *Philyra* Leach, 1817 (Crustacea, Decapoda, Leucosiidae) with descriptions of seven new genera and six new species . *Zoosystema*, 31(2), 279–320.

Guinot, D. 1985. Révision du genre *Parapanope* De Man, 1895 (Crustacea, Decapoda, Brachyura), avec description de trois espèces nouvelles. *Bulletin Du Muséum National d'histoire Naturelle, Paris*, Series 4,7 (A3), 677–707.

Hegde, M. R. 2013. Studies on spatio-temporal variation and community structure of demersal resources of Goa, west coast of India. PhD Thesis, Goa University, Goa, India. http://irgu.unigoa.ac.in/drs/handle/unigoa/5352

Hegde, M. R., Padate, V. P., Velip, D. T., and Rivonker, C. U. 2013. An updated inventory of new records of coastal macrofauna along Goa, west coast of India. Indian Journal of Geo-Marine Sciences, 42(7), 898–902.

Joshi, S., Savant, S., Kulkarni, V., Shenai-Tirodkar, P., Emparanza, E. J. M., and Jagtap, T. G. 2011. Occurrence of the spider crab *Acanthonyx euryseroche*, a seaweed associate along the central west coast of India.

ISBN No.: 978-93-83409-65-5

Current Science, 100(8), 1236–1240.

Kaullysing, D., Padate, V. P., and Rivonker, C. U. 2015. New records of *Epixanthus frontalis* and *Heteropanope glabra* (Decapoda: Brachyura: Oziidae, Pilumnidae) for Goa, India, with identification keys of their respective genera. *Indian Journal of Geo-Marine Sciences*, 44(8), 1191–1199.

Kemp, S. 1917. Notes on Crustacea Decapoda in the Indian Museum. 10. Hymenosomatidae. *Records of Indian Museum*, 13(4), 243–279.

Kemp, S. 1919a. Notes on Crustacea Decapoda in the Indian Museum.12. Scopimerinae. *Records of Indian Museum*, 16(5), 305–348.

Kemp, S. 1919b. Notes on Crustacea Decapoda in the Indian Museum.13. The Indian species of *Macrophthalmus*. *Records of Indian Museum*, 16(5), 383–394.

Komarpant, S., Padate, V. P., and Rivonker, C. U. 2018. Morphology, growth and behaviour of *Ocypode ceratophthalma* (Pallas, 1772) (Decapoda: Brachyura: Ocypodidae) from Goa, west coast of India. *Journal of the Marine Biological Association of India*, 60(1), 71–76.

Kumar, S. V., Pathak, K. C., Pednekar, P., Raju, N. S. N., and Gowthaman, R. 2006. Coastal processes along the Indian coastline. *Current Science*, 91(4), 530–536.

Lee, S., Mendoza, J. C. E., Ng, P. K. L., and Kim, W. 2013. On the identity of the indo-west pacific littoral Xanthid crab, *Leptodius exaratus* (H. Milne Edwards, 1834) (Crustacea: Decapoda: Brachyura: Xanthidae). *Raffles Bulletin of Zoology*, 61(1), 189–204.

Ng, P. K. L., Guinot, D., and Davie, P. J. F. 2008. Systema Brachyurorum : Part I . An annotated checklist of extant brachyuran crabs of the world. *The Raffles Bulletin of Zoology*, 17 (Supplement), 1–286.

Padate, V. P. 2010. Biodiversity of demersal fish along the estuarine shelf regions of Goa. PhD Thesis, Goa University, Goa, India. http://irgu.unigoa.ac.in/drs/handle/unigoa/3744

Padate, V. P., Rivonker, C. U., and Anil, A. C. 2013. A new record of *Scylla olivacea* (Decapoda, Bachyura, Portunidae) from Goa, central west coast of India- A comparative diagnosis. *Indian Journal of Geo-Marine Sciences*, 42(1), 82–89.

Padate, V. P., Rivonker, C. U., Anil, A. C., Sawant, S. S., and Krishnamurthy, V. 2010. A new species of portunid crab of the genus *Charybdis* (De Haan, 1833) (Crustacea: Decapoda: Brachyura) from Goa, India. *Marine Biology Research*, *6*(6), 579–590.

Padate, V., Vijaylaxmi, J., Maurya, S., and Rivonker, C. U. 2015. Morphology and morphometrics of *Dotilla myctiroides* (Decapoda : Brachyura : Dotillidae) from an impacted beach of Goa along west coast of India. *Journal of Marine Biological Association of India*, 57(2) 5–10.

Parulekar, A. H., Dhargalkar, V. K., and Singbal, S. Y. S. 1980. Benthic studies in Goa estuaries. Part 3. Annual cycle f macrofaunal distribution, production and trophic relations. *Indian Journal of Marine Sciences*, 9, 189–200.

Shahdadi, A., and Schubart, C. D. 2018. Taxonomic review of *Perisesarma* (Decapoda: Brachyura: Sesarmidae) and closely related genera based on morphology and molecular phylogenetics: New classification, two new genera and the questionable phylogenetic value of the epibranchial tooth. *Zoological Journal of the Linnean Society*, 182(3), 517–548.

Trivedi, J. N., Trivedi, D. J., Vachhrajani, K. D., and Ng, P. K. L. 2018. An annotated checklist of the marine brachyuran crabs (Crustacea: Decapoda: Brachyura) of India. *Zootaxa* 4502 (1) 1-83.

Velip, D. T. 2017. Studies on demersal fish community along the fishing grounds of Goa, west coast of India. PhD Thesis, Goa University, Goa, India.
http://irgu.unigoa.ac.in/drs/handle/unigoa/5520.

Velip, D. T., and Rivonker, C. U. 2014. *Hexapus bidentatus* sp. nov. (Crustacea: Decapoda: Brachyura: Hexapodidae), a new species from Goa, west coast of India. *Marine Biology Research*, 11(1), 97–105.

Vijaylaxmi, J. 2020. Studies on the inter-tidal rocky shore crabs (Decapoda: Crustacea: Brachyura) from Goa, West coast of India. PhD Thesis, Goa University, Goa, India.
http://irgu.unigoa.ac.in/drs/handle/unigoa/6308.

Vijaylaxmi, J., Padate, V. P., and Rivonker, C. U. 2016. First distributional record of *Carupella banlaensis* from India. *Marine Biology Research*, 12(1), 104–111.

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On chimney building activity of brachyuran crab *Dotilla blanfordi* Alcock, 1900 inhabiting mudflat habitat of Gulf of Khambhat, Gujarat

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ABSTRACT

The present study was carried out to find out effects body size, sex and life stage on the chimney building activity of *Dotilla blanfordi* Alcock, 1900. Field work for present study was conducted at Dandi beach in the months of February and March 2021. After two hours of low tide, once the chimney building activity is over, chimneys were selected randomly and their width, height, and weight were recorded. Once the data for chimney was recorded, the occupant crab was capture by digging the burrow. The inhabitant crab was measured for carapace size and its sex was identified. Total 427 samples were examined to record morphological data of chimney as well as of the occupant crab. The results of the study revealed that chimney construction varied significantly between different sexes and life stages (adult and juvenile) of *D. blanfordi*. Males were observed constructing large chimneys as compared to females, similarly adult individuals were also constructing large chimney as compared to juveniles. In case of females, ovigerous female were constructing wider and heavier chimneys as compared to non- ovigerous females. The body size of *D. blanfordi* showed significant positive relationship with morphological parameters of chimneys. According to the studies, males of mudflat inhabiting crab makes larger chimney to attract the females. Ovigerous females make wider chimney for easy movement during the incubation of period of the eggs attached to their abdomen. The present study reveals that crab body size, sex and life stages have pronounced effect chimney building behaviour.

Key words: *Dotilla blanfordi*, Chimney morphology, biogenic sedimentary structure, Intertidal region, Dandi beach, India

Introduction

Several organisms in nature are associated with the formation of sedimentary structures, which are called as biogenic sedimentary structures (Frey, 1973). These structures are viewed as physical manifestations of the behavioural phenotypes of builders (Bailey, 2012). Such structures are produced by the activity of animals on soil substrate such as feeding holes formed by rays (Gregory *et al.*, 1979), gallery construct by polychaete (François *et al.*, 2002), chimney construct by crayfish (Mcmanus, 1960), burrow construct by mudskipper (Dinh *et al*., 2014), and various mud structure (e.g., hood, mudball, pillar, chimney) build by brachyuran crabs of super family Ocypodoidea (Crane, 1975). Morphology, functions and name of such structure varies with species to species (Pardo *et al*., 2020). One of such organisms are the burrowing crabs who may build chimney over their burrows in the intertidal region of sandy/muddy shore. Chimney have various functions such as protect burrow from intruder (Wada and Murata, 2000), protect owner from predator (Shih *et al.,* 2005), and regulate the internal condition in terms of humidity and temperature (Thurman, 1984; Gusmao-Junior *et al.*, 2012) but significant function of chimney till date remains unclear and very less studies have been conducted (Tina *et al*., 2017a).

In most of the mudflat inhabiting crabs either male or female or both make the chimneys (Shih *et al.,* 2005).The material used for building such chimney varies between the crab species as some species use dug out sediment from the burrow (Shih *et al*., 2005), while some use the surface sediment (Wada and Murata, 2000). It is also observed that the reproductive status of female may also affectsthe characteristics of chimney morphological as ovigerous females build taller and wider chimney as compared to those of non-ovigerous females (Tina *et al*., 2017b).

The crabs of the genus *Dotilla* are ecologically important members of tropical sandy- muddy shore intertidal communities, residing generally in the mid to low intertidal region (Allen, 2010). These crabs are very well associated with the chimney building behaviour. One of the species *D. blanfordi* prefer to live in sandy to muddy shore and commonly reported from the tropical Indo-Pacific region (Bradshaw and Scoffin, 1999). During high tide they live inside the burrow and emerge onto surface for various activity during low tide, when their habitat is exposed. Majority of the studies on the chimney building behaviour is concentrated on different species of fiddler crabs (Wadaand Murata, 2000; Shih *et al*., 2005; Slatyer *et al*., 2008; Tina *et al.*, 2017a; Pardo *et al*., 2020) while t such studies are not done for species of *Dotilla*. Hence the present study was carried out to understand the chimney building activity of *D. blanfordi* in the intertidal region of mudflats of Gulf of Khambhat with respect to different life stages and sexes. Also, we aimed to check the effect of body size of *D. blanfordi* on chimney structure.

Material and methods

Present study was carried out at Dandi beach (20º53'10"N, 72º47'47"E) (Fig. 1) located at the coastal area of Navsari district, Gulf of Khambhat, Gujarat, India in the months of February and March 2021, during low tide. The study area was selected because it supports high abundance of *D. blanfordi*. The burrows of *D. blanfordi* can be easily identified by the presence of chimney and/or specific mudballs pattern present around the burrow opening. Most of crabs complete their chimney building in first two hours of low tide. Chimneys were selected randomly from upper intertidal to lower intertidal region. With the help of scale, height of chimney was measured; the width of chimney was measured using digital vernier callipers (0.01 mm). To record the weight, a thin metal sheet was inserted at the base of the chimney and the entire structure was lifted. The chimney was kept on a calibrated weighing balance and the weight of the chimney was measured in grams. After measuring the

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morphological parameters of chimney, the burrow beneath the chimney was excavated to capture the occupant crab. Once the occupant crab is captured, it was preserved in 10% formalin in a separate vial. In laboratory, the occupant crabs were examined under stereo microscope to record their body size (carapace width (CW) and carapace length (CL)) and sex (male, non-ovigerous female, ovigerous female).The morphological data of the occupant crab was classified in terms of life stages (adult and juvenile) and sex. The occupant crab individuals smaller than 3.5 mm CW were considered as juveniles (Trivedi *et al*., unpublished data). The morphological data of only those chimneys was analysed from which the occupant crab was captured.

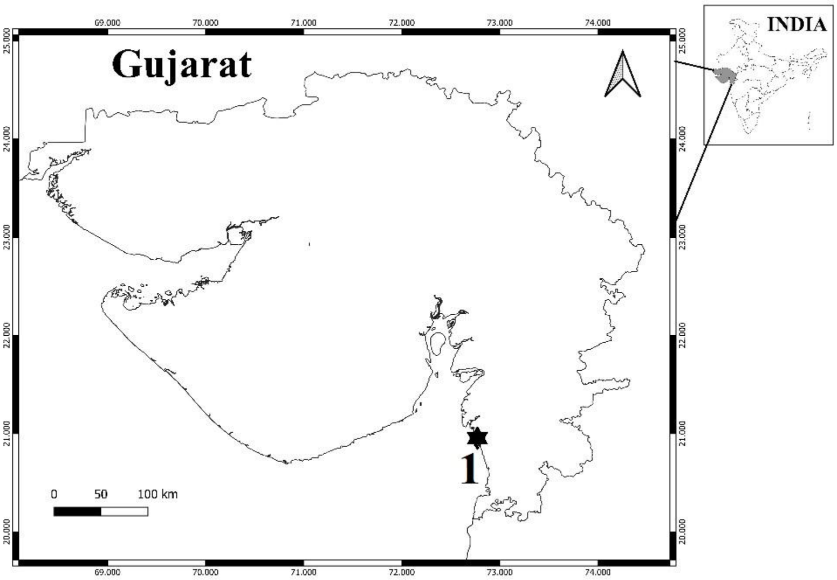

Fig. 1: Map of study site. 1. Dandi, Gujarat, India

The mean values of various morphological characters of chimney were compared between different life stages and sex using paired t test. Regression analysis was also carried out to establish the relationship between carapace width of the occupant crab and different morphological parameters of the chimney. All the statistical analysis were carried out using MS Excel.

Results

In the present study total 427 chimneys were examined, out of which 290 chimneys were constructed by adults and 137 chimneys were constructed by juveniles. In terms of different sexes, 167 chimneys were constructed by males, 231 chimneys were constructed by non-ovigerous females and 29 chimneys were constructed by ovigerous females. Out of total sampled chimneys, the maximum height of the constructed chimney was 36 mm and the minimum height of the constructed chimney was 10 mm with an average height of 16.38$\pm$ 4.85 mm. The maximum width of the constructed chimney was 41.35mm and the minimum width of the constructed chimney was 6.72 mm with the average width of 15.62 $\pm$ 5.69 mm.The maximum weight of the constructed chimney was 26.74 gm and the minimum weight of the constructed chimney was 0.62 gm with the average weight of 5.22$\pm$ 4.28 gm.

Mean carapace width of adult individuals was 4.78± 0.93 mm and of juvenile individuals was 2.72± 0.50 mm.The chimneys constructed by adults and juveniles varied significantly in terms of height, width and weight. Maximum variation was observed for chimney weight followed by chimney width and chimney height (Fig. 2).

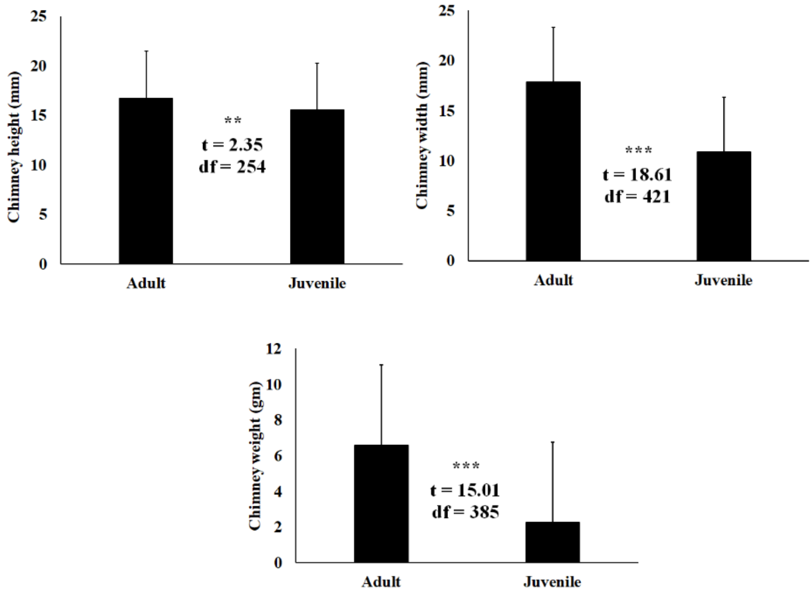

Fig. 2: Mean variation in different morphological parameters in chimney between different life stages *Dotilla blanfordi*.

Mean carapace width of male individuals was 4.76± 1.37 mm and of female individuals was 3.71±1.00 mm. The chimneys constructed by males and females varied significantly in terms of height, width and weight. The maximum variation was observed for chimney weight followed by chimney width and chimney height (Fig. 3).

In case of female individuals, the mean carapace width of non-ovigerous females was 3.61± 1.01 mm and of ovigerous females was 4.40± 0.46 mm. There was a significant variation in the chimneys constructed by non-ovigerous females and ovigerous females too. The maximum variation was observed for chimney weight followed by chimney width and chimney height (Fig. 3). The crab carapace width showed significant correlation with carapace length (r=0.981, P<0.0001), chimney width (r=0.773, p<0.5), chimney height (r=0.222, p<0.0001), and chimney weight (r=0.679, p<0.0001) (Fig. 4).

Discussion

In several species of crabs, male and female both are associated with building of above ground sedimentary structures and *D. blanfordi* is one of them (Wada and Murata, 2000; Slatyer *et al*., 2008; Tina *et al*., 2017a; Padro *et al*., 2020). The individuals of *D. blanfordi* use dug out sediment from the burrow to build chimney around their burrow opening during low tide. The chimney building activity is completed in first two hours of commencement of low tide (Trivedi *et al*., unpublished data). In the present study it was observed that the morphology of chimney constructed by juvenile and adult crabs varied significantly in terms

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of height, width and weight. Chimneys of adults were wider, higher, and heavier than those of juveniles.

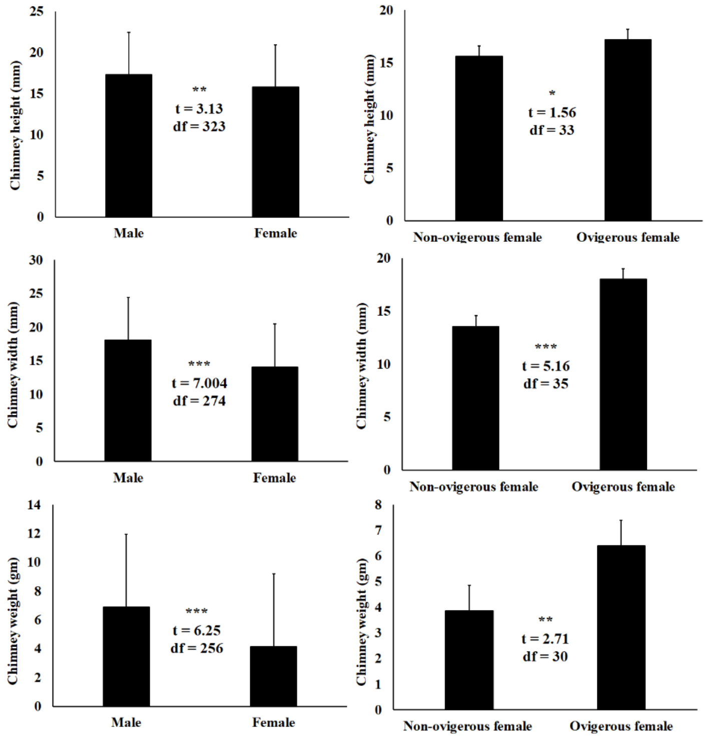

Fig. 3: Mean variation in different morphological parameters in chimney between different sexes of *Dotilla blanfordi*.

Previous studies show that as the crab size (CW) increases, the overall chimney size also increases (Tina *et al*., 2017a, 2018). Studies suggest that the main function of the chimney building is to protect the burrow from the intruders. As the juvenile crabs could not defend the larger intruder crab, they invest more energy and time in chimney building to disguise the intruder (Wada and Murata, 2000).

In the present study, it was observed that both male and female of *D. blanfordi* built chimneys over their burrow. Similar behaviour is found in several other species also like *Uca rosea* (Tina et al., 2017a), *Uca arcuata* (Wada and Murata, 2000), *Uca capricornis* (Slatyer *et al*., 2008) and *Uca thayeri* (Gusmão-Junior *et al*., 2012). The main function of the chimney is to conceal the entrance in order to provide protection against intruders. It has been found that intruder crabs enter more frequently into a burrow without chimney as compared to the burrow with chimney (Tine et al., 2017a). Furthermore, it takes longer time for the intruder crabs to locate and enter in borrow with a chimney than a burrow without chimney (Wada & Murata, 2000; Slatyer *et al*., 2008; Gusmão-Junior *et al*., 2012).

In the present shows that majority of the chimneys were built by females (260 individuals) as compared to males (167 individuals). Similar results were observed in some other species also like *Uca arcuata* (Wada and Muruta, 2000) and *Uca capricornis* (Slatyer *et al*., 2008). Since female have poor ability to fight off the intruding males, building a chimney could benefit more (deRivera *et al*., 2003) also, as females are not involved in courtship behaviour, they can allocate more time and energy for chimney building as compared to males (Slatyer *et al*., 2008). The chimneys are frequently built by females and therefore the function of the chimney in male mate attraction or male-male territorial interactions becomes questionable (Wada and Muruta, 2000). However, in some cases it has been observed that chimney is built by the male to protect the female from other male crabs (Shih *et al*., 2005). The present study also shows that the males of *D. blanfordi* were larger as compared to females. There was a noticeable variation between the chimney morphology build by male and female individuals where the chimney of males was wider, higher, and heavier than those of females. Some studies suggested that relatively large structures build by courting males are sign for attract females (Christy and Wada, 2015) and some biogenic structure such as hood have this function (Christy *et al.,* 2001).

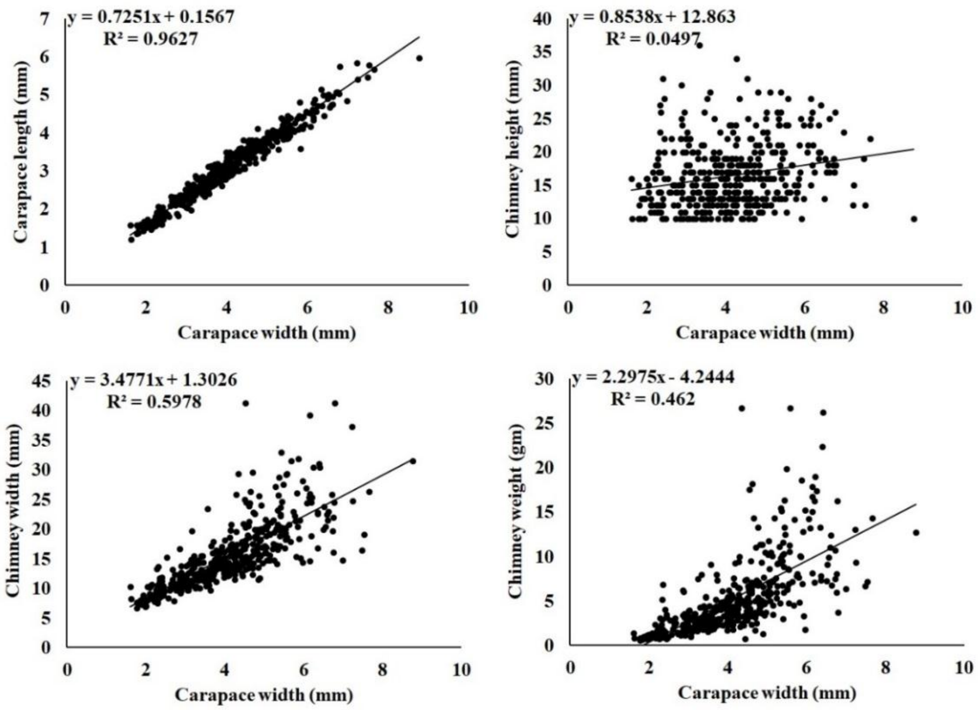

Fig. 4: Regression analysis of carapace width of *Dotilla blanfordi* and different morphological parameters of crab and chimney.

It was also revealed that there are significant variations in the chimney morphological characters of non-ovigerous female and ovigerous female individuals of *D. blanfordi*. Variation in chimney height of ovigerous and non-ovigerous female was very less but ovigerous female were constructing wider and heavier chimneys as compared to non-ovigerous females. Similar results were observed in other burrowing crab species like *Uca rosea* (Tina et al., 2017) and *Uca thayeri* (Gusmão-Junior et al., 2012). Although chimney building is primarily associated with defensive function, building a taller and thicker chimney structure by the ovigerous female would help to regulate the internal conditions of the burrow like burrow moisture and temperature which is important for generation and incubation of egg masses (Gusmão-Junior *et al*., 2012). Studies show that the chimney height and burrow depth are positively correlated to the vertical distance to the water table (Latruffe *et al*., 1999;

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Shih *et al*., 2005). Larger chimney of ovigerous female could be result of more mud excavate for building deeper burrow, compare to those of non-ovigerous females (Tina *et al.*, 2017b). Since deeper burrows would be closer to the underlying water which provides favourable environment for egg incubation (Christy, 1987). Also, ovigerous females build taller and wider chimneys than non-ovigerous females to reduce the intrusion of other crabs (Tina *et al.*, 2017a) as well as to save energy for egg incubation by avoiding conflict with intruder (Gusmao-Junior *et al.*, 2012). The chimney width is positively related to the size of individual (Shih *et al*., 2005) suggesting that the chimney width of ovigerous females is larger as they carry egg mass with them.

Carapace width of *D. blanfordi* showed positive relationship with the chimney morphology in which strong relationship was observed with chimney width and chimney weight. Similar results were observed in *Uca rosea* (Tina *et al*., 2017a). It is suggested that the larger crabs have wider, longer and heavier chimney as compared to the juvenile individuals. A study carried out by Trivedi and Vachhrajani (2016) found that the crab morphometry was having strong correlation with burrow width suggesting that as the size of the crab increases, it requires larger burrow opening to facilitate comfortable movement through the burrow. Tina et al. (2018) in their study found that the chimney characteristics are positively correlated with burrow characteristics suggesting that the chimney morphology is affected by the burrow morphology. Therefore, as the burrow width increases, the chimney width will also increase to enable the individual for easy movement through the chimney. *Dotilla blanfordi* makes chimney by the excavating mud from the burrow, therefore more mud will be excavated to increase the width of the burrow by larger crabs, which will be used to build chimney resulting into increased chimney weight.

Present study revealed that the size, gender and reproductive status have pronounced effect on the morphology of chimney. In the present study it was also observed that the carapace width of crab showed significant correlation with the chimney width, heigh and weight. Since the chimneys were more frequently built by female, the function of chimney in male mate attraction or male-male territorial interactions becomes uncertain and further detailed studies could clearly reveal the role of chimney building in *D. blanfordi* males. The role of building a chimney may vary in different crab species, depending on various factors including population density, competition, sex ratio, predation risk, food availability and reproductive phase.

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References

Allen, C. J. (2010). Ecology of the intertidal crab *Dotilla intermedia* from tsunami-impacted beaches in Thailand. *Ph. D thesis*, University of Southampton, 194 pp.

Bailey, N. W. (2012). Evolutionary models of extended phenotypes. *Trends in ecology & evolution*, 27(10): 561–569.

Bradshaw, C., and Scoffin, T. P. (1999). Factors limiting distribution and activity pattern of the soldier crab *Dotilla myctiroides* in Phuket, South Thailand. *Marine Biology*, 135: 83–87.

Christy, J. H. (1987). Female choice and the breeding behavior of the fiddler crab *Uca beebei*. *Journal of Crustacean Biology*, 7(4): 624–635.

Christy, J. H., and Wada, K. (2015). Social ethology in Brachyura. In: Castro, P., Davie, P., Guinot, D., Schram, F., and von Vaupel Klein, J. C. (Eds.). *Treatise on Zoology-Anatomy, Taxonomy, Biology. The Crustacea, Volume 9 Part C (2 vols).* Leiden, The Netherlands: Brill. 417–468 pp.

Christy, J., Backwell, P. R., and Goshima, S. (2001). The design and production of a sexual signal: hoods and hood building by male fiddler crabs *Uca musica*. *Behaviour*, 138(9): 1065–1083.

Crane, J. (1975). *Fiddler crabs of the world (Ocypodidae: Genus Uca).* Princeton University Press, Princeton, New Jersey, 736 pp.

deRivera, C. E., Backwell, P. R. Y., Christy, J. H., and Vehrencamp, S. L. (2003). Density affects female and male mate searching in the fiddler crab *Uca beebei*. *Behav. Ecol. Sociobiol*, 53: 72–83.

Dinh, Q. M., Giang, N. T. T., Duy, N. N. L., Dong, D. H., and Hau, L. T. (2014). Burrow configuration and utilization of the blue-spotted mudskipper, Boleophthalmus boddarti caught in Soc Trang, Vietnam. *Journal of Fisheries and Environment*, 38(2): 1–9.

François, F., Gerino, M., Stora, G., Durbec, J. P., and Poggiale, J. C. (2002). Functional approach to sediment reworking by gallery-forming macrobenthic organisms: modeling and application with the polychaete Nereis diversicolor. *Marine Ecology Progress Series*, 229: 127–136.

Frey, R. W. (1973). Concepts in the study of biogenic sedimentary structures. *Journal of Sedimentary Research*, 43(1): 6–19.

Gregory, M. R., Ballance, P. F., Gibson, G. W., and Ayling, A. M. (1979). On how some rays (Elasmobranchia) excavate feeding depressions by jetting water. *Journal of Sedimentary Research*, 49(4): 1125–1129.

Gusmão-Junior, J. B., Machado, G. B., and Costa, T. M. (2012). Burrows with chimneys of the fiddler crab *Uca thayeri*: construction, occurrence, and function. *Zoological Studies*, 51(5): 598–605

Latruffe, C., P. K. Mcgregor, and R. F. Oliveira (1999). Visual signalling and sexual selection in male fiddler crabs *Uca tangeri*. *Mar. Ecol. Prog. Ser.*, 189: 233–240.

McManus, L. R. (1960). An Occurrence of" Chimney" Construction by the Crayfish Cambarus B. Bartoni. *Ecology*, 41(2): 383–384.

Pardo, J. C., Stefanelli-Silva, G., Christy, J. H., and Costa, T. M. (2020). Fiddler crabs and their above-ground sedimentary structures: a review. *Journal of Ethology*, 38(2): 137–154.

Shih, H. T., Mok, H. K., and Chang, H. W. (2005). Chimney building by male *Uca formosensis* Rathbun, 1921 (Crustacea: Decapoda: Ocypodidae) after pairing: a new hypothesis for chimney function. *Zoological Studies-Taipei*, 44(2): 242.

Slatyer, R. A., Fok, E. S. Y., Hocking, R., and Backwell, P. R. Y. (2008). Why do fiddler crabs build chimneys? *Biology letters*, 4(6): 616–618.

Thurman, C. L. (1984). Ecological notes on fiddler crabs of south Texas, with special reference to *Uca subcylindrica*. *Journal of Crustacean Biology*, 4(4): 665–681.

Tina, F. W., Jaroensutasinee, M., Keeratipattarakarn, K., and Jaroensutasinee, K. (2018). Sex and burrow/chimney ownership affecting time allocation for surface activities in *Uca rosea* (Tweedie, 1937) (Brachyura, Ocypodidae). *Crustaceana*, 91(1): 51–62.

Tina, F. W., M. Jaroensutasinee, K. Jaroensutasinee, and K. Kanitta, (2017b). Female reproductive status affecting chimney characteristics and time allocation for surface activities in *Uca rosea* (Tweedie, 1937) (Brachyura, Ocypodidae). *Crustaceana*, 90(13): 1605–1613

Tina, F. W., M. Jaroensutasinee, P. Boonsanit, and K. Jaroensutasinee, (2017a). Chimneys of the fiddler crab *Uca rosea* (Tweedie, 1937) reduce the risk of losing burrows to intruders. *Crustaceana*, 90: 589–600.

Trivedi, J. N. and Vachhrajani, K. D. (2016). On burrow morphology of the ghost crab *Ocypode ceratophthalmus* (Decapoda; Brachyura: Ocypodidae) from sandy shore of Gujarat, India. *International Journal of Marine Science*, 6.

Wada, K. and Murata, I. (2000) Chimney building in the fiddler crab *Uca arcuata*. *Journal of Crustacean Biology*, 20: 505–509.

TBC – 115 - PO

Annotated checklist of marine decapods (Crustacea: Decapoda) of Gujarat state with three new records

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Abstract

An annotated checklist of marine decapods crustaceans occurring in coastal areas of Gujarat state, India is compiled on the basis of literature review and specimen collected by authors. The coastal areas of Gujarat state can be divided into three major regions: Gulf of Kachchh, Saurashtra coast and Gulf of Khambhat. The occurrence data on marine decapod crustaceans of Gujarat state is classified in these three regions. A total of 255 species of marine decapod crustaceans belonging to 134 genus and 45 families have been recorded from coastal areas of Gujarat. Out of 255 species of decapods recorded from Gujarat state, 163 species were of brachyuran crabs (Infraorder Brachyura) followed by 53 species of prawns (sub order Dendrobranchiata; Infraorder Stenopodidea and Caridea) and 39 species of anomuran crabs (Infraorder Anomura). In terms of region wise distribution, Gulf of Kachchh is having maximum diversity of marine decapod crustacean diversity (161 species, 97 genera, 39 family) followed by Saurashtra coast (119 species, 74 genera, 32 families), Gulf of Khambhat (49 species, 33 genera, 14 families). In the present study, we are adding three brachyuran crab species *Pseudosesarma glabrum* Ng, Rani & Nandan, 2017, *Carupa tenuipes* Dana, 1852 and *Dotilla malabarica* Nobili, 1903 which are first time reported from Gujarat state.

Keyword: Decapod, Checklist, Gujarat, India, New Records

Introduction

Gujarat has the longest coastline extending about 1650 km among the Indian coastal states, it comprises of various marine habitats including mangroves, coral reefs, rocky shores, mudflats, sandy shores and estuaries (Trivedi *et al.*, 2015a). One of the first studies on crustaceans of Gujarat was carried out in Gulf of Kachchh on anomuran crabs by Southwell (1909). Subsequently Hornell & Southwell (1909) described *Arcotheres placunae* from Beyt

Dwarka, Gulf of Kachchh. Later B.F. Chhapgar curator of Taroporewala Aquarium conducted extensive studies on brachyuran crabs of Gujarat and published series of paper (Chhapgar 1955, 1957a, b 1958a, b). Chhapgar and Mundkar (1955), Chandy (1969, 1973) and Chhapgar *et al.* (2004) published new records of brachyuran crabs from Gulf of Kachchh. Crustacean fauna of Gujarat was compiled by Ghosh (2004) and Fauna of Marine National Park (GOK) was compiled by Subba Rao and Sastry (2005) in Fauna Series of Zoological Survey of India (ZSI). In last two decades many new records and new species have been published from Gujarat (Trivedi *et al.,* 2015b; Trivedi *et al.,* 2016a,b; Gosavi *et al.,* 2017a,b,c; Trivedi and Vachhrajani 2017a,b; Trivedi *et al.*, 2017a,b; Trivedi and Vachhrajani 2018a; Trivedi *et al.,* 2018; Purohit and Vachhrajani, 2019a,b; Bhat and Trivedi, 2021; Patel *et al.,* 2021; Trivedi *et al.,* 2020; Trivedi *et al.,* 2021a,b). Trivedi *et al.* (2015a) compiled a checklist of various crustacean species of Gujarat state. Porcellanid crabs (Infraorder Anomura) and marine crabs (Infraorder Brachyura) of Gujarat were enlisted by Beleem *et al.* (2017a) and Beleem *et al.* (2019a) respectively. Trivedi *et al.,* (2018b) enlisted marine crabs (Infraorder Brachyura) and Radhakrishnan *et al.* (2012) enlisted Penaeoid, Sergestoid, Stenopodid and Caridean prawns (Suborder Dendrobranchiata & Pleocyemata) from Indian waters. The aim of the present study is to create an annotated checklist of marine decapod crustaceans from Gujarat waters based on the recent & previous literature.

Material & Methods

The present checklist is a compilation of species recorded in scientific literature from Gujarat coastal waters and specimen collected by authors. The literature pertaining to Gujarat coastal waters was reviewed, compiled and categorized. Species names were updated according to WORMS website and recent literature. The records were categorized into higher taxonomic groups according to recent decapod classification by DeGrave *et al.* (2009). Records were associated with the verified literature in which they were reported and divided into three regions viz Gulf of Kachchh (GOK), Saurashtra coast (SAU) and Gulf of Khambhat (GOKh). Specimens during the field work were collected by hand picking method during low tide in the intertidal zone. The specimens were cleaned, photographed and preserved in 90% ethanol and deposited in the Zoological Reference collection (LFSc.ZRC), Department of Life Sciences, Hemchandracharya North Gujarat University, Patan, Gujarat, India.

Results

A total of 255 species of marine decapod crustaceans belonging to 134 genus and 45 families have been listed including three new records from Gujarat coast viz. *Pseudosesarma glabrum* Ng, Rani & Nandan, 2017, *Carupa tenuipes* Dana, 1852 and *Dotilla malabarica* Nobili, 1903. Out of 255 species of decapods recorded from Gujarat state, 163 species were of marine crabs (Infraorder Brachyura) followed by 53 species of prawns (sub order Dendrobranchiata; Infraorder Stenopodidea and Caridea) and 39 species of anomuran crabs (Infraorder Anomura).

Infraorder Brachyura consists of 29 families, 93 genera and 163 species. Out of the the 29 families, Portunidae consists highest species diversity (25 species, 8 genera) followed by Xanthidae (18 species, 10 genera), Pilumnidae (13 species, 8 genera), Ocypodidae (12

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species, 4 genera), Sesarmidae (10 species, 7 genera), Leucosiidae (9 species, 7 genera), Macropththalmidae (9 species, 3 genera), Dotillidae (8 species, 3 genera), Epialtidae (8 species, 4 genera), Majidae (6 species, 4 genera), Grapsidae (5 species, 3 genera), Camptandriidae (4 species, 4 genera), Parthenopidae (2 species, 4 genera,), Dromiidae (3 species, 3 genera), Galenidae (3 genera, 3 species), Matutidae (3 species, 2 genera), Varunidae (3 species, 3 genera), Calappidae (2 species,1 genera), Dorippidae (2 species, 2 genera), Eriphiidae (2 species, 1 genera), Euryplacidae (2 species, 1 genera), Hymenosomatidae (2 species, 1 genera), Inachidae (2 species, 2 genera), Menippidae (2 species, 2 genera), Plagusiidae (2 species, 1 genera). Four families like Iphiculidae, Ozzidae, Pinnotheridae, Pseudoziidae were represented by 1 species, 1 genus each. In brachyuran crabs GOK has the maximum diversity of species (109 species, 73 genera, 26 families) followed by SAU (63 species, 45 genera, 21 families) and GOKh (35 species, 26 genera, 11 families).

Infraorder Stenopodidea and Caridea consist of 13 families, 29 genera and 53 species. Out of the 13 families Penaeidae consists highest species diversity (27 species, 10 genera) followed by Palaemonidae (6 species, 5 genera), Alpheidae (5 species, 2 genera), Solenoceridae (4 species, 1 genera), Hippolytidae (3 species, 3 genera). Eight families like Sergestidae, Upogebiidae, Thalassinidae, Callichiridae, Lysmatidae, Thoridae, Pandalidae, Spongicolidae were represented by 1 species, 1 genus each. SAU covers maximum diversity of species (36 species, 21 genera, 8 families) followed by GOK (30 species, 17 genera, 11 families) and GOKh (5 species, 4 genera, 2 families).

Infraorder Anomura (Hermit and Porcellanid crabs) consists of 3 families, 12 genera and 39 species. Out of the 3 families Diogenidae consists highest species diversity (22 species, 4 genera) followed by Porcellanidae (16 species, 7 genera) and Paguridae (1 species, 1 genera). GOK covers maximum diversity of species (22 species, 7 genera, 2 families) followed by SAU (20 species, 8 genera, 3 familes) and GOKh (9 species, 3 genera, 1 family)

Region wise, GOK comprises maximum species diversity of marine decapod crustacean (161 species, 96 genera, 39 family) followed by SAU (119 species, 74 genera, 32 families) and GOKh (49 species, 33 genera, 14 families). Many new species of decapod crustacean have been described from Gujarat especially in recent years from Infraorder Brachyura (*Arcotheres placunae* (Hornell & Southwell, 1909), *Ilyoplax sayajiraoi* Trivedi, Soni, Trivedi & Vachhrajani, 2015, *Lyphira georgei* Trivedi, Soni & Vachhrajani, 2016, *Pilumnus Kempi* Deb, 1987) and Anomura *(Ancylocheles peterngi* Trivedi, Osawa & Vachhrajani, 2017 *Diogenes chhapgari* Trivedi, Osawa & Vachhrajani, 2016).

In India, some decapod crustaceans are only reported from Gujarat state: brachyuran crabs (*Acanthonyx inglei* Tirmizi & Kazmi, 1988, *Austruca iranica* Pretzmann, 1971, *Chaenostoma sinuspersici* (Naderloo & Türkay, 2011), *Dentoxanthus iranicus* Stephensen, 1946, *Ilyoplax frater* (Kemp, 1919), *Ilyoplax stevensi* (Kemp, 1919), *Leptochryseus kuwaitense* (Jones & Clayton, 1983), *Macrophthalmus (Mareotis) laevis* A. Milne-Edwards, 1867, *Nasima dotilliformis* (Alcock, 1900), *Opusia indica* (Alcock, 1900), *Parasesarma persicum* Naderloo & Schubart, 2010, *Pilumnopeus convexus* (Maccagno, 1936), *Scopimera crabricauda* Alcock, 1900, *Seulocia pulchra* (Shen & Chen, 1978)), a shrimp *Neocallichirus jousseaumei* (Nobili, 1904) and anomuran crabs (*Clibanarius virescens* (Krauss, 1843), *Areopaguristes*

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perspicax (Nobili, 1906), *Clibanarius nathi* Chopra & Das, 1940, *Clibanarius ransoni* Forest, 1953, *Diogenes lophochir* (Morgan, 1989))

Table 3. Annotated checklist of marine decapod crustaceans of Gujarat state

	ORDER DECAPODA Latreille, 1802	
	SUBORDER DENDROBRANCHIATA Bate, 1888	
	SUPERFAMILY PENAEOIDEA Rafinesque, 1815	
	Family Penaeidae Rafinesque, 1815	
1	*Ganjampenaeopsis uncta* (Alcock, 1905)	SAU (Pravin and Manohardoss, 1996)
2	*Kishinouyepenaeopsis maxillipedo* (Alcock, 1905)	Gujarat (Dash *et al.*, 2012)
3	*Megokris granulosus* (Haswell, 1879)	SAU (Purohit and Vachhrajani, 2017)
4	*Megokris sedili* (Hall, 1961)	SAU (Purohit and Vachhrajani, 2017)
5	*Metapenaeopsis stridulans* (Alcock, 1905)	SAU (Pravin and Manohardoss, 1996); Gujarat (Dash *et al.*, 2012)
6	*Metapenaeopsis toloensis* Hall, 1962	Gujarat (Dash *et al.*, 2012*);*
7	*Metapenaeus affinis* (H. Milne Edwards, 1837)	GOK (Subba Rao and Sastry, 2005); SAU (Joseph and Soni, 1986; Khan, 1986; Pravin and Manohardoss, 1996, Chanda and Roy, 2004); Gujarat (Dash *et al.*, 2012)
8	*Metapenaeus alcocki* M.J. George & Rao, 1968	GOK (George and Rao, 1968)
9	*Metapenaeus brevicornis* (H. Milne Edwards, 1837)	GOK (Ramamurthy, 1963; 1965; Sarvaiya, 1978; Subba Rao and Sastry, 2005); SAU (Joseph and Soni, 1986; Chanda and Roy, 2004); Gujarat (Dash *et al.*, 2012)
10	*Metapenaeus dobsoni* (Miers, 1878)	GOKh (Patel and Balapatel, 1982; Solanki *et al.*, 2016); Gujarat (Dash *et al.*, 2012)
11	*Metapenaeus kutchensis* P. C. George, *et al.*, 1963	GOK (George *et al.*, 1963; Ramamurthy, 1965; Sarvaiya, 1978;Subba Rao and Sastry, 2005); SAU (Joseph and Soni, 1986; Khan, 1986); Gujarat (Dash *et al.*, 2012)
12	*Metapenaeus monoceros*(Fabricius, 1798)	GOK (Ramamurthy, 1963; Chanda and Roy, 2004; Subba Rao and Sastry, 2005); SAU (Khan, 1986; Joseph and Soni, 1986; Pravin and Manohardoss, 1996; Chanda and Roy; 2004); GOKh (Chanda and Roy, 2004); Gujarat (Dash *et al.*, 2012);
13	*Metapenaeus stebbingi* Nobili, 1904	GOK (Ramamurthy, 1964; 1965)
14	*Mierspenaeopsis hardwickii* (Miers, 1878)	GOK (Rao and Sastry, 2005); SAU (Khan, 1986; Joseph and Soni, 1986; Pravin and Manohardoss, 1996); Gujarat (Dash *et al.*, 2012)
15	*Mierspenaeopsis sculptilis* (Heller, 1862)	GOK (Ramamurthy, 1963a; Ramamurthy, 1965; Subba Rao and Sastry, 2005); SAU (Joseph and Soni, 1986; Khan, 1986); GOKh (Patel and Balapatel, 1982; Chanda and Roy, 2004; Solanki *et al.*, 2016); Gujarat (Dash *et al.*, 2012)
16	*Parapenaeopsis stylifera* (H.Milne Edwards, 1837)	GOK (Ramamurthy, 1963a; Ramamurthy, 1965; Sarvaiya, 1978; Subba Rao and Sastry, 2005); SAU (Joseph and Soni, 1986; Khan, 1986;

		Pravin and Manohardoss, 1996; Chanda and Roy, 2004; Dineshbabu 2005); Gujarat (Dash *et al.*, 2012)
17	*Parapenaeus fissuroides indicus* Crosnier, 1986	SAU (Purohit and Vachhrajani, 2017)
18	*Parapenaeus longipes* Alcock, 1905	SAU (Chakraborty and Thumber, 2007)
19	*Penaeus canaliculatus*(Olivier, 1811)	GOK (Ramamurthy, 1963a; Ramamurthy, 1965;Subba Rao and Sastry, 2005); SAU (Joseph and Soni, 1986); Gujarat (Dash *et al.*, 2012)
20	*Penaeus indicus* H. Milne Edwards, 1837	GOK (Ramamurthy, 1965; Sarvaiya, 1978); Gujarat (Dash *et al.*, 2012)
21	*Penaeus japonicus* Spence Bate, 1888	GOK (Rao and Sastry, 2005); SAU (Joseph and Soni, 1986); Gujarat (Dash *et al.*, 2012);
22	*Penaeus latisulcatus* Kishinouye, 1896	GOK (Chanda and Roy, 2004); SAU (Chanda and Roy, 2004); Gujarat (Dash *et al.*, 2012)
23	*Penaeus merguiensis* de Man, 1888	GOK (Rao and Sastry, 2005); SAU (Joseph and Soni, 1986); Gujarat (Dash *et al.*, 2012)
24	*Penaeus monodon* Fabricius, 1798	GOK (Ramamurthy, 1963a;Subba Rao and Sastry, 2005); SAU (Joseph and Soni, 1986); GOKh (Solanki *et al.*, 2016); Gujarat (Dash *et al.*, 2012)
25	*Penaeus penicillatus* Alcock, 1905	GOK (Rao and Sastry, 2005); SAU (Joseph and Soni, 1986; Chanda and Roy, 2004); Gujarat (Dash *et al.*, 2012);
26	*Penaeus semisulcatus* De Haan, 1844	GOK (Rao and Sastry, 2005); SAU (Joseph and Soni, 1986); Gujarat (Dash *et al.*, 2012)
27	*Trachysalambria curvirostris* (Stimpson, 1860)	SAU (Pravin and Manohardoss, 1996; Chanda and Roy, 2004)
	Family Solenoceridae Wood-Mason & Alcock, 1891	
28	*Solenocera choprai* Nataraj, 1945	Gujarat (Dash *et al.*, 2012)
29	*Solenocera crassicornis* (H. Milne Edwards, 1837)	GOK (Rao and Sastry, 2005); SAU (Joseph and Soni, 1986; Khan, 1986; Pravin and Manohardoss, 1996); Gujarat (Dash *et al.*, 2012)
30	*Solenocera koelbeli* (De Man, 1911)	SAU (Purohit and vachhrajani, 2017)
31	*Solenocera hextii* Wood-Mason & Alcock, 1891	Gujarat (Dash *et al.*, 2012)
	SUPERFAMILY SERGESTOIDEA Dana, 1852	
	Family Sergestidae Dana, 1852	
32	*Acetes indicus* H. Milne Edwards, 1830	GOK (Bhatt *et al.*, 1964;Subba Rao and Sastry, 2005); SAU (Khan, 1986; Pravin and Manohardoss, 1996)
	SUBORDER PLEOCYEMATA Burkenroad, 1963	
	INFRAORDER STENOPODIDEA Bate, 1888	
	Family Spongicolidae Schram, 1986	
33	*Microprosthema validum* Stimpson, 1860	GOK (Purohit and Vachhrajani, 2018)
	INFRAORDER CARIDEA Dana, 1852	
	SUPERFAMILY ALPHEOIDEA Rafinesque, 1815	
	Family Alpheidae Rafinesque, 1815	
34	*Alpheus edwardsii* (Audouin, 1826)	SAU (Purohit and Vachhrajani, 2019a)
35	*Alpheus digitalis* De Haan, 1844	GOK (Singh *et al.*, 2003)

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36	*Alpheus lobidens* De Haan, 1849	SAU (Purohit and Vachhrajani, 2019a); GOKh (Purohit and Vachhrajani, 2019a)
37	*Alpheus pacificus* Dana, 1852	SAU (Purohit and Vachhrajani, 2019a)
38	*Athanas dimorphus* Ortmann, 1894	SAU (Purohit and Vachhrajani, 2019a)
	Family Hippolytidae Spence Bate, 1888	
39	*Exhippolysmata ensirostris ensirostris* (Kemp, 1914)	GOK (Ramamurthy, 1965; Subba Rao and Sastry, 2005); SAU (Khan, 1986); Gujarat (Dash *et al.*, 2012);
40	*Latreutes anoplonyx* Kemp, 1914	GOK (Purohit and Vachhrajani, 2017)
41	*Lysmata vittata* (Stimpson, 1860)	SAU (Purohit and Vachhrajani, 2019a)
42	*Saron marmoratus* (Olivier, 1811)	GOK (Radhakrishnan *et al.*, 2012)
	Family Thoridae Kingsley, 1879	
43	*Thor amboinensis* (de Man, 1888)	GOK (Purohit and Vachhrajani, 2019a)
	SUPERFAMILY PALAEMONOIDEA Rafinesque, 1815	
	Family Palaemonidae Rafinesque, 1815	
44	*Exopalaemon styliferus* (H. Milne Edwards, 1840)	GOK (Ramamurthy, 1963; Sarvaiya, 1978; Subba Rao and Sastry, 2005);
45	*Ancylocaris brevicarpalis* Schenkel, 1902	GOK (Katwate and Sanjeevi, 2011)
46	*Cuapetes grandis* (Stimpson, 1860)	SAU (Purohit and Vachhrajani, 2019a)
47	*Nematopalaemon tenuipes* (Henderson, 1893)	GOK (Subba Rao and Sastry, 2005); SAU (Khan, 1986); Gujarat (Dash *et al.*, 2012);
48	*Palaemon pacificus* (Stimpson, 1860)	SAU (Purohit and Vachhrajani, 2019aa)
49	*Palaemon serrifer* (Stimpson, 1860)	SAU (Purohit and Vachhrajani, 2017); Shivrajpur (Purohit and Vachhrajani, 2017)
	SUPERFAMILY PANDALOIDEA Haworth, 1825	
	Family Pandalidae Haworth, 1825	
50	*Procletes levicarina* (Spence Bate, 1888)	SAU (Purohit and Vachhrajani, 2019b)
	INFRAORDER AXIIDEA de Saint Laurent, 1979b	
	Family Callichiridae Manning & Felder, 1991	
51	*Neocallichirus jousseaumei* (Nobili, 1904)	SAU (Beleem *et al.*, 2019b)
	INFRAORDER GEBIIDEA de Saint Laurent, 1979	
	Family Thalassinidae Latreille, 1831	
52	*Thalassina anomala* Herbst, 1804	GOK (Saravanakumar *et al.*, 2006)
	Family Upogebiidae Borradaile, 1903	
53	*Upogebia carinicauda* (Stimpson, 1860)	GOK (Purohit and Vachhrajani, 2017)
	INFRAORDER ANOMURA MacLeay, 1838	
	SUPERFAMILY GALATHEOIDEA Samouelle, 1819	
	Family Porcellanidae Haworth, 1825	
54	*Ancylocheles gravelei* (Sankolli, 1963)	SAU (Beleem *et al.*, 2017a)
55	*Ancylocheles peterngi* Trivedi, Osawa & Vachhrajani, 2017	SAU (Trivedi *et al.*, 2017)
55	*Enosteoides ornatus* (Stimpson, 1858)	GOK (Beleem *et al.*, 2016b; Beleem *et al.*, 2017a)
56	*Pachycheles natalensis* (Krauss, 1843)	SAU (Gosavi *et al.*, 2017a)
57	*Pachycheles tomentosus* Henderson, 1893	SAU (Beleem *et al.*, 2016b)
58	*Petrolisthes armatus* (Gibbes, 1850)	GOK (Southwell 1909)

59	*Petrolisthes boscii* (Audouin, 1826)	GOK (Southwell 1909; Trivedi *et al.*, 2015a; Beleem *et al.*, 2017a Prakash et al., 2013 checklist); SAU (Trivedi and Vachhrajani 2013c; Trivedi *et al.*, 2014b; Trivedi *et al.*, 2015; Beleem *et al.*, 2016b; Beleem *et al.*, 2017a)
60	*Petrolisthes lamarckii* (Leach, 1820)	GOK (Beleem *et al.*, 2014; Trivedi *et al.*, 2014b; Trivedi *et al.*, 2015; Beleem *et al.*, 2017a) SAU (Trivedi and Vachhrajani 2013c; Trivedi *et al.*, 2014b; Trivedi *et al.*, 2015; Beleem *et al.*, 2016b; Beleem *et al.*, 2017a)
61	*Petrolisthes rufescens* (Heller, 1861)	GOK (Haig 1964; Beleem *et al.*, 2016b; Beleem *et al.*, 2017a); SAU (Beleem *et al.*, 2017a)
62	*Petrolisthes tuberculosus* (H. Milne Edwards, 1837 [in H. Milne Edwards, 1834-1840])	GOK (Southwell 1909)
63	*Pisidia dehaanii* (Krauss, 1843)	GOK (Beleem *et al.*, 2017a); SAU (Beleem *et al.*, 2017a)
64	*Pisidia gordoni* (D.S. Johnson, 1970)	GOK (Beleem *et al.*, 2017a)
65	*Pisidia serratifrons* (Stimpson, 1858)	GOK (Southwell 1909)
66	*Polyonyx hendersoni* Southwell, 1909	GOK (Beleem *et al.*, 2017a)
67	*Polyonyx obesulus* Miers, 1884	GOK (Southwell 1909)
68	*Porcellanella triloba* White, 1851	GOK (Ramanandan 1966)
	SUPERFAMILY PAGUROIDE Latreille, 1802 (modified from Trivedi & Vachhrajani, 2017)	
	Family Diogenidae Ortmann, 1892	
69	*Areopaguristes perspicax* (Nobili, 1906)	SAU (Trivedi and Vachhrajani 2017)
70	*Clibanarius arethusa* de Man, 1888 [in de Man, 1887-1888]	SAU (Gosavi et al 2017a)
71	*Clibanarius humilis* (Dana, 1851)	GOK (Southwell 1909; Venkatraman et al 2004)
72	*Clibanarius infraspinatus* (Hilgendorf, 1869)	GOK (Southwell 1909; Trivedi et al 2015; Kachhiya *et al.*, 2017). SAU (Kachhiya *et al.*, 2016). GOKh (Kachhiya *et al.*, 2016)
73	*Clibanarius longitarsus* (De Haan, 1849 [in De Haan, 1833-1850])	GOKh (Kachhiya *et al.*, 2017; Kachhiya *et al.*, 2016) (re-examination required)
74	*Clibanarius nathi* Chopra & Das, 1940	GOK (Venkatraman et al 2004); SAU (Kachhiya *et al.*, 2016)
75	*Clibanarius ransoni* Forest,1953	SAU (Patel *et al.*, 2020)
76	*Clibanarius rhabdodactylus* Forest, 1953	SAU (Kachhiya *et al.*, 2016 , Kachhiya *et al.*, 2017) GOKh (Kachhiya *et al.*, 2017)
77	*Clibanarius rutilus* Rahayu, 1999	SAU (Kachhiya *et al.*, 2017); GOKh (Kachhiya *et al.*, 2016)
78	*Clibanarius padavensis* de Man, 1888 [in de Man, 1887-1888]	GOK (Trivedi et al 2015)
79	*Clibanarius signatus* Heller, 1961	GOK (Venkatraman et al 2004); SAU (Trivedi et al 2015; Kachhiya *et al.*, 2016; Kachhiya *et al.*, 2017); GOKh (Kachhiya *et al.*, 2017)
81	*Clibanarius virescens* (Krauss, 1843)	SAU (Trivedi and Vachhrajani 2017; Kachhiya *et al.*, 2016; Kachhiya *et al.*, 2017) GOKh (Kachhiya *et al.*, 2017)

82	*Clibanarius zebra* (Dana, 1852)	GOK (Venkatraman et al 2004); SAU (Kachhiya *et al.*, 2016; Kachhiya *et al.*, 2017)
83	*Dardanus setifer* (H. Milne Edwards, 1836)	GOKh (Kachhiya *et al.*, 2016)
84	*Diogenes alias* McLaughin & Holthuis, 2001	GOK (Trivedi et al 2015)
85	*Diogenes avarus* Heller, 1865	GOKh (Kachhiya *et al.*, 2016)
86	*Diogenes chhapgari* Trivedi, Osawa & Vachhrajani, 2016	GOKh (Trivedi *et al.*, 2016)
87	*Diogenes edwardsii* (De Haan, 1849 [in De Haan, 1833-1850])	SAU (Kachhiya *et al.*, 2016)
88	*Diogenes fasciatus* Rahayu & Forest, 1995	GOK (Gosavi *et al.*, 2017a)
89	*Diogenes custos* (Fabricius,1798)	GOK (Trivedi *et al.*, 2015)
90	*Diogenes investigatoris* Alcock, 1905	GOK (Southwell 1909; Venkatraman et al 2004)
91	*Diogenes jousseaumei* (Bouvier, 1897)	Gujarat (Alcock, 1905)
	Family Paguridae Latreille, 1802	
92	*Pagurus kulkarnii* Sankoli, 1962	SAU (Kachhiya *et al.*, 2016 ; Trivedi and Vachhrajani 2016)
	INFRAORDER BRACHYURA Linnaeus, 1758 (modified from Trivedi *et al.* 2018b, Beleem *et al.*, 2019a)	
	SECTION DROMIACEA De Haan, 1833	
	SUPERFAMILY DROMIOIDEA De Haan, 1833	
	Family Dromiidae De Haan, 1833	
93	*Ascidiophilus caphyraeformis* Richters,1880	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005; Dev Roy, 2008)
94	*Conchoecetes artificiosus* (Fabricius, 1798) (*Conchoedromia alcocki* Chopra, 1934, is now considered as synonym of *Conchoecetes artificiosus* (Fabricius, 1798); cf. Guinot & Tavares (2000))	SAU (Trivedi *et al.*, 2018a)
95	*Lewindromia unidentata* (Rüppell, 1830)	GOK (Beleem *et al.*, 2019a)
	SECTION EUBRACHYURA de Saint Laurent, 1980	
	SUBSECTION HETEROTREMATA Guinot, 1977	
	SUPERFAMILY CALAPPOIDEA De Haan, 1833	
	Family Calappidae De Haan, 1833	
96	*Calappa exanthematosa* Alcock & Anderson, 1894 (This species has often been confused with *C. japonica* Ortmann, 1892 with which was synonymised until recently; cf. Ng *et al.*, 2011a))	SAU (Trivedi *et al.*, 2018)
97	*Calappa guerini* Brito-Capello, 1871 (This Indian Ocean species has been confused with *C. lophos* (Herbst, 1782); cf. Lai *et al.*, 2006))	GOK (Chandy 1973; Subba Rao & Sastry, 2005) Gujarat (Dev Roy 2013)
	Family Matutidae De Haan, 1835	
98	*Ashtoret miersii* (Henderson, 1887)	GOK (Beleem *et al.*, 2019a); Gujarat (Dev Roy 2013)
99	*Matuta planipes* Fabricius, 1798	GOK (Chandy, 1973; Chhapgar *et al.*, 2004; Subba Rao & Sastry, 2005); SAU (Trivedi & Vachharajani, 2012)

100	*Matuta victor* (Fabricius, 1781) (This species was earlier identified as *Ashtoret lunaris* (Forskål, 1775) on Gujarat coast. (Beleem *et al.,* 2019a)	GOK (Dev Roy & Das, 2000; Chhapgar *et al.,* 2004; Chhapgar 1957a; Subba Rao & Sastry, 2005; Beleem *et al.,* 2014); GoKh (Chhapgar 1957a; Shukla *et al.,* 2013; Pandya & Vachhrajani, 2013); Gujarat (Dev Roy 2013)
	SUPERFAMILY DORIPPOIDEA MacLeay, 1838	
	Family Dorippidae MacLeay, 1838	
101	*Dorippoides nudipes* Manning & Holthuis, 1986 (This species has been confused with *Dorippoides facchino* (Herbst, 1785); cf. Holthuis & Manning (1990))	GOK (Trivedi *et al.,* 2018a)
102	*Dorippe quadridens* (Fabricius, 1793)	GOK (Beleem et al 2019a)
	SUPERFAMILY ERIPHIOIDEA MacLeay, 1838	
	Family Eriphiidae MacLeay, 1838	
103	*Eriphia sebana* Shaw & Nodder, 1803 (This is the senior synonym of *Eriphia laevimana* Guérin, 1832); cf. Koh & Ng (2008))	GOK(Gopalakrishnan, 1970)
104	*Eriphia smithii* MacLeay, 1838	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005); SAU (Thomas 1969); Dev Roy, 2013 (Gujarat)
	Family Menippidae Ortmann, 1893	
105	*Menippe rumphii* (Fabricius, 1798)	GOK (Trivedi *et al.,* 2012; Beleem *et al.,* 2014); SAU (present study)
106	*Myomenippe hardwickii* (Gray, 1831)	SAU (Trivedi & Vachharajani, 2012)
	Family Oziidae Dana, 1851	
107	*Epixanthus frontalis* (H. Milne Edwards, 1834)	SAU (Trivedi & Vachhrajani, 2012)
	SUPERFAMILY GONEPLACOIDEA MacLeay, 1838	
	Family Euryplacidae Stimpson, 1871b	
108	*Eucrate crenata* (De Haan, 1835)	GOK (Chandy, 1973)
109	*Eucrate indica* Castro & Ng, 2010 (This recent species has been confused with *Eucrate alcocki* Seréne, in Seréne & Lohavanijaya, 1973; cf. Castro & Ng (2010))	GOK (Trivedi *et al.,* 2018a)
	SUPERFAMILY LEUCOSIOIDEA Samouelle, 1819	
	Family Iphiculidae Alcock, 1896	
110	*Pariphiculus mariannae* (Herklots, 1852)	GOK (Chandy, 1973)
	Family Leucosiidae Samouelle, 1819	
111	*Arcania heptacantha* (De Haan, 1861)	GOKh (Beleem *et al.,* 2016c)
112	*Arcania septemspinosa* (Fabricius, 1787)	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005)
113	*Leucisca squalina* MacLeay, 1838	SAU (Beleem *et al.,* 2017c; Gosavi *et al.,* 2017b)
114	*Leucosia sima* Alcock, 1896	GOK (Chhapgar, 1957a; Gopalakrishnan, 1970; Subba Rao & Sastry, 2005)
115	*Lyphira georgei* Trivedi, Soni & Vachhrajani, 2016	GOK (Trivedi *et al.,* 2016)
116	*Lyphira perplexa* Galil, 2009	SAU (Trivedi *et al.,* 2019)
117	*Philyra globus* (Fabricius,1775) (Following Galil (2009), *Philyra globulosa* H. Milne Edwards, 1837, is a junior synonym)	GOK (Trivedi *et al.,* 2018a)

118	*Ryphila cancellus* (Herbst, 1783)	SAU (Beleem *et al.*, 2017a)
119	*Seulocia pulchra* (Shen & Chen, 1978)	GOK (Trivedi & Vachhrajani, 2016b)
120	**SUPERFAMILY MAJOIDEA Samouelle, 1819**	
	Family Epialtidae MacLeay, 1838	
121	*Acanthonyx inglei* Tirmizi & Kazmi, 1988	SAU (Trivedi et al 2018)
122	*Acanthonyx limbatus* A. Milne-Edwards, 1862	GOK (Chhapgar, 1961); Gujarat (Dev Roy 2013)
123	*Doclea muricata* (Fabricius, 1788) (This is the senior synonym of *Doclea hybrida* (Fabricius, 1798); cf. Wagner (1986))	GOK (Beleem et al 2019, Trivedi et al 2018a); SAU (Trivedi *et al.*, 2018a)
124	*Doclea rissoni* Leach, 1815 (This is the senior synonym of *Doclea gracilipes* Stimspon, 1857; cf. Wagner (1986))	GOK (Chandy, 1973); Gujarat (Dev Roy, 2013)
125	*Hyastenus hilgendorfi* De Man, 1887	SAU (Trivedi et al 2020)
126	*Hyastenus planasius* (Adams & White, 1848)	GOK (Chhapgar, 1957a); Gujarat (Dev Roy, 2013)
127	*Hyastenus spinosus* A. Milne-Edwards, 1872	SAU (Trivedi et al 2020)
128	*Menaethius monoceros* (Latreille, 1825)	GOK (Subba Rao & Sastry, 2005; Chhapgar, 1957a), Dev Roy, 2013 (Gujarat)
	Family Hymenosomatidae MacLeay, 1838	
129	*Elamena cristatipes* Gravely, 1927	GOK (Subba Rao & Sastry, 2005); GOK (Chhapgar, 1957a)
130	*Elamena sindensis* Alcock, 1900	SAU (Chhapgar, 1958)
	Family Inachidae MacLeay, 1838	
131	*Camposcia retusa* (Latreille, 1829)	GOK (Beleem *et al.*, 2017b)
132	*Encephaloides armstrongi* Wood-Mason, in Wood-Mason & Alcock, 1891	SAU (Dash *et al.*, 2017)
	Family Majidae Samouelle, 1819	
133	*Micippa philyra* (Herbst, 1803)	GOK (Beleem *et al.*, 2016a)
134	*Micippa thalia* (Herbst, 1803)	GOK (Beleem *et al.*, 2016a)
135	*Prismatopus aculeatus* (H. Milne Edwards, 1834)	SAU (Chhapgar, 1957a)
136	*Paramaya mulli* Ng, Prema & Ravichandran, 2018	SAU (Triveli et al 2020)
137	*Schizophrys aspera* (H. Milne Edwards, 1831) (The taxonomy of this species is quite confused as reviewed in Lee *et al.*, (2018), with these author clarifying the date of publication, type specimen and discussing the many junior synonyms)	GOK (Chandy, 1973; Beleem *et al.*, 2014); SAU (Trivedi & Vachharajani, 2012)
138	*Schizophrys pakistanensis* Tirmizi & Kazmi, 1995	SAU (Trivedi et al 2021a)
	SUPERFAMILY PARTHENOPOIDEA MacLeay, 1838	
	Family Parthenopidae † MacLeay, 1838	
139	*Cryptopodia angulata* H. Milne Edwards & Lucas, 1841	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005); SAU (Trivedi & Vachharajani, 2012; Trivedi & Vachhrajani, 2013a)
140	*Cryptopodia echinosa* Chiong & Ng, 1998	GOK (Dev Roy, 2008); Gujarat (Dev Roy, 2013
141	*Enoplolambrus echinatus* (Herbst, 1790)	GOK (Beleem *et al.*, 2014)
142	*Enoplolambrus pransor* (Herbst, 1796)	GOKh (Chhapgar, 1957a)
	SUPERFAMILY PILUMNOIDEA Samouelle, 1819	

	Family Galenidae Alcock, 1898	
143	*Dentoxanthus iranicus* Stephensen, 1946	GOK (Ng *et al.*, 2015)
144	*Galene bispinosa* (Herbst, 1783) (This is the senior synonym of *Galene granulata* Miers, 1884; cf. Ng *et al.*, (2008))	GOK (Chandy, 1973); Gujarat (Dev Roy, 2013)
145	*Halimede tyche* (Herbst, 1801)	GOK (Trivedi *et al.*, 2018a)
	Family Pilumnidae Samouelle, 1819	
146	*Benthopanope indica* (De Man, 1887)	GOKh (Trivedi *et al.*, 2018a)
147	*Eurycarcinus integrifrons* De Man, 1879	GOK (Trivedi et al 2021b)
148	*Eurycarcinus orientalis* A. Milne-Edwards, 1867 (Following Ng *et al.*, (2018), the records from eastern India (e.g., Dev Roy 2008) should all be checked to see if they are indeed this species)	GOKh (Chhapgar, 1957a; Trivedi *et al.*, 2021b commented the specimens from Gujarat and Maharashtra (recorded as *E. orientalis*) in Chhapgar (1957) should be referred to *E. integrifrons*)
149	*Glabropilumnus laevis* (Dana, 1852)	GOK (Trivedi *et al.*, 2015b; Subba Rao & Sastry, 2005; Chhapgar, 1957a); Gujarat (Dev Roy 2013)
150	*Heteropanope glabra* Stimpson, 1858	SAU (Trivedi *et al.*, 2015b; Trivedi *et al.*, 2021b)
151	*Heteropilumnus angustifrons* (Alcock, 1900)	GOK (Chandy, 1973); Gujarat (Dev Roy, 2013)
152	*Heteropilumnus ciliatus* (Stimpson, 1858)	SAU (Trivedi *et al.*, 2018a)
153	*Heteropilumnus setosus* (A. Milne-Edwards, 1873)	GOK (Subba Rao & Sastry, 2005; Dev Roy, 2008; Chhapgar 1957a); Gujarat (Dev Roy, 2013)
154	*Pilumnopeus convexus* (Maccagno, 1936)	GOKh (Gosavi *et al.*, 2017c; Trivedi *et al.*, 2021b)
155	*Pilumnus kempi* Deb, 1987	GOK (Dev Roy & Nandi, 2005; Dev Roy, 2008; Deb, 1987); Gujarat (Dev Roy, 2013)
156	*Pilumnus longicornis* Hilgendorf, 1878	GOK (Subba Rao & Sastry, 2005; Chhapgar, 1957a); Dev Roy 2013 (Gujarat)
157	*Pilumnus minutus* De Haan, 1835	GOK (Trivedi *et al.*, 2018a)
158	*Pilumnus vespertilio* (Fabricius, 1793)	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005; Trivedi *et al.*, 2012; Beleem *et al.*, 2014); SAU (Trivedi & Vachharajani, 2012) ; Dev Roy 2013 (Gujarat)
	SUPERFAMILY PORTUNOIDEA Rafinesque, 1815	
	Family Portunidae Rafinesque, 1815	
159	*Carupa tenuipes* Dana, 1852 (fig. 1 A, B)	SAU (Present study; Material examined: 1 female (CW 33.63 mm, CL 21.87mm) LFSc. ZRC- 73, Kuchchhdi Reef, Gujarat state, India, 31 January, 2018, coll. Jigneshkumar Trivedi)
160	*Charybdis* (*Charybdis*) *affinis* Dana, 1852	SAU (Trivedi *et al.*, 2018a)
161	*Charybdis* (*Charybdis*) *annulata* Fabricius, 1798	GOK (Chandy, 1973); SAU (Trivedi & Vachharajani, 2012); Gujarat (Dev Roy 2013)
162	*Charybdis (Charybdis) callianassa* (Herbst, 1798)	GOK (Chandy, 1973); GOKh (Chhapgar, 1957a); Gujarat (Dev Roy 2013, Rao & Rath, 2013)

163	*Charybdis (Charybdis) feriata*(Linnaeus, 1758) (This is the senior synonym of Charybdis cruciatus (Herbst, 1794))	GOKh & SAU (present study); GOK (Chhapgar, 1957a; Trivedi *et al.*, 2012); Gujarat (Dev Roy 2013, Rao & Rath, 2013)
164	*Charybdis* (*Charybdis*) *lucifera* (Fabricius, 1798)	SAU (Trivedi & Vachharajani, 2012)
165	*Charybdis* (*Charybdis*) *miles* (De Haan, 1835)	GOK (Trivedi *et al.*, 2018a)
166	*Charybdis* (*Charybdis*) *natator* (Herbst, 1794)	GOK (Chandy, 1973) Gujarat (Dev Roy 2013)
167	*Charybdis* (*Charybdis*) *orientalis* Dana, 1852	GOK (Chandy, 1973; Beleem *et al.*, 2014; Dev Roy and Das 2000); Gujarat (Dev Roy 2013)
168	*Charybdis* (*Charybdis*) *riversandersoni* Alcock, 1899	SAU (Trivedi *et al.*, 2018a)
169	*Charybdis* (*Goniohellenus*) *hoplites* (Wood-Mason, 1877)	GOK (Chhapgar, 1957a,); Gujarat (Dev Roy 2013; Dev Roy, 2008)
170	*Charybdis* (*Goniohellenus*) *smithii* MacLeay, 1838 (This is the senior synonym of *Charybdis edwardsi* Leene & Buitendijk, 1949)	GOK & SAU (Trivedi *et al.*, 2018a)
171	*Charybdis* (*Goniohellenus*) *vadorum* Alcock, 1899	GOKh (Trivedi *et al.*, 2018a)
172	*Monomia petrea* (Alcock, 1899)	GOK (Dev Roy & Nandi, 2005; Dev Roy, 2008)
173	*Podophthalmus vigil* (Fabricius, 1798)	SAU (Trivedi *et al.*, 2018a)
174	*Portunus sanguinolentus* (Herbst, 1783)	GOKh & SAU (present study); GOK (Subba Rao & Sastry, 2005) Gujarat (Dev Roy, 2013)
175	*Portunus segnis* (Forskål, 1775) (This species has been confused with *P. pelagicus* (Linnaeus, 1758); cf. Lai *et al.*, (2010))	SAU (Beleem, 2019a; Chhapgar, 1957a; Trivedi & Vachhrajani, 2012;); GOK (Beleem, 2019a; Chandy 1973; Dev Roy & Das, 2000; Trivedi *et al.*, 2012; 2013; Beleem *et al.*, 2014; Subba Rao & Sastry, 2005); Gujarat (Dev Roy, 2013)
176	*Scylla olivacea* (Herbst, 1796)	SAU (Trivedi & Vachhrajani, 2013b)
177	*Scylla serrata* (Forskål, 1775)	GOK (Beleem *et al.*, 2014; Chandy, 1973; Saravanakumar *et al.*, 2007; Trivedi *et al.*, 2012; Trivedi & Vachhrajani, 2013b); SAU (Trivedi & Vachhrajani, 2013b); GOKh (Chhapgar, 1957a; Pandya & Vachhrajani, 2013; Trivedi & Vachhrajani, 2013b); Gujarat (Dev Roy, 2013)
178	*Scylla tranquebarica* (Fabricius, 1798)	SAU, GOKh (Trivedi & Vachhrajani, 2013b)
179	*Thalamita crenata* (Latreille, 1829)	SAU (Trivedi *et al.*, 2018a)
180	*Thalamita poissonii* (Audouin & Savignyi, 1817)	GOK (Chandy, 1969) ; Gujarat (Dev Roy, 2013)
181	*Thalamita prymna* (Herbst, 1803)	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005; Beleem *et al.*, 2014); Gujarat (Dev Roy, 2013)
182	*Xiphonectes hastatoides* (Fabricius, 1798)	GOK (Trivedi *et al.*, 2018a)
183	*Xiphonectes tenuipes* (De Haan, 1835)	GOK (Chhapgar *et al.*, 2004; Trivedi *et al.*, 2015b); Gujarat (Dev Roy, 2013)
	SUPERFAMILY PSEUDOZIOIDEA Alcock, 1898	
	Family Pseudoziidae Alcock, 1898	
184	*Pseudozius caystrus* (Adams & White, 1849)	GOK (Subba Rao & Sastry, 2005)
	SUPERFAMILY XANTHOIDEA MacLeay, 1838	
	Family Xanthidae MacLeay, 1838	
185	*Actaea calculosa* H. Milne Edwards, 1834	GOK (Trivedi *et al.*, 2015b); Gujarat (Dev Roy,

		2013)
186	*Actaea savignii* (H. Milne Edwards, 1834)	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005; Trivedi *et al.*, 2015b); Gujarat (Dev Roy, 2013)
187	*Atergatis integerrimus* (Lamarck, 1818)	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005; Trivedi *et al.*, 2012; Beleem *et al.*, 2014); Gujarat (Dev Roy, 2013)
188	*Atergatis ocyroe* (Herbst, 1801) (This species has been confused with *Atergatis floridus* (Linnaeus, 1767) which is now known only from Southeast Asia and the western Pacific; cf. Ng & Davie (2007))	SAU (Trivedi & Vachhrajani, 2016a)
189	*Atergatis roseus* (Rüppell, 1830)	GOK (Chhapgar, 1957a, 1979; Gopalakrishnan, 1970; Subba Rao & Sastry, 2005); SAU (Trivedi & Vachharajani, 2012) Gujarat (Dev Roy, 2013)
188	*Atergatis subdentatus* (De Haan, 1835)	GOK (Trivedi *et al.*, 2012)
189	*Chlorodiella nigra* (Forskål, 1775)	GOK (Beleem *et al.*, 2014)
190	*Demania baccalipes* (Alcock, 1898)	GOK (Chandy, 1973); SAU (Trivedi & Vachharajani, 2012); Gujarat (Dev Roy, 2013)
191	*Etisus laevimanus* Randall, 1840	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005; Beleem *et al.*, 2014); SAU (Trivedi & Vachharajani, 2012) Gujarat (Dev Roy, 2013)
192	*Euxanthus exsculptus* (Herbst, 1790)	GOK (Chhapgar & Mundkur, 1995; Beleem *et al.*, 2014); Gujarat (Dev Roy, 2013)
193	*Leptodius affinis* (De Haan, 1835) (This widespread species has been confused with *Leptodius exaratus* (H. Milne Edwards, 1834); cf. Lee *et al.*, (2013))	SAU, GOK (Trivedi & Vachhrajani, 2015)
194	*Leptodius exaratus* (H. Milne Edwards, 1834)	GOK (Chandy, 1973; Dev Roy & Das, 2000); Gujarat (Dev Roy, 2013)
195	*Macromedaeus crassimanus* (A. Milne-Edwards, 1867)	SAU (Trivedi *et al.*, 2018a)
196	*Macromedaeus quinquedentatus* (Krauss, 1843)	GOK (Chhapgar, 1958; Chhapgar, 1957a; Subba Rao & Sastry, 2005) Gujarat (Beleem et al 2019a)
197	*Macromedaeus voeltzkowi* (Lenz, 1905)	GOK (Trivedi et al 2021a)
198	*Medaeops granulosus* (Haswell, 1882) (In view of the reports by Mendoza *et al.*, (2009) and Naderloo (2017) of this species, these Indian records are dubious and the reported material should be re-examined)	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005); Gujarat (Dev Roy, 2013)
199	*Medaeops neglectus* (Balss, 1922)	GOK (Trivedi *et al.*, 2018a)
200	*Platypodia cristata* (A. Milne-Edwards, 1865)	GOK (Chhapgar, 1957a; Subba Rao & Sastry, 2005; Trivedi *et al.*, 2012; Beleem *et al.*, 2014); SAU (; Trivedi & Vachharajani, 2012) Gujarat (Dev Roy, 2013)
	SUBSECTION THORACOTREMATA Guinot, 1977	
	SUPERFAMILY GRAPSOIDEA MacLeay, 1838	
	Family Grapsidae MacLeay, 1838	

201	*Grapsus albolineatus* Latreille, in Milbert, 1812 (This species is often confused with the Atlantic species *Grapsus grapsus* (Linnaeus, 1758); cf. Banerjee (1960))	GOK (Subba Rao & Sastry, 2005; Trivedi *et al.*, 2012; Beleem *et al.*, 2014); SAU (Chhapgar, 1957b; Trivedi & Vachharajani, 2012) (Chhapgar 1957b, c; Ghosh 2004)
202	*Metopograpsus latifrons* (White, 1847)	GOKh (Chhapgar, 1957b)
203	*Metopograpsus messor* (Forskål, 1775)	GOK (Ghosh, 2004; Subba Rao & Sastry, 2005; Saravanakumar *et al.*, 2007; Beleem *et al.*, 2014); SAU (Chhapgar, 1957b; Ghosh, 2004; Trivedi & Vachharajani, 2012); GOKh (Chhapgar, 1957b)
204	*Metopograpsus thukuhar* (Owen, 1839)	GOK (Trivedi *et al.*, 2018a)
205	*Planes major* (MacLeay, 1838)	SAU (Bleem *et al.*, 2019)
	Family Plagusiidae Dana, 1851	
206	*Plagusia depressa* (Fabricius, 1775)	GOK (Chhapgar *et al.*, 2004); SAU (Chhapgar, 1957b)
207	*Plagusia squamosa* (Herbst, 1790) (This is the senior synonym of *P. tuberculata* (Latreille, in Milbert, 1812); cf. Schubart & Ng (2000))	SAU (Chhapgar, 1957b; Trivedi & Vachharajani, 2012) Gujarat (Dev Roy 2013)
	Family Sesarmidae Dana, 1851	
208	*Episesarma mederi* (H. Milne Edwards, 1854) (*Sesarma taeniolata* Miers, 1877, is a junior synonym of *E. mederi*)	GOK (Saravanakumar *et al.*, 2007; Trivedi *et al.*, 2012)
209	*Episesarma versicolor* (Tweedie,1940)	GOK (Bhat & Trivedi, 2021)
210	*Circulium vitatum* (P.K.L. Ng & Davie, 2011) (This species has been confused with *Labuanium rotundatum* (Hess, 1865); cf. Ng & Davie (2011))	GOK (Chandy, 1973; Gopalakrishnan, 1970); GOKh (Chhapgar, 1957b)
211	*Nanosesarma jousseaumei* (Nobili, 1996)	GOK (Ghosh, 2004); SAU (Ghosh, 2004); Gujarat (Dev Roy, 2013)
212	*Nanosesarma minutum* (De Man, 1887)	GOK (Saravanakumar *et al.*, 2007); Gujarat (Dev Roy, 2013)
213	*Neosarmatium smithi* (H. Milne Edwards, 1853)	GOK (Chandy, 1973); GOKh (Chhapgar, 1957b)
214	*Parasesarma persicum* Naderloo & Schubart, 2010	GOK & GOKh (Trivedi & Vachhrajani, 2017 persicum)
215	*Parasesarma plicatum* (Latreille, 1803) (The concept of this common species was revised by Rahayu & Ng (2010))	GOK (Chandy, 1973; Saravanakumar *et al.*, 2007; Trivedi *et al.*, 2012;); GOKh (Chhapgar, 1957b); Gujarat (Dev Roy, 2013)
216	*Pseudosesarma glabrum* Ng, Rani & Nandan, 2017 (fig. 1 E, F) (Ng et. al (2017) and Trivedi *et al.*, (2018) comment that considering the geographical location, re-examination of all records *P. edwardsii* from India is needed as they might belong to *P. glabrum*, *P. crassimanum* or *P. anteactum* from the Indian subcontinent.)	GOKh (Present study; Material examined: 1 male (CW 14.4 mm, CL 11.9 mm); 1 female (CW 12.5 mm, CL 11.1 mm) LFSc. ZRC- 93, Daman, Gujarat state, India, 10th November, 2016, coll. Jigneshkumar Trivedi)
217	*Selatium brockii* (De Man, 1887)	GOK (Saravanakumar *et al.*, 2007)
	Family Varunidae H. Milne Edwards, 1853	
218	*Metaplax indica* H. Milne Edwards, 1852	GOKh (Chhapgar, 1957b; Shukla *et al.*, 2013)
219	*Ptychognathus barbatus* (A. Milne-Edwards, 1873)	SAU (Ghosh, 2004); Gujarat (Dev Roy, 2013)
220	*Varuna litterata* (Fabricius, 1798)	GOKh (Chhapgar, 1957b)

	SUPERFAMILY OCYPODOIDEA Rafinesque, 1815	
	Family Camptandriidae Stimpson, 1858	
221	*Leptochryseus kuwaitense* (Jones & Clayton, 1983)	GOK (Trivedi *et al.*, 2017)
222	*Manningis arabicum* (Jones and Clayton, 1983)	GOK (Patel *et al.*, 2021)
223	*Nasima dotilliformis* (Alcock, 1900)	GOK (Trivedi *et al.*, 2017)
224	*Opusia indica* (Alcock, 1900)	GOK (Trivedi *et al.*, 2017)
225	**Family Dotillidae Stimpson, 1858**	
226	*Dotilla blanfordi* Alcock 1900	GOKh (Shukla *et al.*, 2013; Pandya & Vachhrajani, 2013)
227	*Dotilla malabarica* Nobili, 1903 (fig 1. C, D)	SAU (Present study; Material examined: 3 males (CW 8.4– 14.4 mm, CL 6.9–11.9 mm); 1 female (CW 12.5 mm, CL 11.1 mm) LFSc. ZRC- 35, Diu, Gujarat state, India, 8th November, 2016, coll. Jigneshkumar Trivedi)
228	*Dotilla myctiroides* H. Milne Edwards, 1852	GOK (Saravanakumar *et al.*, 2007; Dev Roy 2013)
229	*Ilyoplax frater* (Kemp, 1919)	GOK (Trivedi *et al.*, 2018 (Checklist))
230	*Ilyoplax sayajiraoi* Trivedi, Soni, Trivedi & Vachhrajani, 2015	GOKh (Trivedi *et al.*, 2015a); Trivedi *et al.*, 2018 (Checklist)
231	*Ilyoplax stevensi* (Kemp, 1919)	GOK (Trivedi *et al.*, 2018 (Checklist))
232	*Scopimera crabricauda* Alcock, 1900	GOK (Trivedi & Vachhrajani, 2018); Trivedi *et al.*, 2018 (Checklist)
233	*Scopimera proxima* Kemp, 1919	GOKh (Trivedi *et al.*, 2018a)
	Family Macrophthalmidae Dana, 1851b	
234	*Chaenostoma sinuspersici* (Naderloo & Türkay, 2011)	SAU (Trivedi & Vachhrajani 2017)
235	*Macrophthalmus (Macrophthalmus) brevis* (Herbst, 1804)	GOKh (Pandya & Vachhrajani, 2013)
236	*Macrophthalmus* (*Macrophthalmus*) *sulcatus* H. Milne Edwards, 1852	GOK & SAU (present study); GOKh (Chhapgar, 1957b; Pandya & Vachhrajani, 2013)
237	*Macrophthalmus* (*Mareotis*) *crinitus* Rathbun, 1913	GOK (Chhapgar, 1957b)
238	*Macrophthalmus* (*Mareotis*) *depressus* Rüppell, 1830	GOK (Saravanakumar *et al.*, 2007); GOKh (Chhapgar, 1957b)
239	*Macrophthalmus* (*Mareotis*) *japonicus* (De Haan, 1835)	SAU (Trivedi *et al.*, 2018a)
240	*Macrophthalmus* (*Mareotis*) *laevis* A. Milne-Edwards, 1867	GOKh (Trivedi *et al.*, 2014a)
241	*Macrophthalmus* (*Mareotis*) *pacificus* Dana, 1851	GOK (Subba Rao & Sastry, 2005); SAU (Chhapgar, 1957b)
242	*Venitus dentipes* (Lucas, in Guérin-Méneville, 1838)	GOKh (Chhapgar, 1957b); GOK (Trivedi *et al.*, 2012)
	Family Ocypodidae Rafinesque, 1815	
243	*Austruca annulipes* (H. Milne Edwards, 1837) (This species is sometimes confused with *A. lactea* (De Haan, 1835); see discussion in Naderloo *et al.*, (2010))	GOK (Subba Rao & Sastry, 2005; Trivedi *et al.*, 2012; Beleem *et al.*, 2014); SAU (Chhapgar, 1957b); GOKh (Chhapgar, 1957b)
244	*Austruca iranica* Pretzmann, 1971	GOK (Trivedi & Vachhrajani 2017)
245	*Austruca sindensis* (Alcock, 1900)	GOKh (Chhapgar, 1958)

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246	*Gelasimus vocans* (Linnaeus, 1758)	GOKh (Shukla *et al.*, 2013)
247	*Ocypode brevicornis* H. Milne Edwards, 1837 (This is the senior synonym of *Ocypode platytarsis* H. Milne Edwards, 1852; cf. Sakai & Türkay (2013))	GOK (Chhapgar *et al.*, 2004; Dev Roy 2013)
248	*Ocypode ceratophthalmus* (Pallas, 1772) (For reasons of Latin etymology, how the name was originally used and requirements by the zoological code, the correct spelling for species name must be "*ceratophthalmus*" rather than "*ceratophthalma*" as is sometimes used)	GOK (Trivedi *et al.*, 2012); SAU (Trivedi & Vachharajani, 2012); GOKh (Chhapgar, 1957b)
249	*Ocypode cordimana* Latreille, 1818 (For reasons of Latin etymology, how the name was originally used and requirements by the zoological code, the correct spelling for species name must be "*cordimana*" rather than "*cordimanus*" as is often used)	GOKh (Chhapgar, 1957b)
250	*Ocypode macrocera* H. Milne Edwards, 1852	GOK (Saravanakumar *et al.*, 2007)
251	*Ocypode rotundata* (Miers, 1882)	GOK (Alcock, 1900; Chhapgar, 1957b; Gopalakrishnan, 1970)
252	*Tubuca acuta* (Stimpson, 1858)	GOK (Saravanakumar *et al.*, 2007)
253	*Tubuca alcocki* Shih, Chan & Ng, 2018 (All the records of *Tubuca urvillei* (H. Milne Edwards, 1852) from Indian Ocean belongs to new species *Tubuca alcocki* Shih, Chan & Ng, 2018; cf. Shih *et al.*, (2018))	GOK (Chandy 1973; Trivedi *et al.*, 2015c)
254	*Tubuca dussumieri* (H. Milne Edwards, 1852)	GOK (Chandy, 1973; Saravanakumar *et al.*, 2007; Trivedi *et al.*, 2012); GOKh (Chhapgar, 1957b; Shukla *et al.*, 2013; Pandya & Vachhrajani, 2013)
	SUPERFAMILY PINNOTHEROIDEA De Haan, 1833	
	Family Pinnotheridae De Haan, 1833	
255	*Arcotheres placunae* (Hornell & Southwell, 1909)	GOK (Hornell & Southwell, 1909; Subba Rao & Sastry, 2005; Trivedi *et al.*, 2018c) Gujarat (Dev Roy 2013)

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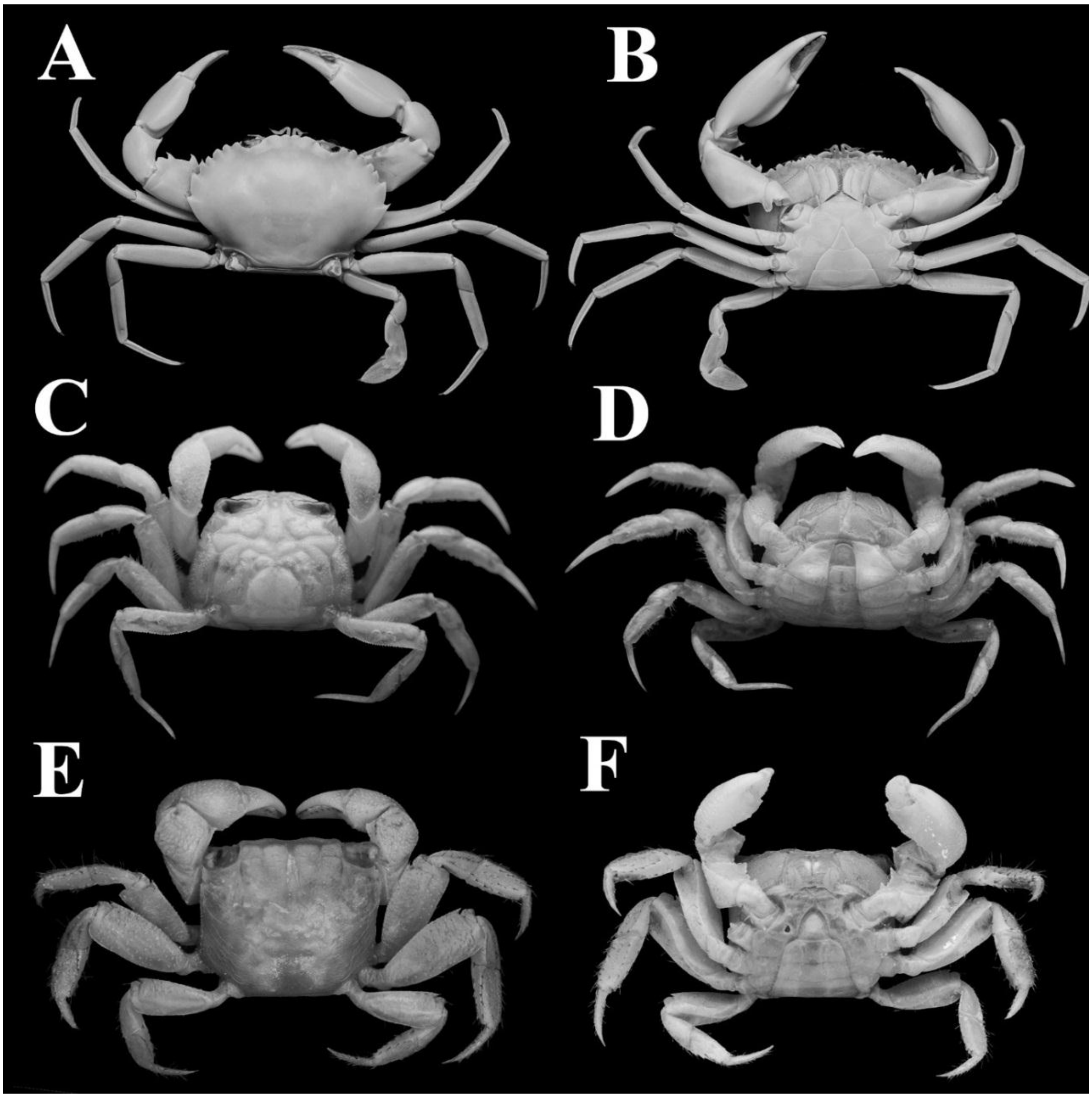

Fig. 1: A, B *Carupa tenuipes* Dana, 1852, female (CW 33.63 mm, CL 21.87mm) (LFSc. ZRC- 731). C, D *Dotilla malabarica* Nobili, 1903, male (CW 8.4, CL 6.9 mm) (LFSc. ZRC- 35). E, F *Pseudosesarma glabrum* Ng, Rani & Nandan, 2017, male (CW 14.4 mm, CL 11.9 mm) (LFSc. ZRC- 93)

References

Alcock, A. 1900 *Materials for a carcinological fauna of India. by A. Alcock. No. 6, The Brachyura Catometopa, or Grapsoidea.* Baptist Mission Press, Calcutta : Available from: http://www.biodiversitylibrary.org/item/52376

Alcock, A. 1905. *Catalogue of the Indian decapod Crustacea in the collection of the Indian Museum. Part II. Anomura. Fasciculus I. Pagurides*. Printed by order of the Trustees of the Indian Museum, Calcutta, xi, 193 pp.

Beleem, I., Poriya, P. and Gohil, B. 2016a. Two new records of majid crabs (Crustacea: Decapoda: Majidae) from west coast of India. *International Journal of Fisheries and Aquatic Studies,* 4: 85–88.

Beleem, I., Poriya, P. and Gohil, B. 2016b. Porcelain crabs (Crustacea: Decapoda: Anomura) of western coast of India. *Marine Biodiversity Records*, 9: 43.https://doi.org/10.1186/s41200-016-0057-y

Beleem, I., Poriya, P. and Gohil, B. 2016c. First record of *Arcania heptacantha* (De Man, 1907)(Crustacea: Decapoda: Leucosiidae) from west coast of India. *Journal of Marine Biological Association of India,* 58: 108–112.

Beleem, I., Poriya, P. and Gohil, B. 2017a. Diversity and distribution of porcelain crabs of Gujarat, India. *Iranian Journal of Animal Biosystematics13 (1):41-51*. https://doi.org/10.22067/ijab.v13i1.58903

Beleem, I., Poriya, P. and Gohil, B. 2017b. First record of spider decorator crab *Camposcia retusa* (Latreille, 1829) from west coast of India. *Journal of Marine Biological Association of India,* 59 122–124.

Beleem, I., Poriya, P. and Gohil, B. 2017c. New records of two Leucosiid crabs (Crustacea: Decapoda: Leucosiidae) from Gujarat coast, India. *Indian Journal of Geo-Marine Sciences,* 46: 2132–2136.

Beleem, I., Poriya, P. and Gohil, B. 2019a. An annotated checklist of marine brachyuran crabs of Gujarat waters, India. *Iranian Journal of Animal Biosystematics (IJAB)* 15, 9–46.

Beleem, I., Poriya, P. and Gohil, B. 2019b. First record of the callianassid ghost shrimp *Neocallichirus jousseaumei* (Nobili, 1904) (Decapoda: Axiidea) from India. *Journal of Threatened Taxa*, 11: 13402–13405. https://doi.org/10.11609/jott.3251.11.3.13402-13405

Beleem, I.B., Kumar, J.S.Y., Satyanarayana, C., Venkataraman, K. and Kamboj, R.D. 2014. Distribution of Marine Crabs from the Marine National Park, Gulf of Kachchh. *Scholars Academic Journal of Biosciences,* 2(7): 419-427

Bhat, M. and Trivedi, J. 2021. New record of the Sesarmid crab *Episesarma versicolor* (Tweedie, 1940)(Crustacea: Decapoda: Sesarmidae) from the West Coast of India. *Journal of Biological Studies* 3, 165–170.

Bhatt, Y.M., Kutty, M.N., Rao, K.V. and Punwani, D.M. 1964. " Ghol-Dara" fishery off Bedi port in the Gulf of Kutch. *Indian Journal of Fisheries* 11, 135–156.

Chakraborty, R.D. and Thumber, B.P. 2007. Fishery and biology of the Flamingo shrimp *Parapenaeus longipes* (Alcock, 1705) off Veraval. *Journal of the Marine Biological Association of India,* 49: 97–99.

Chanda, A. and Roy, T. 2004. Prawns of Gujarat Coast. *Zool Surv India State Fauna Series* 8, 211–218.

Chandy, M. 1969. *Thalamita Poissonii* (Audouin & Savigny) De Man, (Crustacea: Brachyura), a new Record To Indian Coasts. *The journal of the Bombay Natural History Society,* 66: 635–637.

Chandy, M. 1973. New Records of Brachyuran Decapods from the Gulf of Kutch. *The journal of the Bombay Natural History Society*, 70: 401–402.

Chhapgar, B.F. 1955. On two new species and a new variety of crabs (Decapoda: Brachyura) from Bombay State. *Records of the Indian Museum (A Journal of Indian Zoology, Calcutta),* 53: 251–259.

Chhapgar, B.F. 1957a. On the Marine crabs (Decapoda: Brachyura) of Bombay State, Part 1. *Journal of the Bombay Natural History Society,* 54: 399–439.

Chhapgar, B.F. 1957b. On the Marine crabs (Decapoda: Brachyura) of Bombay State, Part 2. *Journal of the Bombay Natural History Society,* 54: 503–549.

Chhapgar, B.F. 1958a. Additions to the crab fauna of Bombay State. *Journal of the Bombay Natural History Society,* 55: 582–585.

Chhapgar, B.F. 1958b. On two new species and a variety of crabs (Decapoda: Brachyura) from Bombay state. *Records of the Indian Museum,* 53: 251–257.

Chhapgar, B.F. 1979. Colour during life of the crab Atergatis roseus (Rüppell).(Okha, Gulf of Kachchh, Gujarat, Arabian Sea). *Journal of the Bombay Natural History Society*, 76: 370–371.

Chhapgar, B.F. and Mundkur, T. 1995. Occurrence of the crab *Euxanthus exsculptus* (Herbst) in Gujarat. *Journal of Bombay Natural History Society,* 92: 286.

Chhapgar, B.F., Desai, B. and Patel, S. 2004. On two interesting marine crabs (decapoda: brachyura) from mandvi kutch. *Journal of Bombay natural history society* 101, 184–185.

Dash, G., Dash, S.S., Sreenath, K.R., Koya, M., Mojjada, S.K. and Bharadiya, S.A.. 2012. *Field identification manual for the commercially important shrimp species of Gujarat*. Central Marine Fisheries Research Institute, Kochi, 1-27.

Dash, G., Koya, M.K. and Makwana, N.P. 2017. First report of a deep sea spider crab, *Encephaloides armstrongi* Wood-Mason and Alcock, 1891 from Gujarat waters of India. *Indian Journal of Geo-Marine Sciences* 46, 982–985.

De Grave, Sammy, Pentcheff, N. Dean, Ahyong, Shane T, Chan, Tin-Yam, Crandall, Keith A., Dworschak, Peter C., Felder, Darryl L., Feldmann, Rodney M., Fransen, Charles H. J. M., Goulding, Laura Y. D., Lemaitre, Rafael, Low, Martyn E. Y., Martin, Joel W., Ng, Peter K. L., Schweitzer, Carrie E., Tan, S. H., Tshudy, Dale, and Wetzer, Regina. 2009. A Classification of Living and Fossil Genera of Decapod Crustaceans. *Raffles Bulletin of Zoology*, 21:1–109.

Deb, M. 1987. Description of seven new species and one new record of pilumninae; xanthidae: decapoda: crustacea from india. *Bulletin of Zoological Survey of India*, 8: 299–312.

Dev Roy, M.K. 2008. An annotated checklist of mangrove and coral reef inhabiting Brachyuran crabs of India. *Records of Zoological Survey of India, Occasional Paper*, 289: 1–212.

Dev Roy, M.K. 2013. Diversity and Distribution of Marine Brachyuran Crab Communities Inhabiting West Coast of India. In: K. Venkataraman, C. Sivaperuman, and C. Raghunathan (Eds), *Ecology and Conservation of Tropical Marine Faunal Communities*. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 147–169.

Dev Roy, M.K. and Das, A.K. 2000. Taxonomy, ecobiology and distribution pattern of the Brachyuran Crabs of mangrove ecosystem in Andaman Islands. *Records of the Zoological Survey of India*, 1–211.

Dineshbabu, A.P. 2005. Growth of kiddy shrimp, *Parapenaeopsis stylifera* (H. Milne Edwards, 1837) along Saurashtra coast. *Indian Journal of Fisheries* 52, 165–170.

George, M.J. and Rao, P.V. 1968. A new species of *Metapenaeus* (Decapoda, Penaeidae). *Journal of the Marine Biological Association of India* 8, 146–151.

George, P.C., George, M.J. and Rao, P.V. 1963. *Metapenaeus kutchensis* sp. nov., a penaeid prawn from the Gulf of Kutch. *Journal of the Marine Biological Association of India* 5, 284–288.

Ghosh, S.K. 2004. Crustacea: Decapoda: Grapsidae. *Zoological Survey of India* 2, 207–210.

Gopalakrishnan, P. 1970. Some observations on the shore ecology of the Okha coast. *Journal of Marine Biology Association of India* 12, 15–34.

Gosavi, S., Trivedi, J.N. and Trivedi, D.J. 2017a. New records of anomurans (Crustacea: Decapoda) from Gujarat, India. *Journal of Entomology and Zoology Studies*, 5(4), 658-662.

Gosavi, S., Trivedi, J.N., Trivedi, D.J. and Vachhrajani, K.D. 2017b. First record of *Leucisca squalina* MacLeay, 1838 (Decapoda: Leucosiidae) from Gujarat state, India. *Journal of Entomology and Zoology Studies*, 5(1), 400-402.

Gosavi, S., Trivedi, J.N., Trivedi, D.J. & Vachhrajani, K.D. 2017c. First record of Pilumnopeus convexus (Maccagno, 1936) (Crustacea; Decapoda, Pilumnidae) from the Indian coast. Check List 13, 429–433. https://doi.org/10.15560/13.5.429

Haig, J. 1964. Papers from Dr. Th. Mortensen's Pacific Expedition 1914–1916. 81. Porcellanid crabs from the Indo-West Pacific, Part I. *Videnskabelige Meddelelser Dansk Naturhistrisk Forening i Kjøbenhavn*, 126: 355–386.

Hornell J and Southwell T. 1909. Description of a new species of *Pinnotheres* from *Placuna placenta*, with a note on the genus. In: Hornell J (ed.), Report to the Government of Baroda on the Marine Zoology of Okhamandal in Kattiawar. Part 1. Richard Clay and Sons Ltd., Bungay, Suffolk. Pp. 99–103

Joseph, A. and Soni, V. 1986. Length-weight relationship and relative condition factor of prawn, Metapenaeus kutchensis (George, George & Rao)., from Okha (Gujarat). *Indian J. Fish*, 33: 127–128.

Kachhiya, P., Poriya, P., Raval, J. & Kundu, R. 2016. Distribution of Newly Recorded Intertidal Hermit Crabs Along Gujarat Coast. *International Journal of Ecology and Environmental Sciences*, 42: 327–332.

Kachhiya, P., Raval, J., Poriya, P. and Kundu, R. 2017. Diversity and new records of intertidal hermit crabs of the genus Clibanarius (Crustacea: Decapoda: Diogenidae) from Gujarat coast off the northern Arabian Sea, with two new records for the mainland Indian coastline. *Journal of Threatened Taxa*, 9: 10334. https://doi.org/10.11609/jott.2268.9.6.10334-10339

Katwate, U. and Sanjeevi, P. 2011. On a documentation of Haddon's Carpet anemone (*Stichodactyla haddoni*)(Saville-Kent 1893)(Anthozoa: Actiniaria: Stichodactylidae) and its unique symbiotic fauna from Gulf of Kutch. *Bugs 'R'All Newsletter,* 17: 31–34.

Khan, M.Z. 1986. Dol net fishery off Nawabunder (Gujarat).. *Fishery Technology*, 23: 92–99.

Ng, P.K.L and Schubart, C.D. 2017. On the taxonomy of *Pseudosesarma edwardsii* (De Man, 1887) and *P. crassimanum* (De Man, 1887).(Crustacea: Decapoda: Brachyura: Sesarmidae), with description of a new species from Sri Lanka. *Raffles Bulletin of Zoology* 65, 655–669.

Ng, P.K.L., Trivedi, J.N. and Vachhrajani, K.D. 2015. *Dentoxanthus iranicus* Stephensen, 1946 (Crustacea: Brachyura: Galenidae): a new record from Gujarat, India, with systematic notes. *Marine Biodiversity Records*, 8: e132. https://doi.org/10.1017/S1755267215001098

Pandya, P.J. and Vachhrajani, K.D. 2013. Brachyuran crab diversity of lower estuarine mud flats of Mahi River with new record of two species from Gujarat, India, 2.4: 242-250.

Patel, B.H. and Balapatel, I.A. 1983. Some observations on the prawn fishery of Gulf of Khambhat, Gujarat. *Indian journal of fisheries*.

Patel, K., Patel, P. and Trivedi, J. 2021. First record of *Manningis arabicum* (Jones and Clayton, 1983) (Decapoda, Brachyura, Camptandriidae) from India. *Nauplius* 29, e2021017. https://doi.org/10.1590/2358-2936e2021017

Patel, P., Patel, K. and Trivedi, J. 2020. First record of Hermit crab *Clibanarius ransoni* Forest, 1953 (Crustacea: Anomura: Diogenidae) from India. *Journal of Biological Studies,* 3: 19–23.

Prakash, S., Kumar, T.T.A. and Khan, S.A. 2013. Checklist of the Porcellanidae (Crustacea: Decapoda: Anomura) of India. *Check List,* 9: 1514. https://doi.org/10.15560/9.6.1514

Pravin, P., and Manohardoss, R. C. 1996. Constituents of low value trawl by-catch caught off Veraval. Fishries Technology, 33 (2), 121-123.

Purohit, B. and Vachhrajani, K. 2019a. Eight New Records of Caridean (Crustacea: Decapoda) Shrimps from Shallow Water along the Coastal Area of Gujarat. *Journal of Marine Biology* and *Oceanography* 8, 1–5.

Purohit, B. and Vachhrajani, K.D. 2019b. New record of the monotypic genus *Procletes* (Decapoda: Pandalidae) from the West coast of India. *Cuadernos de Investigación UNED*, 11: 292–295.

Purohit, B. and Vachhrajani, K.D. 2017. New records of prawns and shrimps (Crustacea: Decapoda) from Gujarat coast, India. *International Journal of Fisheries and Aquatic Studies,* 5: 405–411.

Purohit, B. and Vachhrajani, K.D. 2018. First record of stenopodidean shrimp, *microprosthema validum* (crustacea: decapoda: spongicolidae) from west coast of india. *Flora and Fauna,* 24: 145–147.

Radhakrishnan, E.V., Deshmukh, V.D., Maheswarudu, G., Josileen, J., Dineshbabu, A.P., Philipose, K.K., Sarada, P.T., Pillai, S.L., Saleela, K.N. and Chakraborty, R.D. 2012. Prawn fauna (Crustacea: Decapoda) of India-an annotated checklist of the Penaeoid, Sergestoid, Stenopodid and Caridean prawns. *Journal of the Marine Biological Association of India*, 54: 50–72.

Ramamurthy, S. 1963. A note on the prawn fishery of Kutch. *Journal of the Marine Biological Association of India,* 5: 146–147.

Ramamurthy, S. 1964. On a new record of *Metapenaeus stebbingi* Nobili, in Indian waters. *Journal of the Marine Biological Association of India*, 6: 170–170.

Ramamurthy, S. 1965. Studies on the prawn fishery of Kutch. *Proceedings Symposium on Crustacea* , 4: 1424–1436.

Ramanandan, R. 1966. On the Occurrence of *Porcellanella Picta* Stimpson (Decapoda: Anomura) in the Gulf of Kutch. *The journal of the Bombay Natural History Society.* 63, 770–771.

Rao, D.V. and Rath, S. 2013. Ichthyofauna and Decapod Crustacean Fauna of the Nuanai Estuary, Odisha, Estuarine Ecosystem Series, S: 1-64. *Published by the Director, Zoo1ogical Survey of India, Kolkata*, 8: 1-64

Saravanakumar, A., Serebiah, J.S., Thivakaran, G.A. and Rajkumar, M. 2007. Benthic macrofaunal assemblage in the arid zone mangroves of gulf of Kachchh-Gujarat. *Journal of Ocean University of China,* 6: 303–309.

Sarvaiya, R.T. and RT, S. 1978. Prawn fisheries of Kutch with special reference to Sukhper and Lakhpat. Indian Journal of Fisheries, 25(1 & 2): 35-40

Shukla, M.L., Patel, B.K., Trivedi, J.N. and Vachhrajani, K.D. 2013. Brachyuran Crabs Diversity of Mahi and Dhadhar Estuaries, Gujarat, India. *Research Journal of Marine Sciences*. 1: 8–11.

Solanki, D., Kanejiya, J., Beleem, I. and Gohil, B. 2016. Checklist of intertidal marine fauna in mangrove ecosystem, Ghogha coast, Gulf of Khambhat, India. *Journal of Entomology and Zoology Studies,* 4: 1281–1284.

Southwell, T. 1909. Report on the Anomura collected by Mr. James Hornell at Okhamandal in Kattiawar in 1905–6. *Okhamandal Marine Zoology Report*, 105–123.

Subba Rao, N.V. and Sastry, D.R.K. 2005. *Fauna of Marine National Park, Gulf of Kachchh, Gujarat: an overview*. Zoological Survey of India, Kolkata, 79 pp.

Thomas, M.M. 1969. Catalogue of crabs and hermit-crabs in the reference collections of the central marine fisheries research institute. *Bulletin of the Central Marine Fisheries Research Institute*, 7: 41–50.

Trivedi, J.N. and Vachhrajani, K.D. 2012. Distribution and diversity of bachyuran crabs along the coastal region of Junagdh district, Gujarat. In: *Proceedings of national seminar on biodiversity and conservation of coastal and maine ecosystems of India*. Ramniranjan Jhunjhunwala College, Mumbai, pp. 6–12.

Trivedi, J.N., Gadhavi, M.K. and Vachhrajani, K.D. 2012. Diversity and habitat preference of brachyuran crabs in Gulf of Kutch, Gujarat, India. *Arthropods* 1, 13–23

Trivedi, J.N. and Vachhrajani, K.D. 2013a. First record of *Cryptopodia angulata* H. Milne Edwards and Lucas, 1841 from Saurashtra coast, Gujarat, India (Decapoda: Brachyura: Parthenopidae). *Check List* 9, 897. https://doi.org/10.15560/9.4.897

Trivedi, J. N. and Vachhrajani, K. D. 2013b. Taxonomic account of genus *Scylla* (de Haan, 1833) from Gujarat State, India with two new records of species. *Arthopods* 2, 159–171.

Trivedi, J.N. and Vachhrajani, K.D. 2013c. First record of two porcellanid crabs from Gujarat state, India (Crustacea: Decapoda: Porcellanidae). *Journal of the Marine Biological Association of India* 55, 55–58. https://doi.org/10.6024/jmbai.2013.55.1.01756-09

Trivedi, J. N., Soni, G. M.., Arya, S. and Vachhrajani, K. D. 2014a. First record of *Macrophthalmus laevis* A. Milne Edwards, 1867 (Decapoda: Brachyura: Macrophthalmidae) from India. *Journal of the Marine Biological Association of India* 56, 85–87. https://doi.org/10.6024/jmbai.2014.56.2.01789-13

Trivedi, J.N., Arya, S. and Vachhrajani, K.D. 2014b. Study of the Macro Faunal Associates of the Littoral Zoanthid *Palythoa mutuki* (Cnidaria, Anthozoa) from Saurashtra Coast, Gujarat, India. *International Journal of Marine Science*. https://doi.org/10.5376/ijms.2014.04.0034

Trivedi, D.J., Trivedi, J.N., Soni, G.M., Purohit, B.D. and Vachhrajani, K.D. 2015a. Crustacean fauna of Gujarat state of India: A review. *Electronic Journal of Environmental Sciences* 8, 23–31.

Trivedi, J.N., Soni, G.M., Trivedi, D.J. and Vachhrajani, K.D. 2015b. A new species of *Ilyoplax* (Decapoda, Brachyura, Dotillidae) from Gujarat, India. *Journal of Asia-Pacific Biodiversity* 8, 173–177. https://doi.org/10.1016/j.japb.2015.02.005

Trivedi, J.N. and Vachhrajani, K.D. 2015. First record of brachyuran crab *Leptodius affinis* (De Haan, 1835)(Crustacea: Decapoda: Xanthidae) from the western coast of India. *Marine Biodiversity Records* 8.

Trivedi, J.N., Soni, G.M., Trivedi, D., Purohit, B. and Vachhrajani, K.D. 2015c. On new records of hermit crabs (Anomura: Paguroidea: Diogenidae) from Gujarat state of india. *Electronic Journal of Environmental Sciences* 8, 32–34.

Trivedi, J.N. and Vachhrajani, K.D. 2016a. First record of *Seulocia pulchra* from India with a note on its colour pattern. *Marine Biodiversity* 47, 613–615. https://doi.org/10.1007/s12526-016-0517-y

Trivedi, J.N. and Vachhrajani, K.D. 2016b. On identity of *Atergatis ocyroe* (Herbst, 1801)(Crustacea: Brachyura: Xanthidae) in Indian waters. *International Journal of Fauna and Biological Studies* 3, 62–64.

Trivedi, J.N. and Vachhrajani, K.D. 2016c. On new record of *Pagurus kulkarni* Sankolli, 1962 (Crustacea: Anomura: Paguridae) from Gujarat, India. *Journal of Entomology and Zoology Studies*, 3.

Trivedi, J.N., Osawa, M. and Vachhrajani, K.D. 2016a. A new species of the genus *Diogenes* Dana, 1851 (Crustacea: Decapoda: Anomura: Diogenidae) from Gujarat, northwestern India. *Zootaxa* 4208, 189. https://doi.org/10.11646/zootaxa.4208.2.6

Trivedi, J.N., Soni, G.M. and Vachhrajani, K.D. 2016b. A new species of *Lyphira* Galil, 2009 (Crustacea, Decapoda, Leucosiidae) from Gujarat, India. *Tropical Zoology* 29, 148–154. https://doi.org/10.1080/03946975.2016.1181954

Trivedi, J. and Vachhrajani, K. 2017a. On distributional range extension of two species of brachyuran crabs *Parasesarma persicum* and *Austruca iranica* in Indian waters. Journal of the Marine Biological Association of India 59, 80–84.

Trivedi, J.N. and Vachhrajani, K.D. 2017b. On the distribution range of *Chaenostoma sinuspersici* (Naderloo & Türkay, 2011) (Decapoda: Brachyura: Macrophthalmidae) in Indian waters. *Nauplius* 25. https://doi.org/10.1590/2358-2936e2017030

Trivedi, J.N. and Vachhrajani, K.D. 2017c. An annotated checklist of hermit crabs (Crustacea, Decapoda, Anomura) of Indian waters with three new records. *Journal of Asia-Pacific Biodiversity* 10, 175–182. https://doi.org/10.1016/j.japb.2017.01.001

Trivedi, J.N., Osawa, M. and Vachhrajani, K.D. 2017a. A new species of the genus *Ancylocheles* Haig, 1978 (Crustacea: Decapoda: Anomura: Porcellanidae) from Gujarat, northwestern India. *Zootaxa* 4299, 384. https://doi.org/10.11646/zootaxa.4299.3.4

Trivedi, J.N., Trivedi, D.J. and Vachhrajani, K.D. 2017b. Range extension of brachyuran crabs of the family Camptandriidae Stimpson, 1858 (Crustacea: Decapoda: Brachyura) in Indian waters. *Check List* 13, 2145. https://doi.org/10.15560/13.3.2145

Trivedi, J.N., Gosavi, S. and Vachhrajani, K. 2018a. Range Extension of Two Brachyuran Crabs (Crustacea: Decapoda), *Acanthonyx inglei* Tirmizi & Kazmi, 1988 (Epialtidae) and *Scalopidia indica* Ng & Castro, 2013 (Scalopidiidae) in India. *Thalassas: An International Journal of Marine Sciences* 34, 305–309. https://doi.org/10.1007/s41208-018-0065-2

Trivedi, J.N., Trivedi, D.J., Vachhrajani, K.D. and Ng, P.K.L. 2018b. An annotated checklist of the marine brachyuran crabs (Crustacea: Decapoda: Brachyura) of India. *Zootaxa* 4502, 1. https://doi.org/10.11646/zootaxa.4502.1.1

Trivedi, J.N. and Vachhrajani, K.D. 2018. On new record of brachyuran crab *Scopimera crabicauda* Alcock, 1900 (Crustacea: Decapoda) from India. *Journal of the Marine Biological Association of India* 60, 105–107. https://doi.org/10.6024/jmbai.2018.60.1.1945-17

Trivedi, J., Gosavi, S. and Vachhrajani, K. 2020. First record of three species of spider crabs from west coast of India (Crustacea: Decapoda: Brachyura). *Journal of Biological Studies* 3, 24–29.

Trivedi, J., Mitra, S., Patel, P., Gosavi, S. and Vachhrajani, K. 2021a. Four New Records of Brachyuran Crabs (Crustacea: Decapoda: Brachyura) from India. *Thalassas: An International Journal of Marine Sciences* 37, 235–242. https://doi.org/10.1007/s41208-020-00252-6

Trivedi, J., Mitra, S., Patel, P., Maheta, N., Patel, K., Ng, P.K.L. 2021b. On the Indian species of *Eurycarcinus* A. Milne-Edwards, 1867, Heteropanope Stimpson, 1858, and Pilumnopeus A. Milne-Edwards, 1867 (Decapoda: Brachyura: Pilumnidae). *Nauplius* 29. https://doi.org/10.1590/2358-2936e2021004

Venkataraman, K., Jeyabhasharan, R., Raghuram, K.P. and Alfred, J.R.B. 2004. Bibliography and checklist of Corals and Coral reef associated organisms. *Ret', zool. Surv. India Occ. Paper*, 1–468.

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Study of colour variation in intertidal crab *Leptodius exaratus* (H. Milne Edwards, 1834) inhabiting rocky shores of Saurashtra coast, Gujarat, India

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Abstract

The present study was aimed to understand the colour variation in a brachyuran crab *Leptodius exaratus* and its relationship with different life stages and body size. The specimens of *L. exaratus* were collected from the rocky intertidal region of Shivrajpur using hand picking method in March, 2021. The size (carapace length and width) and sex of collected individuals were recorded. The individual specimens were placed on white background after proper washing with seawater and photographs of different body parts (carapace, chelae, carpus, third maxilliped, sternite and abdomen) were captured in daylight. The histogram of images of various body parts was generated using Adobe Photoshop software to record the intensity of red, blue and green (R, G and B). The mean values of R, G and B of different body part varied significantly between adult and juvenile with maximum variation recorded for third maxilliped, sternites and abdomen. Strong correlation was not observed between body size (carapace width) and R, G and B intensity values. The colour pattern in juvenile individuals ranged from light to dark grey, whereas in adults, it ranges from creamish to dark olive. The colouration of abdomen and sternite of juveniles are densely spotted, while in adults, these parts are almost white. The study reveals that colouration of ventral body parts varied maximally as compared to the dorsal body parts of adult and juvenile. This colour change information between different life stages of *L. exaratus* is essential in noting the onset of sexual maturity of species.

Keywords: Brachyura, Ontogenic effect, Colour morph, Polychromatism, Rocky coast

Introduction

'Polychromatism' that is the polymorphism in colouration is commonly observed in varied animal taxa. Sexual maturity is generally associated with changes in body colour (Pinheiro and Taddei, 2000; Watanabe *et al.*, 2015). It has been observed that the colour pattern changes with the animal overall size where the juvenile individuals being darker as compared to the mature individuals (Watanabe *et al.*, 2015). In animal kingdom several ectothermic animals could change their colouration including invertebrates and vertebrates like crustaceans (Thurman, 1988), insects (Hinton and Jarman, 1972), cephalopods (Hanlon, 2007), fishes (Kodric-Brown 1998), amphibians (Garcia and Sih, 2003) and reptiles (Cooper and Greenberg, 1992). The changes in colouration could be achieved by chromatophores or pigment cells which is more common in the ectothermic animals, including crustaceans (Thurman, 1988). According to Thurman (1988), coloration in decapod crustaceans is determined by the number, type and distribution of chromatophores. Such changes in colouration could have several purposes of inter- or intraspecific communication (Detto *et al.*, 2008; Cummings *et al.*, 2008) including warning different predators (Briolat *et al*. 2019), responding to different degrees of sexual selection (Boughman 2001), differences in humidity (Delhey, 2017), protection from ultraviolet radiation (Jablonski and Chaplin 2017) and/or camouflage strategies (Hemmi *et al.*, 2006). Camouflage is one of the commonest forms of defensive coloration (Endler 1991; Ruxton *et al*. 2004). It is believed that background matching ('crypsis') is the most widespread form of camouflage (Endler, 1981).

Numerous crustaceans with spatial segregation of different size classes may present variation in body colouration depending on the habitat they inhabit (Casariego *et al*., 2011). Such phenotypic changes in an individual could be the result of diet changes or predator avoidance (Figueroa *et al*., 2003). The change in colouration may also be due to the change in the risk of predation during the life of the organism. Hence the smaller organisms with higher risk of predation invest more resources to defensive structures and behaviours while they decrease the allocation to defence with increasing body size (Anderson *et al*., 2013). Such shift in the resource allocation for the defensive strategies helps to increase survivorship (Pigliucci, 2001; Relyea, 2005). Numerous studies support this opinion by reporting ontogenetic changes in body proportions or coloration during ontogeny (Hartnoll, 1965, 1974; Palma and Steneck, 2001; Berke and Woodin, 2008; Baeza and Asorey, 2012). In several species, colour is related to reproductive success, directly by female choice, or indirectly as a visual signal of territoriality (Reid *et al*., 1997; Detto *et al*., 2004; Styrishave *et al*., 2004).

Few studies are conducted on the polymorphism in colours of brachyuran crabs (Luiz- Junior, 2003; Sangthong and Jondeung, 2006; Casariego *et al.*, 2011; Pontes *et al.*, 2020). However, such studies on the brachyuran crabs for polychromatism are scanty in India (Trivedi and Vachhrajani, 2013). During the field surveys, we have come across a very common species of brachyuran crab *Leptodius exaratus* (H. Milne Edwards, 1834) that has a wide distribution throughout the Indian Ocean, ranging from the south eastern coast of Africa to the western coast of India, including the Red Sea, Gulf of Oman and the Persian Gulf (Lee *et al*., 2013). Like many other members of the family Xanthidae, *L. exaratus* shows great diversity in colour patterns (Reuschel and Schubart, 2006; Todd *et al*., 2009). The crab species is abundantly found on the rocky shores of Saurashtra coast showing colour variation in individuals but no study is carried out till date on the colour variation of the crab species. Thus, the present work was carried out to evaluate the colour variation between different life stages of *L. exaratus.* The study also evaluated the relationship between crab body size and intensity of colour on different body parts.

Materials and Methods

The present study was conducted in the rocky intertidal region of Shivrajpur coast (22°19'58"N, 68°57'21"E) (Fig. 1) situated in Dev Bhoomi Dwarka district on the Saurashtra coast, Gujarat state, India. *Leptodius exaratus* is found abundantly on the rocky shores of the study site during low tide. The specimens were collected randomly by catch-per-unit effort using hand picking method in the month of March, 2021 during low tide. The collected specimens were kept in a container filled with sea water and transported to the laboratory. In laboratory the specimens were identified according to the morphological characteristics described by Lee et al. (2013), sexed into male, non-ovigerous female and ovigerous female. The carapace width (CW) and carapace length (CL) of the specimens were measured using vernier callipers (±0.01mm accuracy). Juveniles and adults were separated based on the size of the CW, individuals having CW less than 17.7 mm were considered as juvenile (Trivedi *et al*, unpublished data).

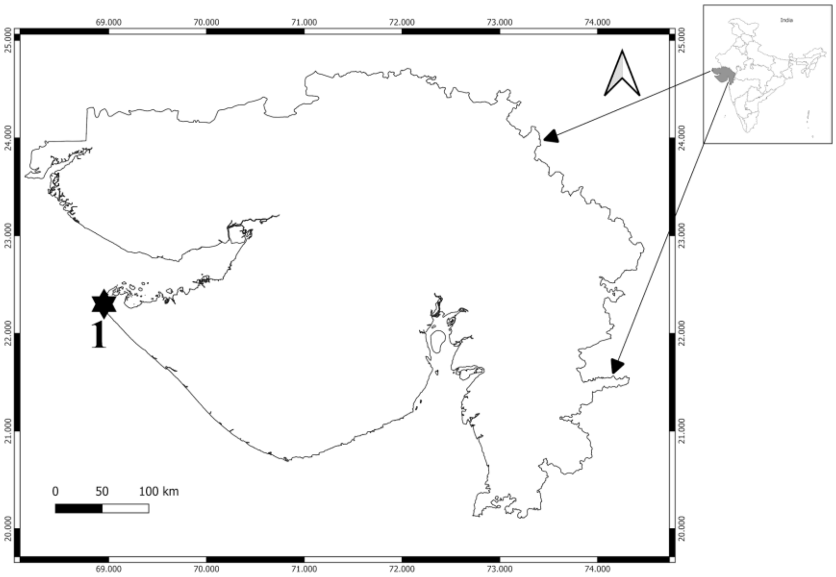

Fig. 1: Map of study area. 1. Shivrajpur, Saurashtra coast, Gujarat, India.

The specimens were washed properly with sea water to remove debris, then carapace was gently dabbed dry with a cloth to remove surface water. Total six body parts viz. carapace, chela, carpus, third maxilliped, sternites, abdomen of the crab were photographed for analysis. The crabs were photographed using a CANON EOS 1300D digital camera with 18-55 mm lens in daylight. A UV and infrared (IR) blocking filter was placed, which transmits wavelengths only between 400-700 nm. The crabs were placed on the white, flat and non-reflected 2 mm thick sheet and camera was set on the fixed height of 15 cm from the base. Photographs were taken in manual settings (ISO–100, aperture–6.3 and shutter speed–1/100) without flash. Photographs were analysed with Adobe Photoshop CS6 software. Each individual was photographed dorsally and ventrally with a white reference square in order to standardize the colour values of the photographs. Pictures were opened in Red–Green–Blue (RGB) colour mode (open image in Photoshop → select option "image" → mode → RBG) and a part of the crab could be selected giving the average value for red, green and blue from a histogram plot provided by the software. Each colour value ranged from 0 to 255 where the values of 255 in the 3 bands represent white and 0 represent black.

Statistical analysis

The colour intensity value of each region of the crab was compared between juveniles and adults with a tc test (t-test corrected) for unequal variances (Casariego *et al*., 2011) separately for each colour bands (R, G and B). To check the effect of crab body size on intensity of Red, Green and Blue colour, regression analysis was carried out between CW and intensity values of colours. To analyse if crab size is related to coloration, the 6 regions were analysed with correlation analysis between colour intensity value and crab size, separately for each colour band (R, G and B). The statistical analysis was carried out using MS Excel.

Results

A total of 419 individuals were collected during the study period, out of which 218 were male, 168 were non- ovigerous female and 33 were ovigerous female. Male carapace size ranged from 6.3 mm to 31.1 mm CW while of females ranged from 6.84 mm to 23.85 mm CW. Out of 419 specimens collected, 246 were adults and 173 were juveniles. It was observed that the males (21.44 mm ± 5.77 mm) were larger in size as compared to non-ovigerous female (16.32 mm ± 3.23 mm) and ovigerous female (19.49 mm ± 1.15 mm). The mean carapace width of juveniles and adults was 14.32 mm ± 2.81 mm and 22.70 mm ± 3.50 mm respectively. The colour variation pattern in juvenile individuals ranged from light to dark grey whereas in adults it ranges from creamish to dark olive.

Fig. 2: Different colour morphs of *Leptodius exaratus* (H. Milne Edwards, 1834).

In case of red colour intensity, the mean values varied significantly for different body parts between adults and juveniles (Fig. 3). High mean variation was observed for ventral body parts (third maxilliped, sternite and abdomen) of adult and juvenile as compared to dorsal body parts (Fig. 3).

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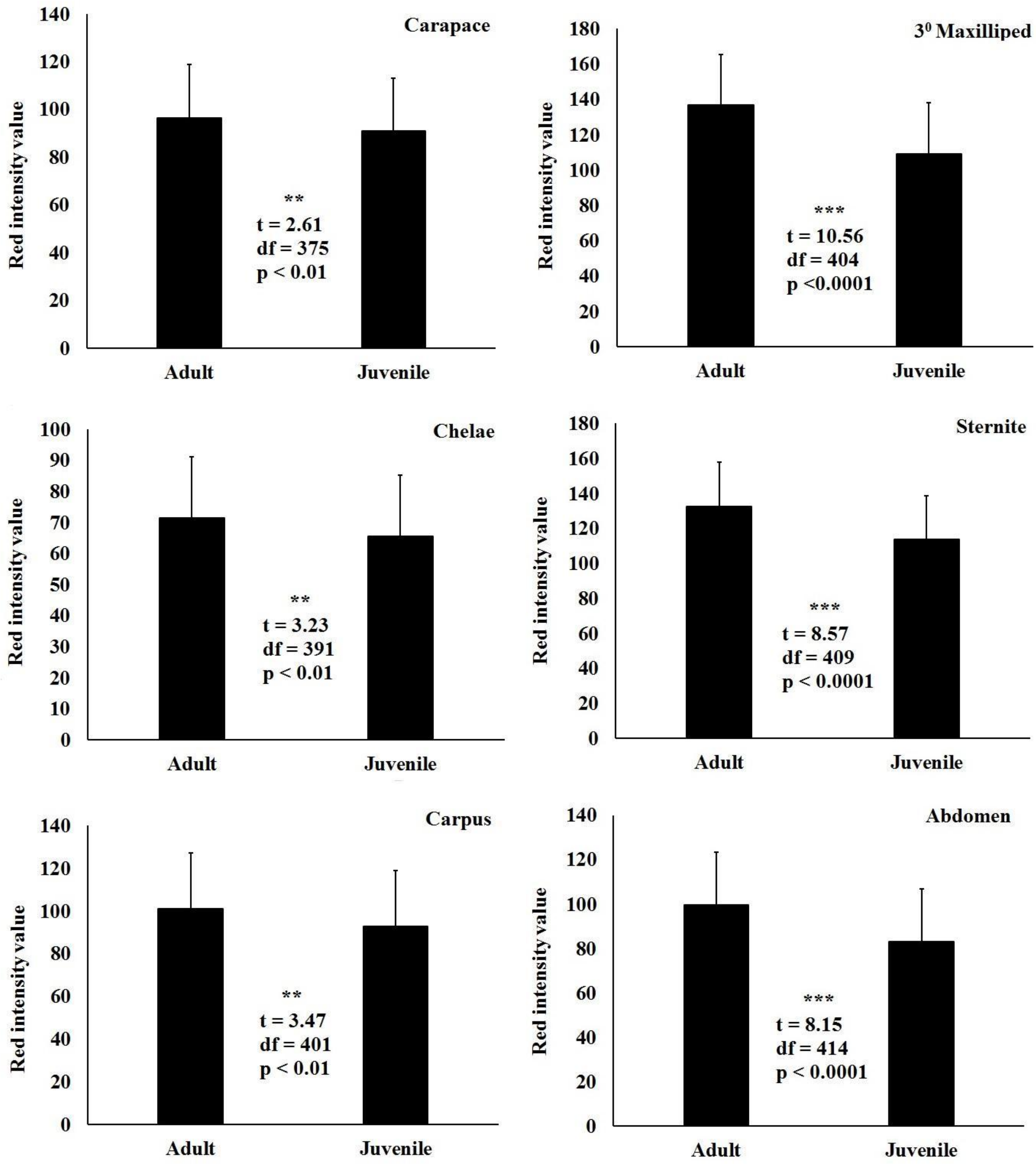

Fig. 3: Mean variation of red colour intensity in different body parts of adult and juvenile individuals of *L. exaratus.*

In case of green colour intensity, the mean values varied significantly for different body parts between adults and juveniles (Fig. 4). High mean variation was observed for ventral body parts (third maxilliped, sternite and abdomen) of adult and juvenile as compared to dorsal body parts (Fig. 4).

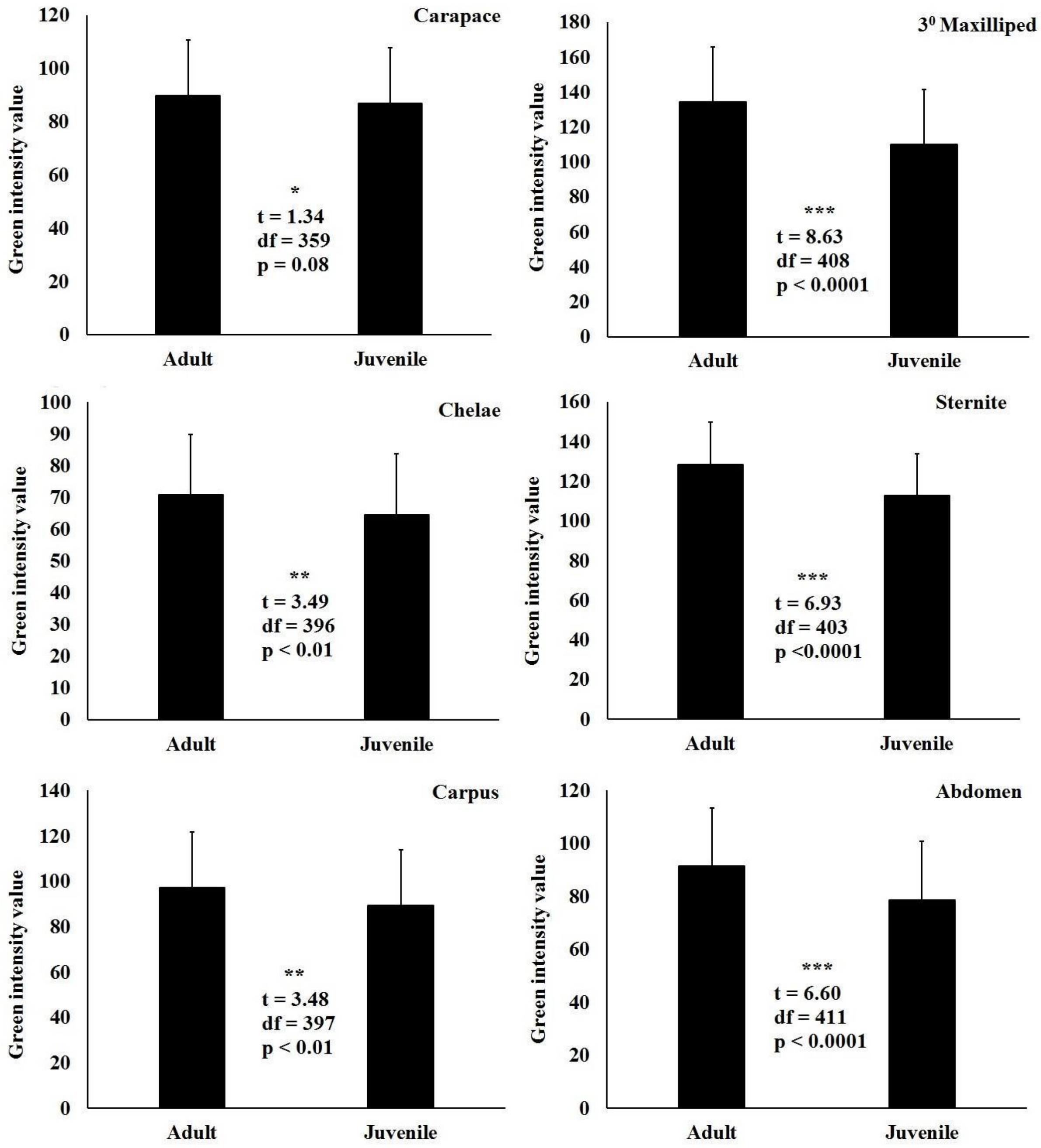

Fig. 4: Mean variation of green colour intensity in different body parts of adult and juvenile individuals of *L. exaratus.*

In case of blue colour intensity, the mean values varied significantly for different body parts between adults and juveniles (Fig. 5). High mean variation was observed for ventral body part (third maxilliped) of adult and juvenile as compared to dorsal body parts (Fig. 5).

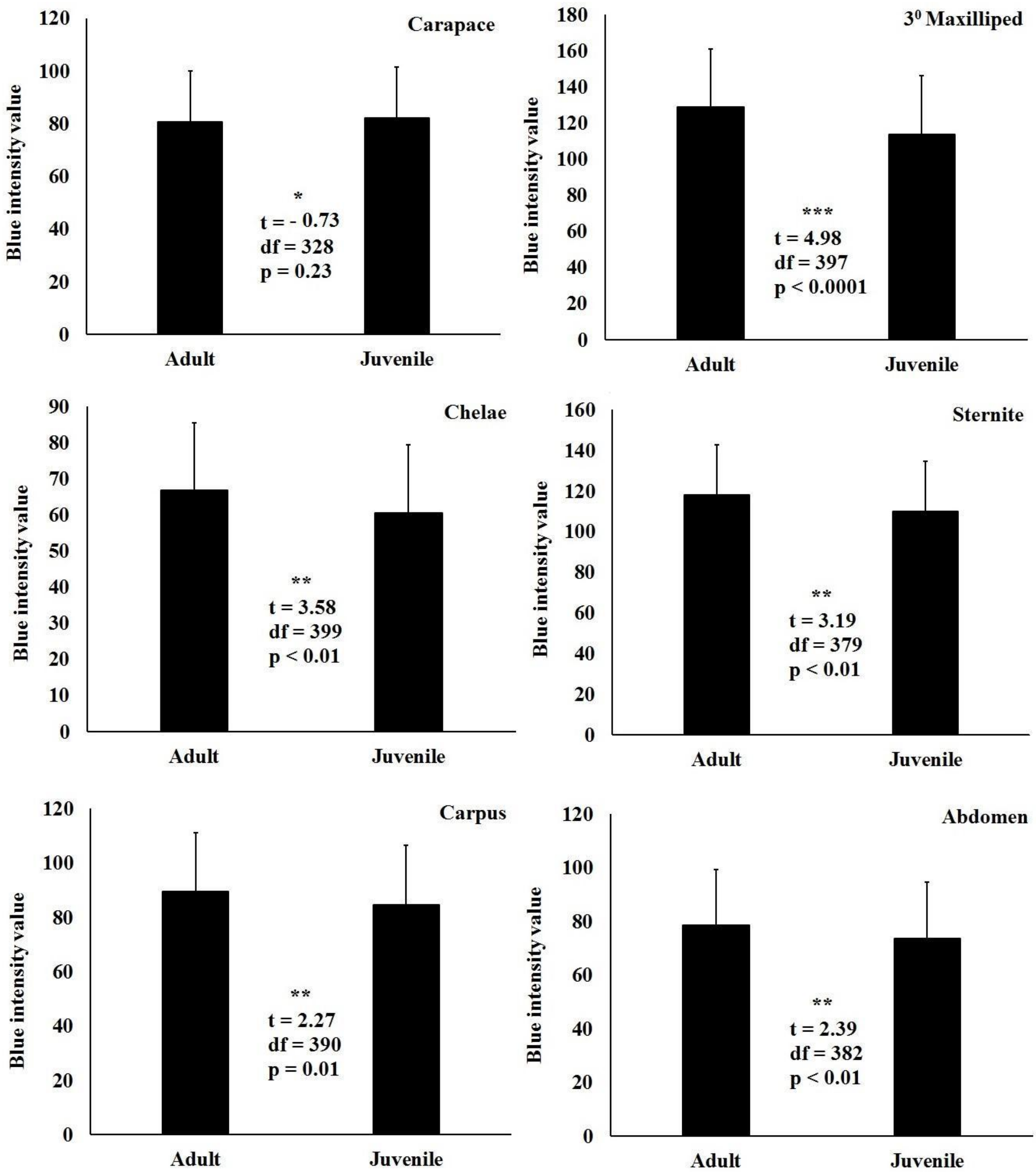

Fig. 5: Mean variation of blue colour intensity in different body parts of adult and juvenile individuals of *L. exaratus.*

The results shows that there was a significant variation between the values of red, green and blue spectra of ventral body parts (third maxilliped, sternite and abdomen) in adult and juvenile individuals. However, moderate to low variations were observed between the values of red, green and blue spectra of dorsal body parts (carapace, chela and carpus) in the adult and juvenile individuals. The adults possess high value of red, green and blue spectrum as compared to juveniles which reveal that adults are significantly lighter in colour on ventral side, whereas juveniles are darker (Fig. 6).

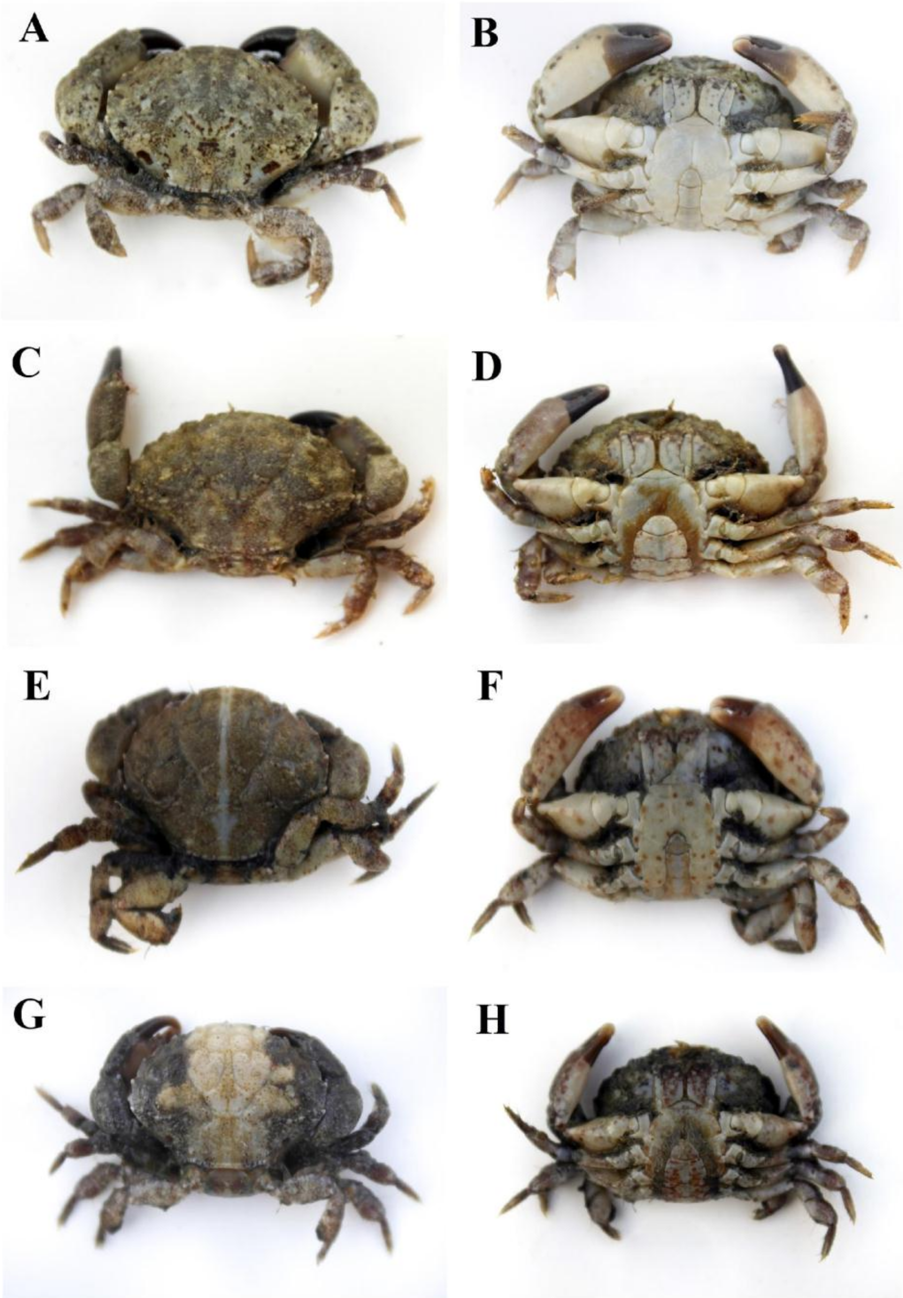

Fig. 6: Ontogenic colour variation in *Leptodius exaratus* (H. Milne Edwards, 1834). A. Adult male dorsal; B. Adult female ventral; C. Adult female dorsal; D. Adult female ventral; E. Juvenile male dorsal; F. Juvenile male ventral; G. Juvenile female dorsal; H. Juvenile female ventral.

Regression analysis showed significant positive relationship between crab body size (CW) and colour intensity values (red, green and blue) of different body parts of *L. exaratus* (Figs. 7, 8, 9). The relationship between each variable was positive but the value of relationship (r^2) was low to moderate. The values of relationship were bit higher for ventral body parts as compared to dorsal body parts which show that the changes in coloration of ventral body parts are significantly affected by increase in body size.

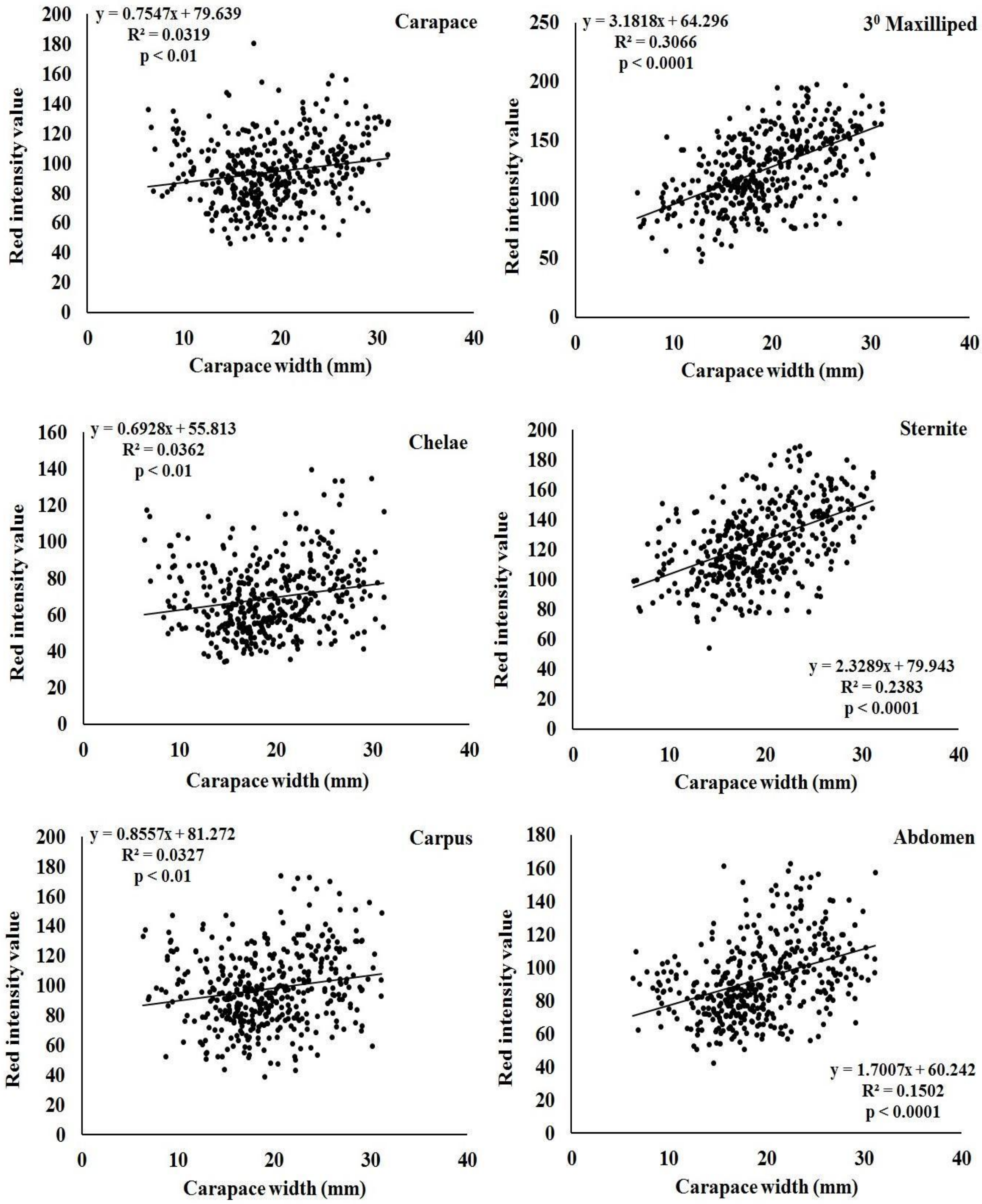

Fig. 7: Regression analysis between red intensity values of different body parts and carapace width of *L. exaratus.*

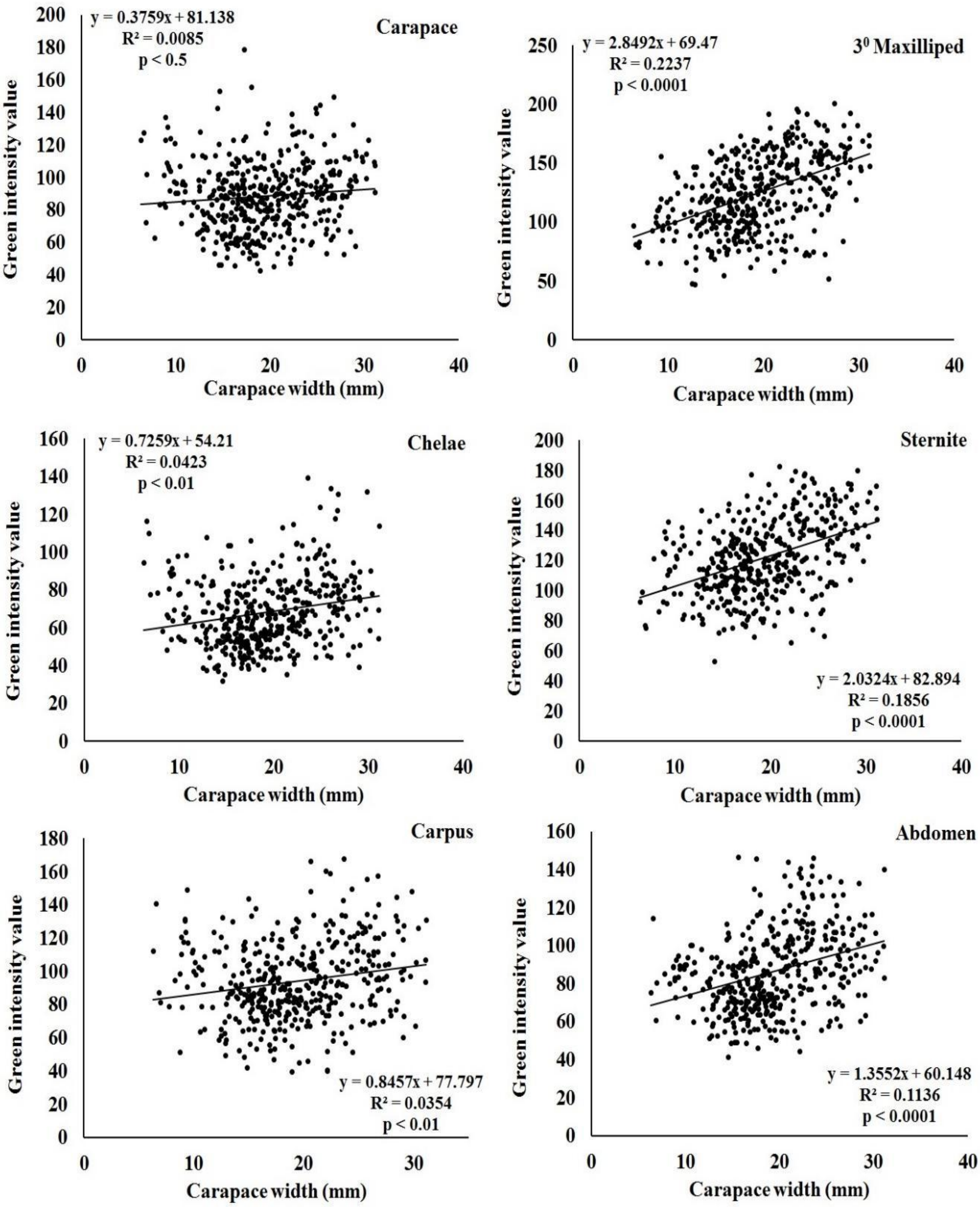

Fig. 8: Regression analysis between green intensity values of different body parts and carapace width of *L. exaratus.*

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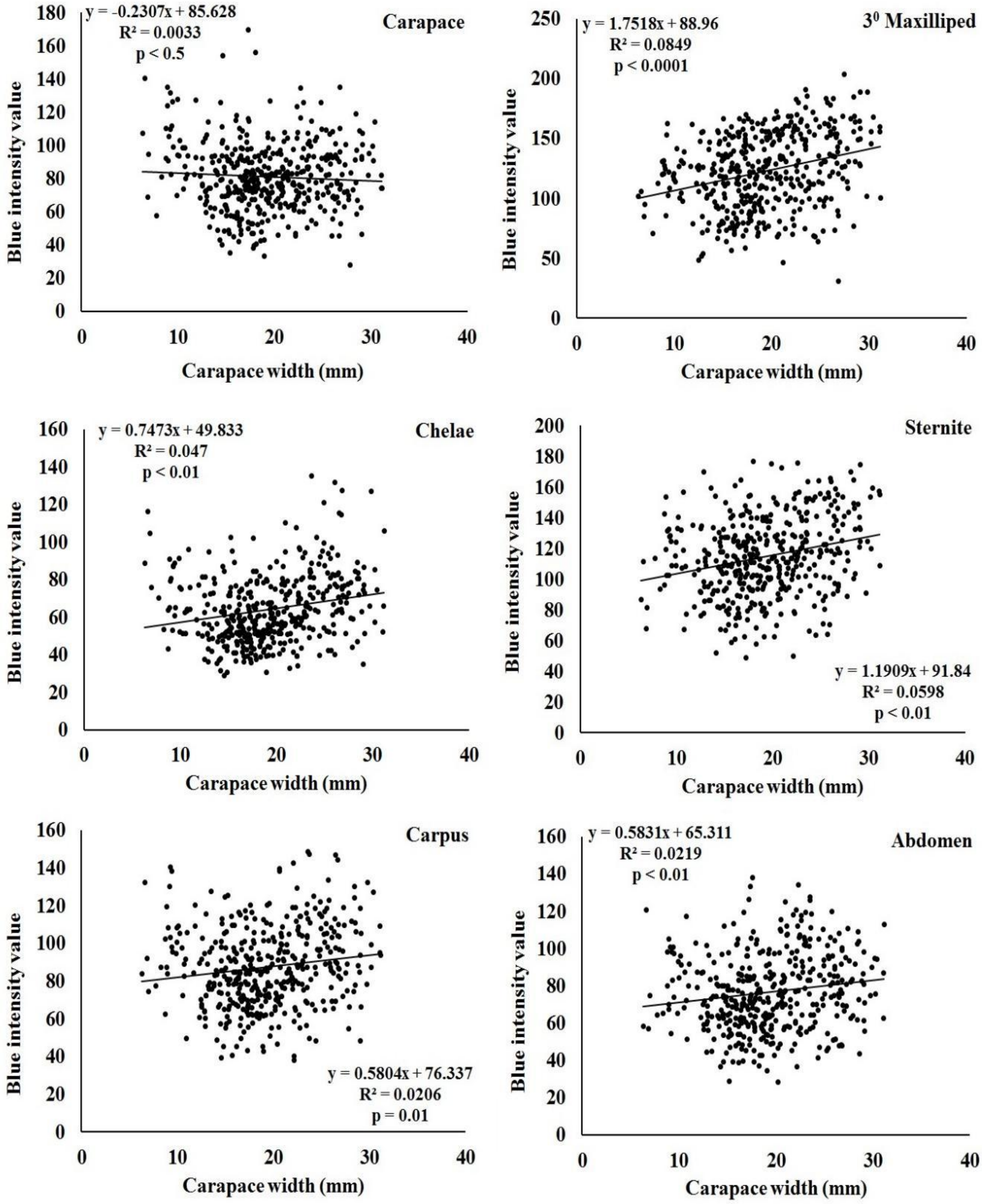

Fig. 9: Regression analysis between blue intensity values of different body parts and carapace width of *L. exaratus.*

Discussion

The external body coloration of *L. exaratus* varied from light gray to dark gray or dark olive which is confirmed by the different values of red, green and blue colour spectra. Similar results were also observed in *Dilocarcinus pagei* (Pontes *et al*., 2020). Such changes in the coloration pattern are related to the growth of morphological structures in the crabs (Pontes *et al*., 2020). The changes in coloration intensity and pattern are related to the movement of pigments which causes dispersion or concentration of epithelial chromatophores leading to change in body colour (Rao, 2001). The present study revealed that the crab body size changes have significant positive relationship with the changes in the body coloration of the species but the value of relationship (r^2) were low to moderate. The result shows that as compared to increase in the body size there are several other physical and biological factors responsible for the exoskeleton colour variation in brachyurans such as moult cycle, predation (cryptic or camouflage colours), microhabitat use, salinity, desiccation and carapace thickness, temperature and sexual maturity (Watanabe *et al*., 2015).

In the present study it was observed that the intensity of red, green and blue spectra varied between adults and juvenile for different body parts. On the basis of the intensity of red, green and blue spectra it is revealed that the juveniles were darker in coloration while adults were lighter. Majority of the studies on other animals showed contrasting results where the juveniles were showing varied patterns and light in coloration while the adults become less patterned, often darker and apparently less cryptic (Palma and Steneck, 2001; Todd *et al*., 2009; Carvalho-Batista *et al*., 2015; Jensen and Egnotovich, 2015; Russell and Dierssen, 2015). It is observed that during juvenile condition, the risk of predation is higher and therefore the individuals allocate more resources to defensive structures like cryptic body. However, with increasing body size, their resource allocation shifts from defensive coloration to reproductive strategies (Hartnoll, 1965, 1974; Palma and Steneck, 2001; Berke and Woodin, 2008; Baeza and Asorey, 2012).

In the present study significant variation for the intensity of red, green and blue spectra between the ventral parts of the adult and juvenile individuals. It shows that the ventral parts of the juvenile individuals were darker and the adult individuals were lighter. Similar results were observed in several other species like *Uca perplexa* (Takeda, 2006), *Cherybdis hellerii* (Watanabe *et al*., 2015) and *Arenaeus cribrarius* (Pinheiro and Taddei, 2000). In his study, Takeda (2006) commented that the ontogenic change in the coloration of the abdomen of crab is considered as the indicator of growth and sexual maturity.

The present study reveals that overall body colour of the juvenile individuals was darker as compared to the adult individuals suggesting ontogenic changes in the coloration occurring in *L. exeratus*. The significant variation in the ventral body colour of *L. exaratus* from darker in juveniles to lighter in adults is associated with the onset of sexual maturity.

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References

Anderson, J. R., Spadaro, A. J., Baeza, J. A., and Behringer, D. C. 2013. Ontogenetic shifts in resource allocation: colour change and allometric growth of defensive and reproductive structures in the Caribbean spiny lobster *Panulirus argus*. *Biological Journal of the Linnean Society*, 108(1), 87–98.

Baeza, J. A., and Asorey, C. M. 2012. Testing the role of male–male competition in the evolution of sexual dimorphism: a comparison between two species of porcelain crabs. *Biological Journal of the Linnean Society*, 105(3), 548–558.

Berke, S. K., and Woodin, S. A. 2008. Energetic costs, ontogenetic shifts and sexual dimorphism in spider crab decoration. *Functional Ecology*, 1125–1133.

Boughman, J. W. 2001. Divergent sexual selection enhances reproductive isolation in sticklebacks. *Nature*, 411(6840), 944–948.

Briolat, E. S., Burdfield-Steel, E. R., Paul, S. C., Ronka, K. H., Seymoure, B. M., Stankowich, T., and Stuckert, A. M. 2019. Diversity in warning coloration: selective paradox or the norm? *Biological Reviews*, 94(2), 388–414.

Carvalho-Batista, A., Pescinelli, R. A., Garcia, J. R., Guerra, P. G., Pardo, L. M., & Mantelatto, F. L. 2015. Crypsis in the mud crab *Panopeus americanus* Saussure, 1857 (Decapoda, Panopeidae): relationship to sexual maturity. *Crustaceana*, 88(9), 963–977.

Casariego, A. M., Luppi, T., and Iribarne, O. 2011. Differential coloration patterns in the intertidal crab *Neohelice granulate*. *Journal of the Marine Biological Association of the United Kingdom*, 91: 1041–1047.

Cooper, W. E., Greenberg, N. E. I. L., and Gans, C. 1992. Reptilian coloration and behavior. *Biology of the Reptilia*, 18, 298–422.

Cummings, M.E., Jordao, J.M., Cronin, T.W. and Oliveira, R.F. 2008. Visual ecology of the fiddler crab, *Uca tangeri*: effects of sex, viewer and background on conspicuousness. *Animal Behaviour*, 75: 175–188.

Delhey K. (2017). Gloger's rule. *Current Biology*. 27: 689–691.

Detto, T., Hemmi, J. M., and Backwell, P. R. 2008. Colouration and colour changes of the fiddler crab, *Uca capricornis*: a descriptive study. *PLoS One*, *3*(2), e1629.

Detto, T., Zeil, J., Magrath, R. D., and Hunt, S. 2004. Sex, size and colour in a semi-terrestrial crab, *Heloecius cordiformis* (H. Milne Edwards, 1837). *Journal of experimental marine biology and ecology*, 302(1), 1–15.

Endler J. A. 1991. Interactions between predators and prey. In: Krebs JR, Davis NB, editors. *Behavioural ecology: an evolutionary approach*, 3rd ed. Oxford: Blackwell. p 169–96.

Endler, J. A. 1981. An overview of the relationships between mimicry and crypsis. *Biological Journal of the Linnean Society*, 16(1), 25–31.

Figueroa, J. A., Islas, R. P., Palafox, J. P., and Carter, E. V. 2003. Pigmentation of pacific white shrimp (*Litopenaeus vannamei*, Boone 1931) with esterified and saponified carotenoids from red chili (*Capsicum annuum*) in comparison to astaxanthin. *Revista Mexicana de Ingeniería Química*, 2(2), 101–108.

Garcia, T. S., and Sih, A. 2003. Color change and color-dependent behavior in response to predation risk in the salamander sister species *Ambystoma barbouri* and *Ambystoma texanum. Oecologia*, 137(1), 131–139.

Hanlon, R. 2007. Cephalopod dynamic camouflage. *Current Biology*, 17(11), R400-R404.

Hartnoll, R. G. 1965. The biology of spider crabs: a comparison of British and Jamaican species. *Crustaceana*, 1–16.

Hartnoll, R. G. 1974. Variation in growth pattern between some secondary sexual characters in crabs (Decapoda Brachyura). *Crustaceana*, 27(2), 131–136.

Hemmi, J. M., Marshall, J., Pix, W., Vorobyev, M., and Zeil, J. 2006. The variable colours of the fiddler crab *Uca vomeris* and their relation to background and predation. *Journal of Experimental Biology*, 209(20), 4140–4153.

Hinton, H. E., and Jarman, G. M. 1972. Physiological colour change in the Hercules beetle. *Nature*, 238(5360), 160–161.

Jablonski, N. G., and Chaplin, G. 2017. The colours of humanity: the evolution of pigmentation in the human lineage. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 372(1724), 20160349.

Jensen, G. C., and Egnotovich, M. S. 2015. A whiter shade of male: color background matching as a function of size and sex in the yellow shore crab *Hemigrapsus oregonensis* (Dana, 1851). *Current Zoology*, 61(4), 729–738.,

Kodric-Brown, A. 1998. Sexual dichromatism and temporary color changes in the reproduction of fishes. *American Zoologist*, *38*(1), 70–81.

Lee, K.T. and Vespoli, J.L. 2015. Tracking Color Change in Individual Green Crabs, *Carcinus maenas* (L.). *Northeastern Naturalist*, 22: 413–423.

Lee, S. K., Mendoza, J. C. E., Ng, P. K., and Kim, W. 2013. On the identity of the Indo-West Pacific littoral xanthid crab, *Leptodius exaratus* (H. Milne Edwards, 1834) (Crustacea: Decapoda: Brachyura: Xanthidae). *Raffles Bulletin of Zoology*, 61(1): 189–204.

Luiz-Junior, O. J. 2003. Colour morphs in a queen angelfish *Holacanthus ciliaris* (Perciformes: Pomacanthidae) population of St. Paul's Rocks, NE Brazil. *Tropical fish hobbyist*, 51(5), 82–90.

McGaw, I. J., Kaiser, M. J., Naylor, E., and Hughes, R. N. 1992. Intraspecific morphological variation related to the moult-cycle in colour forms of the shore crab *Carcinus maenas*. *Journal of Zoology*, 228(2), 351–359.

Palma, A. T., and Steneck, R. S. 2001. Does variable coloration in juvenile marine crabs reduce risk of visual predation? *Ecology*, 82(10), 2961–2967.

Pigliucci M. (2001). Phenotypic plasticity: beyond nature and nurture. Johns Hopkins University Press, Baltimore. 356pp. ISBN 978-08-0186-788-0.

Pinheiro, M. A. A., and Taddei, F. G. 2000. Chromatic alteration in *Arenaeus cribrarius* (Lamarck) (Crustacea, Portunidae): an indicator of sexual maturity. *Revista Brasileira de Zoologia*, 17(4), 945–951.

Pontes, N. D. A., Sant’Anna, B. S., and Hattori, G. Y. 2020. Color variation of the freshwater crab *Dilocarcinus pagei* Stimpson, 1861 captured in the Amazon region at Itacoatiara, Amazonas, Brazil. *Nauplius*, 28.

Rao, K. R. 2001. Crustacean pigmentary-effector hormones: chemistry and functions of RPCH, PDH, and related peptides. *American Zoologist*, 41(3), 364–379.

Reid, D. G., Abello, P., Kaiser, M. J., and Warman, C. G. 1997. Carapace colour, inter-moult duration and the behavioural and physiological ecology of the shore crab *Carcinus maenas*. *Estuarine, Coastal and Shelf Science*, 44(2), 203–211.

Relyea, R. A. 2005. Constraints on inducible defenses: phylogeny, ontogeny, and phenotypic trade-offs. *Ecology of predator-prey interactions*, 189–207.

Reuschel, S., and Schubart, C. D. 2007. Contrasting genetic diversity with phenotypic diversity in coloration and size in *Xantho poressa* (Brachyura: Xanthidae), with new results on its ecology. *Marine Ecology*, 28(2), 296–305.

Russell, B. J., and Dierssen, H. M. 2015. Use of hyperspectral imagery to assess cryptic color matching in *Sargassum* associated crabs. *PLoS One*, 10(9), e0136260.

Ruxton, G. D., Sherratt, T. N., and Speed M. P. 2004. Avoiding attack: The Evolutionary ecology of crypsis, Warning Signal and Mimicry. Oxford: Oxford University Press. 248pp. ISBN 978-01-9852-860-9.

Sangthong, P., and Jondeung, A. 2006. Classification of three crab morphs in the genus *Scylla* using morphometric analysis. *Agriculture and Natural Resources*, 40(4), 958–970.

Silva, C. C., Schwamborn, R. C., and Oliveira, J. E. 2014. Population biology and color patterns of the blue land crab, *Cardisoma guanhumi* (Latreille 1828) (Crustacea: Gecarcinidae) in the Northeastern Brazil. *Brazilian Journal of Biology*, 74(4), 949–958.

Styrishave, B., Rewitz, K., and Andersen, O. 2004. Frequency of moulting by shore crabs *Carcinus maenas* (L.) changes their colour and their success in mating and physiological performance. *Journal of Experimental Marine Biology and Ecology*, 313(2), 317–336.

Takeda, S. 2006. Behavioural evidence for body colour signaling in the fiddler crab *Uca perplexa* (Brachyura: Ocypodidae). *Journal of experimental marine biology and ecology*, 330(2), 521–527.

Thurman, C. L. 1988. Rhythmic physiological color change in crustacea: a review. *Comparative Biochemistry and Physiology Part C: Comparative Pharmacology*, 91(1), 171–185.

Todd, P. A., Qiu, W., and Chong, K. Y. 2009. Ontogenetic shifts in carapace patterning and/or colouration in intertidal and subtidal brachyuran crabs. *Raffles Bulletin of Zoology*, 57(2), 543–550.

Trivedi, J. N., and Vachhrajani, K. D. 2013. Study of Color Morphs of Brachyuran Crab *Etisus laevimanus* Randall, 1840. *Indian Journal of Geo-Marine Science* 42(5): 659–664.

Watanabe, T. T., Zara, F. J., Hattori, G. Y., Turra, A., and Sant'Anna, B. S. 2015. Biological associations of color variation in the Indo-Pacific swimming crab *Charybdis hellerii*. *Anais da Academia Brasileira de Ciencias*, *87*(1), 219–232.

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Decadal change in marine fish landing and fish composition in Odisha coast of India

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Abstract

Climate change is now identified as a global issue impacting the Earth with variable magnitude. Globally, fisheries and aquaculture serve as prime source of animal protein by providing about 3.2 billion people with 20% of their average per capita animal protein intake. The present paper has tried to focus on the marine fish landing status in six major districts of coastal Odisha from 2005-06 to 2019-20. Data on fish landing states that there is an increasing trend towards 2018-19 and 2019-20 in almost all the districts. Species composition observed showed Penaeidae (21%) as the most dominant family followed by Sciaenidae (18%) and Ariidae (16%) of total captured specimens. Species wise catch exhibited major composition of *Arias*, *Croaker*, *Mugil*, *Trichurus*. *Stolephorus* and *Metapenaeus* spp. in catch over 05 years (2015-16 to 2019-20). In order to find out the district-wise catch diversity, Shannon-Weiner Species diversity index was calculated which showed maximum diversity at Puri and lowest in Ganjam. With the aim to find out the effect of climate change on fish catch statistics, data on sea surface temperature over a period of 15 years were correlated with the catch (in MT) district-wise. The data showed significant positive relationship ($p<0.01$) in districts like Puri, Jagatsinghpur and Ganjam whereas insignificant for others. The study depicts that fisheries conservation measures are very significant in the State. A more critical analysis along with surrounding anthropogenic factors may drive the work towards the lane of climate change.

Keywords: Fish landing stations, Fish composition, Catch Diversity Index, SST, Climate change, Correlation

Introduction

Billions of people are depended on the marine fisheries around the world. According to UN Food and Agriculture Organization, 16.7% of people take fish as the source of animal protein. This is about 6.5% of the total consumed protein (Laffoley D *et al.,* 2019). According to CMFRI, India (2019) about 3.56 million metric tons of marine fish is caught. This has an estimated price value of 8.1 billion USD. Thus, the marine fish production is rising as the economical industry.

Odisha has about 480 kms of coastline spread over the six districts. It is ranked 8th for the contribution of marine fish production. Although motorised, mechanised and traditional methods are used for fishing, motorised and mechanised methods are dominating

(Maheswaraudu G *et al.*, 2013). Different motors are operated in different districts for fishing. In Ganjam, Puri and Jagatsinghpur relatively low i.e., 8-26 hp engine with 5-17m OAL trawlers are used. Where as in other districts, 68-450 hp engines with 10-18.4m OAL trawlers are used (Roul SK *et al.*, 2020). These trawlers also used for multiday (7-15 days) fishing. In single day fishing, no preservation processing is done where as in multiday fishing, icing is done to store for longer time period (Roul SK *et al.*, 2020). To preserve for a longer time period, drying and salting methods are followed.

The climate change has a huge impact on each and every organism. As the marine fishes are directly exposed to the pollution and various oceanographic disturbances, the productivity might get affected. The spatial distribution of fishes might affect due to the rise in the temperature gradually (Mohanty BP *et al.,* 2010). In this background, the present paper has tried to document the fish landing data over a period of 15 years and correlate it with sea surface temperature.

Methods

Study Area

The study area is located in the 6 coastal districts of Odisha along the Bay of Bengal. **Balasore** is in the northern most part of the coast. The district has about 80kms of coastal area. It has about 13 landing stations namely Chandipur, Bahabalpur Mahisali, Choumukh, Kankadapal, Dagara, Talasari, Kirtania, Ransinghpur, Udayapur, Panchubisa, Gadeisagar, Jammuka. **Bhadrak** district is an eastern district surrounded by Balasore, Jajpur and Keonjhar. It has 50kms of coastal region. There are about 10 landing stations i.e., Dhamara, Chandinipal, Baincha, Karanapalli, Karanjamal, Kaithakhola, Chudamani, Bideipur, Kansabansa. **Jagatsinghpur** has an economical importance because of its geographical position. The coastal area spreads up to 67kms. The economically important landing stations in this district are Paradeep, Noliasahi and Bandar. **Kendrapara** district lies in the central coastal plain of Odisha. The coast line of Kendrapara covers about 68kms. This district is mainly known for the mangrove forests. It includes about 7 landing stations namely; Kajalpatia, Kharinasi, Jamboo, Tantiapal, Talchua, Gopalpur and Barunei. **Ganjam** district has about 60kms long coast line. The district has a lot of scope for fishing and also port for trading. There are 10 landing stations namely; Prayagi, Kantiagarh, Gokharkuda, Nolianuagaon, Gopalpur, New Baxipalli, Garampeta, Markandi, Rameyapatna, Sonapur etc. **Puri** district covers coastline of 155kms with 8 landing stations i.e., Nuagarh, Chandrabhaga, Ramachandi, Penthakata, Harachandi and Arakhakuda. (Fig.1).

Collection of Fish Landing and Diversity Data

Secondary data of the fish landing over a period of 15 years (2005-06 to 2019-20) for the 6 districts was collected from the Directorate of Fisheries, Government of Odisha. Fish diversity data was obtained only from 2015-16 to 2019-20 (5 years) was available.

Collection of Sea Surface Temperature (SST) Data

Secondary data from previously published literature were collected (Chanda A et al., 2018; Banerjee K et al., 2020).

Statistical Analysis

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Past software was used to calculate the Shannon- Weiner Diversity Index. Regression equations with R^2 values were computed to find the relationship between SST and Landing data using Microsoft Excel.

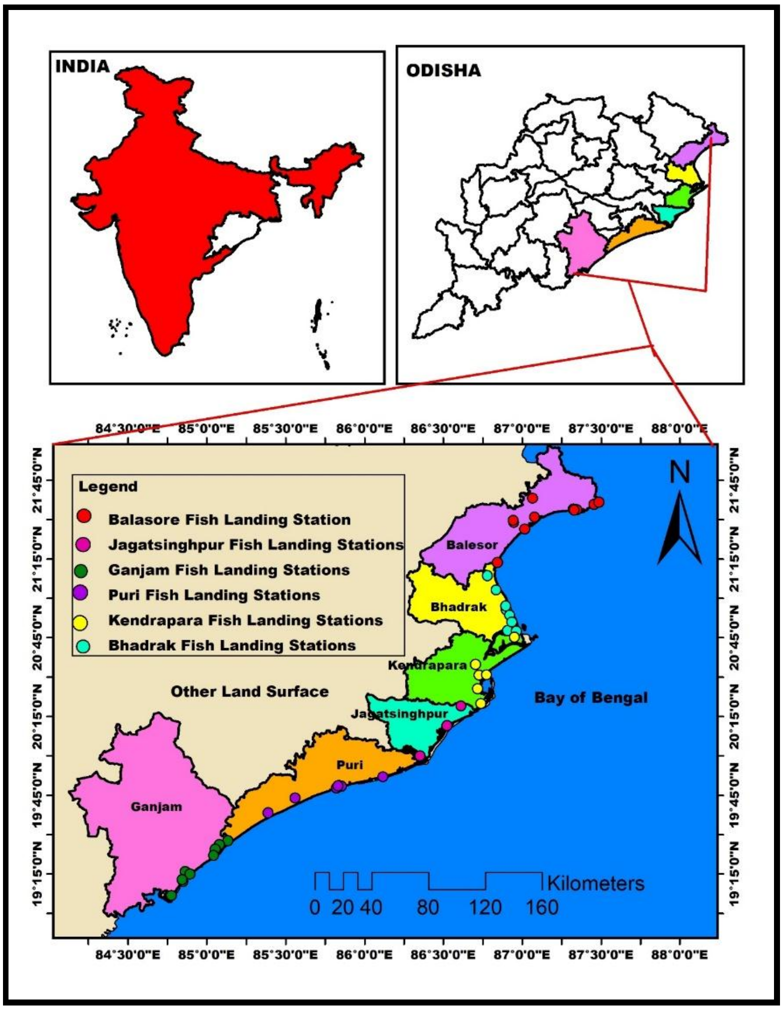

Fig.1: Map of study area

Results & Discussion

Coastal and marine ecosystems provide various services to support the livelihood of millions of people worldwide (Chen Z et al. 2015; Lau JD et al. 2019). It has been estimated that coastal fish landing accounts for 50-60 million tons each year which is about half of the global marine catch (Palomares and Pauly 2019). Decadal fish landing data is presented in Fig. 2.

Landing data were highest during 2018-19 and 2019-20 in all the districts, owing to the fact that improved gears and mechanized trawling vessels might have led to this increased catch. Family-wise dominant fish landing accounted for Penaeidae (21%) followed by Sciaenidae (18%) and Ariidae (16%) (Fig. 3). Species wise landing data was obtained from 2015-16 to 2019-20 which revealed maximum landings at Jagatsinghpur > Balasore > Bhadrak > Kendrapara > Puri > Ganjam. Catch diversity index of fishes were however more or less uniform with values ranging from 2.01 (Ganjam) < 2.02 (Kendrapara) < 2.05 (Balasore) <

2.07 (Bhadrak) = 2.07 (Jagatsinghpur) < 2.20 (Puri). The major group of fishes which are found in all the landing stations were *Arius* sp., *Mugil* sp., *Trichiurus* sp., *Croaker* sp., *Metapenaeus* sp. and *Stolephorus* sp. respectively (Fig. 4). Species wise marine fish landing data has clearly revealed an increased fish catch over the years from 2015-16 to 2019-20 which is a clear indication of hygienic increased conservation methods adopted by Government of Odisha during its banning season.

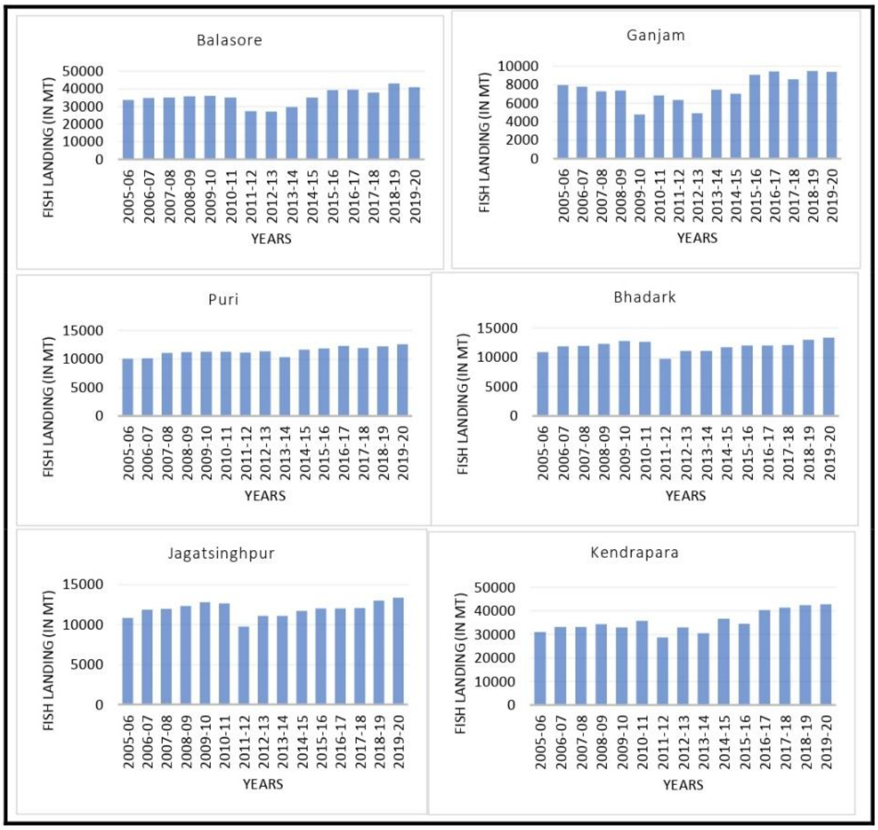

Fig.2: District-wise fish landing data over a period of 15 years

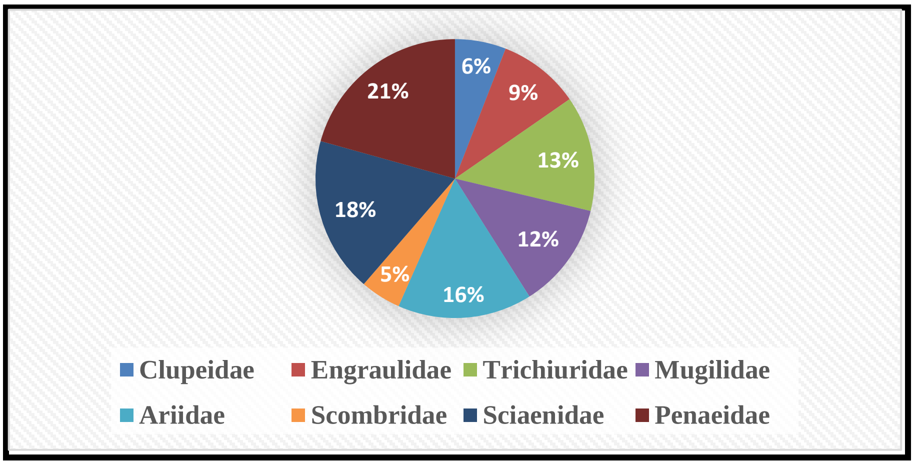

Fig.3: Family-wise fish composition over a period of 5 years

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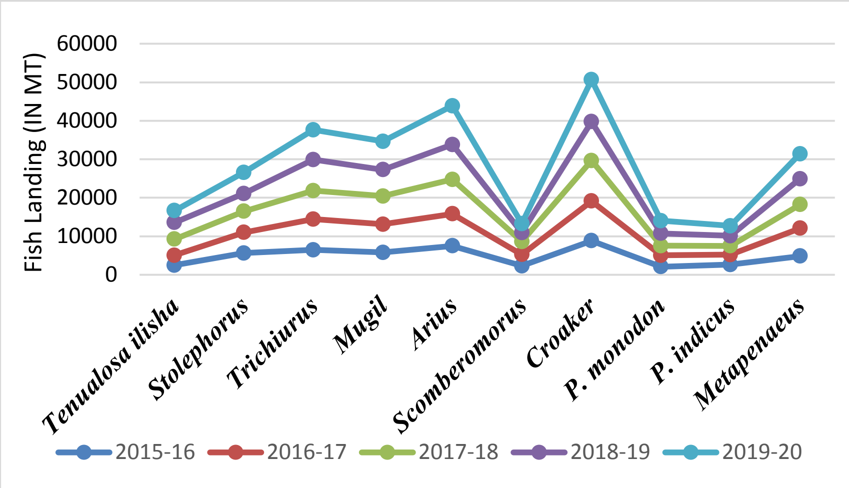

Fig.4: Species-wise fish composition over a period of 5 years

In order to understand the climate change effects on fish catch statistics, a correlation between SST and fish landings in the six selected districts were computed. SST over the last 15 years varied from 25.9^{0}C (2005-06) to 28.7^{0}C (2019-20) which is 2.8^{0}C change in temperature. The R^2 values have shown significant positive relationship of fish landing and temperature ($p<0.01$) at Puri, Jagatsinghpur, and Ganjam which clearly reveals that change in temperature has significant effect on the fish landing data. However, the other three districts namely Bhadrak, Balasore and Kendrapara has also shown positive insignificant relationship which indicates that the presence of mangroves have played significant role in combating the effects of SST (Fig. 5). Variations in the fish catch composition, number etc. have shifted over last three decades due to multiple stress factors like over fishing, pollution, industrialization, climate change and aquaculture (Bland LM et al. 2018; Han D et al. 2018). Furthermore, rising water temperatures due to anthropogenic climate change has also influenced reduction in species abundance and food web dynamics (Yu J et al. 2010; Doney SC et al. 2012).

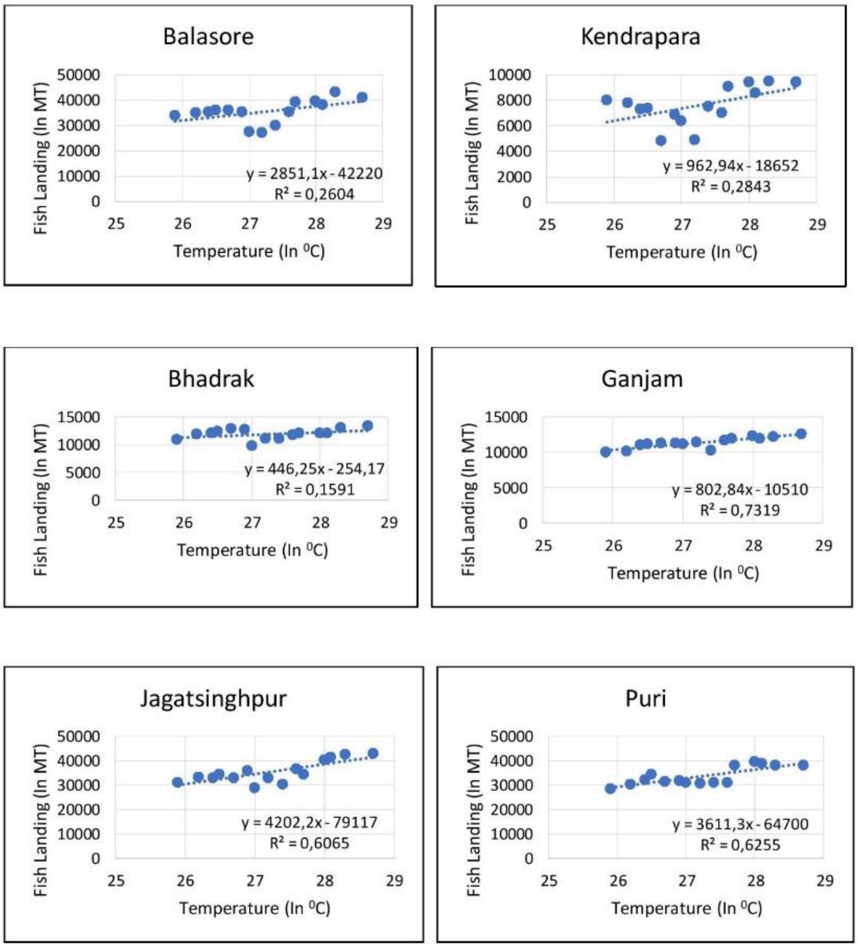

Fig.5: Scatter plots showing relationship between SST and Fish landing at the study area

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Conclusion

The present research program has pointed out to the fact that over 15 years landing data has increased with a record of only 10 fish species. However, there is a high probability factor of anthropogenic pollution in the seas which might have affected the composition variation of fishes. Therefore, more emphasis needs to be given for integrating multiple anthropogenic factors to achieve better management of marine ecosystem.

Acknowledgement

The authors are grateful to Fisheries Department, Government of Odisha for providing the data bank.

References

Banerjee, K., Chandan, K. S., Gobinda, B., Kapileswar, M., Rakesh, P., Abhijit, M. 2020. High blue carbon stock in mangrove forests of Eastern India. *Tropical Ecology*, 61:150–167.

Bland, L.M., Watermeyer, K.E., Keith, D.A., Nicholson, E., Regan, T.J., Shannon, L.J. 2018. Assessing risks to marine ecosystems with indicators, ecosystem models and experts. *Biol. Conserv*. 227, 19–28.

Chanda, A., Sourav, D., Anirban, M., Amit, G., Anirban, A., Pramit, G., Tuhin, G., Debashis, M., Sugata, H. 2018. Sea surface temperature and rainfall anomaly over the Bay of Bengal during the El Niño-Southern Oscillation and the extreme Indian Ocean Dipole events between 2002 and 2016. Remote Sensing Applications: Society and Environment.

Chen, Z., Xu, S., Qiu, Y. 2015. Using a food-web model to assess the trophic structure and energy flows in Daya Bay, China. *Cont. Shelf Res*. 111: 316–326.

CMFRI, 2019. Marine fisheries census 2019. Part 1. Ministry of Agriculture, Dept. of Animal Husbandry, Dairying & Fisheries and Central Marine Fisheries Research Institute, Indian Council of Agricultural Research. New Delhi, India.

Doney, S.C., Ruckelshaus, M., Duffy, J.E., Barry, J.P., Chan, F., English, C.A., Galindo, H.M., Grebmeier, J.M., Hollowed, A.B., Knowlton, N., Polovina, J., Rabalais, N.N., Sydeman, W.J., Talley, L.D. 2012. Climate change impacts on marine ecosystems. *Annu. Rev. Mar. Sci*. 4, 11–37.

Han, D., Chen, Y., Zhang, C., Ren, Y., Xu, B., Xue, Y. 2018. Evaluation of effects of shellfish aquaculture and capture fishery on a semi-closed bay ecosystem. *Estuar. Coast. Shelf. Sci*. 207: 175–182.

Laffoley D., John M. B., Jon C. D., Lauren, W., Paula, B., Katherine, Z. 2019. Marine Protected Areas. pp 549-569.

Lau, J.D., Hicks, C.C., Gurney, G.G., Cinner, J.E. 2019. What matters to whom and why? Understanding the importance of coastal ecosystem services in developing coastal communities. *Ecosyst. Serv*. 35, 219–230.

Maheswarudu, G., Rao, G. S., Prathibha, R. P. Laxmilatha, Shubhadeep, G. and Muktha, M. 2013. Marine fisheries of Andhra Pradesh: a decadal analysis. *Indian Journal of Fisheries*, 60(3): 27-33.

Mohanty, B. P., Sasmita, M., Jyanendra, K. S. and Anil, P. S. 2010. Climate change: impacts on fisheries and aquaculture. pp 119-138.

Palomares, M.D., Pauly, D., 2019. Coastal fisheries: the past, present, and possible futures. In: Wolanski, E., Day, J.W., Elliott, M., Ramachandran, R. (Eds.), Coasts and Estuaries: The Future. Elsevier, Amsterdam, pp. 569–576.

Roul, S.K., Rajesh, K. P., Manas, H. M., Shubhadeep, G., Ganga, U. Abdussamad, E. M., Mini, K. G., Prathibha, R. 2020. Large Pelagics fisheries along Odisha coast – An overview. Marine Fisheries Information Service Technical & Extension Series No. 245.

Yu, J., Tang, D., Yao, L., Chen, P., Jia, X., Li, C. 2010. Long-term water temperature variations in Daya Bay, China using satellite and in situ observations. *Terr. Atmos. Ocean. Sci*. 21: 393–399.

SESSION 2: Blue Carbon and Coastal Ecosystems (Code: BCCE)

BCCE – 201- OR

Role of coastal blue carbon in climate change mitigation and ecosystem restoration- A review

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Abstract

The carbon arrested and deposited in coastal and marine ecosystems are known as blue carbon. Mangroves, seagrass meadows, tidal salt marshes etc sequester and deposit more carbon than land ecosystem and are now being accepted for their role in mitigating climate change. The coastal ecosystems also supply necessary benefits for climate change adaptation, including coastal protection and food security for many coastal communities. However, if the ecosystems are degraded or damaged, their carbon sink capacity is lost or adversely affected, and the carbon stored is released, resulting in emissions of carbon dioxide (CO2) that contribute to climate change. Ecosystems with blue carbon storage help in preventing climate change, protect the coastal communities from rising seas and flooding and also provides habitat for marine life. The impacts of climate change on coastal ecosystems may lead to a reversal of carbon sequestration in the future. Mangroves and sea grasses are vulnerable to the impacts of climate change, such as ocean warming, sea level rise and increased storminess. Considering the recent scenario of global economy, thrust should be given to expand the horizon of blue carbon sector through afforestation, scientific soil management, protected area development and conservation measures, rather than investing in costly technology to sequester carbon. In this paper, we tried to outline the importance of restoration of Mangroves, Sea grasses and Tidal Salt Marshes habitats to enhance carbon sequestration in the coastal zones.

Keywords: Blue carbon, mangroves, tidal marshes and seagrass meadows, climate change.

Introduction

Coastal blue carbon is the carbon that is absorbed by the higher plants, algae and phytoplankton. They absorb atmospheric CO2 during photosynthesis and then conserved in sediments under the effect of microorganisms and plants. The blue carbon is stored in mangroves, salt tidal marshes, and seagrass meadows. The carbon sequestered in coastal and marine vegetated ecosystems (Macreadie *et al*., 2019) is also known as coastal wetland blue carbon (Himes -Cornell *et al.*, 2017). It is stored within the soil, leaves, branches, stems, roots and in the non-living biomasses like litter and dead wood (McLeod *et al*., 2011).

The organic and other carbon transported from the sea side to deep sea the ocean is described as coastal blue carbon. Blue carbon in coastal area lies between the green carbon (terrestrial) and blue carbon (ocean). The coastal zone is under the influence of seawater, tides, salt marsh, mangrove and seagrass. Nowadays, coastal blue carbon is also referred to as the carbon fixed by coastal plants (salt marshes, mangroves, and seagrasses) (McLeod *et al*., 2011; Zhang *et al*., 2015; Howard *et al*., 2017). This is due to the higher productivity of salt marshes, mangroves and seagrasses. Coastal wetlands help to maintain the coastal communities and biodiversity (Buditama, 2016; Cornell *et al., 2018;* Meng *et al.,* 2019. The carbon sequestration capacity of these coastal ecosystem is about ten times more than the terrestrial ecosystem (McLeod *et al*., 2011). Even though this coastal ecosystem is only 0.2% of the ocean area, it accounts about 50% carbon deposit than in ocean sediments (Duarte *et al.,* 2013). Sea grasses, mangroves and salt marshes in the coastal ecosystem sequester the carbon in a faster rate and act as a carbon sink and conserve the carbon for several years. Coastal wetland ecosystem is about < 3% of forest coverage of land ecosystem but they are able to preserve equal amounts of organic carbon yearly (Duarte *et al.,* 2013). These wetland ecosystems have the capacity to drop the externally produced organic carbon suspended in tidal flows and terrestrial runoff (McLeod *et al*., 2011). If the human activities can destroy this coastal ecosystem it results in decrease of stored carbon and it may cause climate change. If we protect these systems it leads to increase in blue carbon. The mitigation of climate change can be achieved by incorporating coastal blue carbon into carbon credit. By protecting and rehabilitating these coastal wetland ecosystems from degradation we can remove carbon from the atmosphere and achieve climate change mitigation.

Mangroves

Mangroves are about 0.5% of the world coastal area and 0.7% of the world terrestrial forest area (Nehren, et.al 2018). They can conserve up to five times the carbon present in forests per area (Ahmed and Glaser, 2016; Palacios, 2019) and they play a major role in mitigation of climate change. On an average rate they sequester over 2 tons of carbon per hector/year (Palacios, 2019). Mangrove blue carbon stocks are the sum of carbon stored in tree shoots, scrubs, roots, downed wood, dead trees, roots, rhizomes and soils (Murdiyarso *et.al.,* 2015). Mangroves have four main carbon sinks such as living biomass in the above and below ground, dead biomass in the above ground and below ground dead biomass (soil). Soil in this ecosystem is thick, submerged by tides, decomposition is facilitated by anaerobic organisms. This ecosystem has average to high level of carbon (Donato *et al*., 2011). The mangrove soil formation depends upon different ecological processes like weathering, shipment, deposition of organic matter, and sedimentation. So, the main reason for the overrate or underrate mangrove carbon sink is due to these ecological processes which changes the seashore properties. Restoration of mangrove ecosystem will help in the adaptation to climate change and it is a low cost method to mitigate climate change (Adame *et al.,* 2017; Ahmed and Glaser, 2016).

Seagrass

Seagrasses are found in tropical and temperate coastal waters except in Antarctica. They are distributed along the shallow sediments of estuarine and coastal areas forming huge seagrass meadows. These meadows are effective in carbon capture, storage and they are considered as one of the major worlds carbon reservoir. Even though they occupy only 0.1% of the ocean surface and store about 27–44 Tg organic carbon/year. That is they account for 10–18% of the total carbon in the marine ecosystem. They have carbon stock comparable to forest ecosystem and other coastal ecosystem such as mangroves, and tidal marshes (Duarte *et al*., 2005; Fourqurean *et al*., 2012). Both living and nonliving components in these ecosystem controls the degree of carbon accumulation and preservation (Mateo *et al.,* 2006). The components which determine the preservation and accumulation of carbon are composition of organic matter sediment accumulation rate and particle size of sediments (Keil and Hedges, 1993; Torbatinejad et al., 2007; Serrano et al., 2016). Seagrasses consists of variety of species (Carruthers et al., 2007), so the carbon accumulation ratet also vary according to the species of seagrass meadows (De Falco et al., 2000; Kennedy et al., 2010).

The major carbon pools in seagrass meadows are living biomass in the above and below ground soil carbon (dead biomass). In aboveground biomass, they capture small quantity of carbon and in the belowground biomass they store majority of carbon. Belowground biomass has roots and rhizomes that create long lasting root structures. Living belowground biomass represents 0.3% of the total carbon sink that is found below the surface. For the estimation of carbon pool, it is combined with the carbon sink of the soil (Fourqurean *et al*., 2012).

Salt marshes

Salt marshes are ecological neutral zones between the ground soil and open sea. They have high productiveness, abundant biodiversity. Salt marshes are tolerant to high salinity and have rooted vegetation. They occupy the low-energy transition zone between immersed and surface habitat and occupy the top border of the fresh water and saline ecosystem. The submersion of salt marshes are due to submersion by the tides (Siikamäki *et al.,* 2013).

These blue carbon ecosystems extend more than the mangroves, and herb and shrubs are the major plant community. They sequester the CO_2 from the atmosphere and are one of the major productive ecosystems, also serve as a carbon pool. The three carbon pools in the tidal salt marsh ecosystems are the living biomass in the above and below ground soil carbon (dead biomass). In salt marshes, annual primary productivity occurs in the belowground biomass (Valiela *et al*., 1976) and majority of carbon is preserved in the living biomass under the ground area and the non-living soil. Therefore, both these pools are considered as a single carbon pool (Chmura *et al*., 2003). Salt marshes provide long-term storage of carbon through by sequestering them in anaerobic sediments (Mcloed, 2011). Since they have high primary productivity, they actively remove the atmospheric carbon through the process of photosynthesis (Duarte, 2005). C3 salt marsh plants grow more in high CO_2 concentrations, whereas growth C4 salt marsh species ceases at elevated CO_2 levels. So, the elevated level of atmospheric may lead to the out production of C4 marsh and overgrowth of C3 marsh plants (Erickson *et al*., 2007; Gedan *et al*., 2009).

Conclusion

Blue carbon has received international recognition for its beneficial role in mitigating CO_2 emissions. Mitigation and adaptation properties of blue carbon ecosystems help them to play a key role in finding a solution to climate change. These wetlands in coastal area conserve carbon at higher rates than terrestrial forests ecosystems. They sequester carbon within their underground and aboveground living biomasses such as leaves, stems, wood, roots, rhizomes,

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and also in soil which holds abundant carbon. By protecting these blue carbon ecosystems, we can sequester the carbon in future and can prevent CO_2 emissions. The blue carbon ecosystems also protects from tidal surge, coastal erosion, flooding and sea water level rise. So, the conservation of these coastal ecosystems ar beneficial for human health and sustainability, protects as from impacts of climate change, helps in carbon sequestration and climate change mitigation.

References

Adame, M. F., Cherian, S., Reef, R., & Stewart-Koster, B. (2017). Mangrove root biomass and the uncertainty of belowground carbon estimations. *Forest ecology and management*, *403*, 52-60.

Ahmed, N., & Glaser, M. (2016). Coastal aquaculture, mangrove deforestation and blue carbon emissions: is REDD+ a solution?. *Marine Policy*, *66*, 58-66.

Buditama, A. (2016). Blue carbon for reducing the impacts of climate change: An Indonesian case study. *Global Ecology & Biogeography*, *154*, 157.

Carruthers, T. J. B., Dennison, W. C., Kendrick, G. A., Waycott, M., Walker, D. I., & Cambridge, M. L. (2007). Seagrasses of south–west Australia: A conceptual synthesis of the world's most diverse and extensive seagrass meadows. *Journal of Experimental Marine Biology and Ecology*, *350*(1-2), 21-45.

Chmura, G. L., Anisfeld, S. C., Cahoon, D. R., & Lynch, J. C. (2003). Global carbon sequestration in tidal, saline wetland soils. *Global biogeochemical cycles*, *17*(4).

De Falco, G., Ferrari, S., Cancemi, G., & Baroli, M. (2000). Relationship between sediment distribution and Posidonia oceanica seagrass. *Geo-Marine Letters*, *20*(1), 50-57.doi: 10.1016/j.scitotenv.2019.05.418

Donato, D. C., Kauffman, J. B., Murdiyarso, D., Kurnianto, S., Stidham, M., & Kanninen, M. (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature geoscience*, *4*(5), 293-297.

Duarte, C. M., Middelburg, J. J., & Caraco, N. (2005). Major role of marine vegetation on the oceanic carbon cycle. *Biogeosciences*, *2*(1), 1-8.

Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I., & Marbà, N. (2013). The role of coastal plant communities for climate change mitigation and adaptation. *Nature Climate Change*, *3*(11), 961-968.

Erickson, J. E., Megonigal, J. P., Peresta, G., & Drake, B. G. (2007). Salinity and sea level mediate elevated CO2 effects on C3–C4 plant interactions and tissue nitrogen in a Chesapeake Bay tidal wetland. *Global Change Biology*, *13*(1), 202-215.

Fourqurean, J. W., Duarte, C. M., Kennedy, H., Marbà, N., Holmer, M., Mateo, M. A., ... & Serrano, O. (2012). Seagrass ecosystems as a globally significant carbon stock. *Nature geoscience*, *5*(7), 505-509.

Gedan, K. B., Silliman, B. R., & Bertness, M. D. (2009). Centuries of human-driven change in salt marsh ecosystems. *Annual review of marine science*, *1*, 117-141.

Himes-Cornell, A., Pendleton, L., & Atiyah, P. (2018). Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests. Ecosystem Services, 30, 36–48. https://doi.org/10.1016/j.ecoser.2018.01.006

Howard, J., Sutton-Grier, A., Herr, D., Kleypas, J., Landis, E., Mcleod, E., ... & Simpson, S. (2017). Clarifying the role of coastal and marine systems in climate mitigation. *Frontiers in Ecology and the Environment*, *15*(1), 42-50.

Keil, R. G., & Hedges, J. I. (1993). Sorption of organic matter to mineral surfaces and the preservation of organic matter in coastal marine sediments. *Chemical Geology*, *107*(3-4), 385-388.

Kennedy, H., Beggins, J., Duarte, C. M., Fourqurean, J. W., Holmer, M., Marbà, N., & Middelburg, J. J. (2010). Seagrass sediments as a global carbon sink: Isotopic constraints. *Global Biogeochemical Cycles*, *24*(4).

Macreadie, P. I., Anton, A., Raven, J. A., Beaumont, N., Connolly, R. M., Friess, D. A., ... & Duarte, C. M. (2019). The future of Blue Carbon science. *Nature communications*, *10*(1), 1-13.

Mateo, M., Cebrián, J., Dunton, K., & Mutchler, T. (2006). Carbon flux in seagrass ecosystems. *Seagrasses: biology, ecology and conservation*, 159-192.

Mcleod, E., Chmura, G. L., Bouillon, S., Salm, R., Björk, M., Duarte, C. M., ... & Silliman, B. R. (2011). A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. *Frontiers in Ecology and the Environment*, *9*(10), 552-560.

Meng, W., Feagin, R. A., Hu, B., He, M., & Li, H. (2019). The spatial distribution of blue carbon in the coastal wetlands of China. *Estuarine, Coastal and Shelf Science*, *222*, 13-20.

Murdiyarso, D., Purbopuspito, J., Kauffman, J. B., Warren, M. W., Sasmito, S. D., Donato, D. C., ... & Kurnianto, S. (2015). The potential of Indonesian mangrove forests for global climate change mitigation. *Nature climate change*, *5*(12), 1089-1092.

Nehren, U., & Wicaksono, P. (2018). Mapping soil carbon stocks in an oceanic mangrove ecosystem in Karimunjawa Islands, Indonesia. *Estuarine, Coastal and Shelf Science*, *214*, 185-193.

Peñaranda, M. L. P., Kintz, J. R. C., & Salamanca, E. J. P. (2019). Carbon stocks in mangrove forests of the Colombian Pacific. *Estuarine, Coastal and Shelf Science*, *227*, 106299.

Serrano, O., Lavery, P. S., Duarte, C. M., Kendrick, G. A., Calafat, A., York, P. H., ... & Macreadie, P. I. (2016). Can mud (silt and clay) concentration be used to predict soil organic carbon content within seagrass ecosystems?. *Biogeosciences*, *13*(17), 4915-4926.

Siikamäki, J., Sanchirico, J. N., Jardine, S., McLaughlin, D., & Morris, D. (2013). Blue carbon: coastal ecosystems, their carbon storage, and potential for reducing emissions. *Environment: Science and Policy for Sustainable Development*, *55*(6), 14-29.

Torbatinejad, N. M., Annison, G., Rutherfurd-Markwick, K., & Sabine, J. R. (2007). Structural constituents of the seagrass Posidonia australis. *Journal of agricultural and food chemistry*, *55*(10), 4021-4026.

Valiela, I., & Teal, J. M. (1979). The nitrogen budget of a salt marsh ecosystem. *Nature*, *280*(5724), 652-656.

Zhang, H. B., Luo, Y. M., Liu, X. H., & Fu, C. C. (2015). Current researches and prospects on the coastal blue carbon. *Scientia Sinica Terrae*, *45*(11), 1641-1648.

BCCE – 204- PO

Study on the phytoplankton assemblages of the estuarine ecosystem along the Karnataka Coast, West coast of India

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Abstract

Estuaries are complex and resilient coastal ecosystem where salinity plays a key factor in floral and faunal distributions. To analyse the salinity dependent phytoplankton communities, five major estuarine ecosystems were studied along the Karnataka coast. The river Kali, Gangavali and Aghanashini are neighbouring estuaries of north coastal Karnataka, where in Gangolli and Shambhavi representing the south coast. A total of 40 dominant species of phytoplankton taxa were recorded during the study period from August 2020 to April 2021. Bacillariophyceae represented 70% followed by Dinophyceae 24%, Chlorophyceae 3% and Cynophyceae 3% respectively to the phytoplankton composition. *Chaetoceros sp.*, *Pleurosigma sp.* and *Ceratium sp.* were the most dominant genera contributing to the plankton community structure representing all the studied estuaries. Overall plankton diversity is highest in the Kali estuary (31%) with higher salinity gradient and lowest observed along the Gangavali (11%) estuary. Harmful algal species (HAB’s) *Pseudonitzschia sp.*, *Noctiluca sp.*, *Alexandirum sp.*, *Prorocentrum sp.* and *Dinophysis sp.* were mainly observed from the Kali estuary. Hence the present study reveals that the salinity plays a prime factor in the phytoplankton distribution and diversity along these estuaries.

Keywords: Diatom, Dinoflagellate, Algal blooms, Salinity, Phytoplankton and Estuary

Introduction

Estuarine environments are productive ecosystem on the earth as they attributed to the marked bio-geochemical variations. Indian peninsular estuaries together account for 83% of the total catchment area and 85% of the annual runoff into the continental shelf (Ansari and Parulekar, 1998). These catchment areas of tropical zones are characterised as monsoonal estuaries due to the significant riverine discharge during the southwest monsoon period (Sarma *et al.*, 2014). Seasonally influenced runoff into these typical monsoonal estuaries turns into river minimising the estuarine conditions. Similarly, along the Karnataka coast the major river originates in the plateau of Western Ghats and with westward terrain flow layouts into the Arabian Sea. At this junction salinity drastically reduces during the monsoon season as 80% of the annual rainfall (4000mm) during the Southwest monsoon period. Subsequently, due to the rhythmic tidal amplitude with less runoff the estuarine condition prevails during the succeeding seasons. These cyclic phenomena recycle the nutrient turnover triggering the blooms of dependent organisms during the suitable conditions. Thus, perennial connections of these estuarine complexes with sea, results in persistent ingress and egress of marine resilient organisms. Thus, estuaries are vital habitat in refuelling the entire aquatic tropic level.

Neritic aquatic sphere profoundly dominated by phytoplankton community which covers 70% of world’s surface (Reynold’s, 2006). Phytoplanktons are the aquatic autotrophs and only source of primary productivity on which entire microbial and faunal populace dependent. Variation in primary production is due to external factors such as nutrient access, light and temperature. Along the estuarine region seasonal changes amongst the phytoplankton diversity, composition and biomass are evident mainly due to dynamics of hydrographic conditions (Anil *et al*., 2002). Thus, the structure of phytoplankton community is influenced by several biotic and abiotic factors. The abundance and distribution of phytoplankton community constitutes an important ecological indicator to reveal the status of ecological health and biological integrity of an aquatic ecosystem. Thus, the present study emphasizes on the distribution of phytoplankton community particular to the salinity gradient across the major estuaries of Karnataka.

Materials and methods

In order to understand the phytoplankton variation based on the salinity gradient five estuaries along the Karnataka coast were selected. Kali (14°83' N 74°13' E), Gangavali (14°59' N 74°30' E) and Aghanashini (14°52' N 74°36 ' E) estuaries representing the north regional estuaries followed by Gangolli (13°37' N 74°46' E) and Shambhavi (13°05' N 74°47' E) are towards the south of the Karnataka coast (Fig 1). Salinity gradient viz., high saline zones (20 – 30 psu) and low saline zones (5 – 15 psu) were demarcated across these estuaries following the tidal amplitude of greater than 2 metres.

Phytoplankton samples were collected by towing a plankton net (20 µm mesh) for 10 minutes along the surface areas of different salinity zones. Samples were siphoned out and transferred into 100 ml containers, and preserved with 10% Lugol’s iodine solution. Samples were allowed to settle for a week period and concentrated to 5 - 10 ml by decanting the top layers with siphon tube. Phytoplankton were scrutinized for qualitative and quantitative analysis and collected phytoplankton viewed under a compound microscope at 40X and 100X magnifications and identified to the lowest taxonomic level using standard reference manuals (Tomas, 1997).

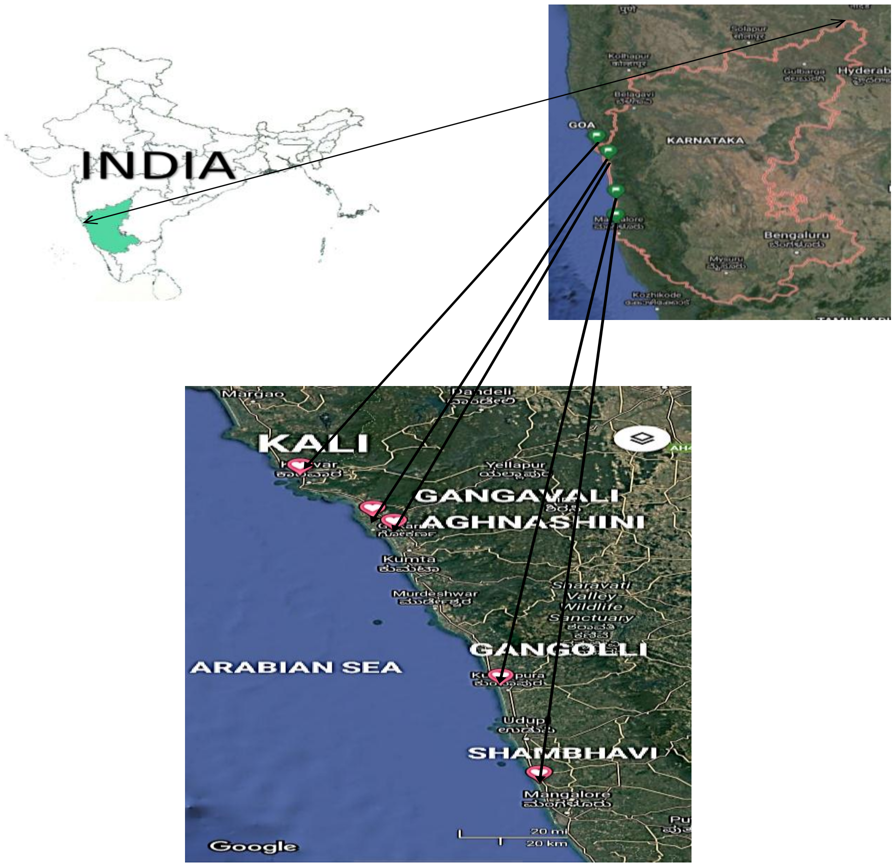

Fig 1: Map of sampling locations of the Karnataka coast showing the position of north and south regional estuaries.

Results and Discussion

A list of phytoplankton collected from the study areas is presented in Table 1. The total number of phytoplankton listed in different salinity zones varied considerably. The total phytoplankton comprised of 40 taxa belonging to Zygnematophyceae (1), Cyanophyceae (1), Chlorophyceae (2), Bacillariophyceae (27), and Dinophyceae (9). Bacillariophyceae represented as a dominant Class in water samples.

Table 1. Diversity of phytoplankton across the major estuaries of Karnataka

No.	Class	High saline zones	Low saline zones
	ZYGNEMATOPHYCEAE		
1	*Staurastrum sp.*	-	+
	CYANOPHYCEAE		
2	*Oscillatoria sp.*	+	+
	CHLOROPHYCEAE		
3	*Pediastrum sp.*	-	+
4	*Scenedesmus sp.*	+	+
	BACILLARIOPHYCEAE		

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5	*Asterionella glacialis*	+	+
6	*Asterionella sp.*	+	-
7	*Bacteriastrum sp.*	+	+
8	*Biddulphia sp.*	+	-
9	*Chaetoceros coarctatus*	+	-
10	*Chaetoceros curvisetum*	+	+
11	*Chaetoceros pseudocurvisetum*	+	+
12	*Corethron sp.*	+	+
13	*Ditylium sp.*	+	+
14	*Entomoneis sulcata*	-	+
15	*Grammatophora sp.*	+	-
16	*Guinardia sp.*	+	+
17	*Laudaria annulata*	+	+
18	*Mastogloia sp.*	+	-
19	*Navicula sp.*	+	-
20	*Nitzschia sp.*	+	+
21	*Pleurosigma sp.*	+	+
22	*Pseudo- nitzschia sp.*	+	+
23	*Rhizosolenia sp.*	+	-
24	*Skeletonema costatum*	+	+
25	*Thalassionema sp.*	+	-
26	*Cylindrotheca sp.*	+	-
27	*Cerataulina sp.*	+	+
28	*Coscinodiscus sp.*	+	+
29	*Odontella sp.*	+	-
30	*Thalassiosira sp.*	+	+
31	*Leptocylindrus sp.*	+	+
	DINOPHYCEAE		
32	*Alexandrium sp.*	+	-
33	*Ceratium furca*	+	+
34	*Ceratium fusus*	+	+
35	*Ceratium sp.*	+	+
36	*Dinophysis sp.*	+	-
37	*Noctulica sp.*	+	-
38	*Ornithoceros magnificus*	+	+
39	*Prorocentrum micans*	+	+
40	*Protoperidinium sp.*	+	+

Note : (+) = Presence in the estuary,: (-) = Absence in the estuary

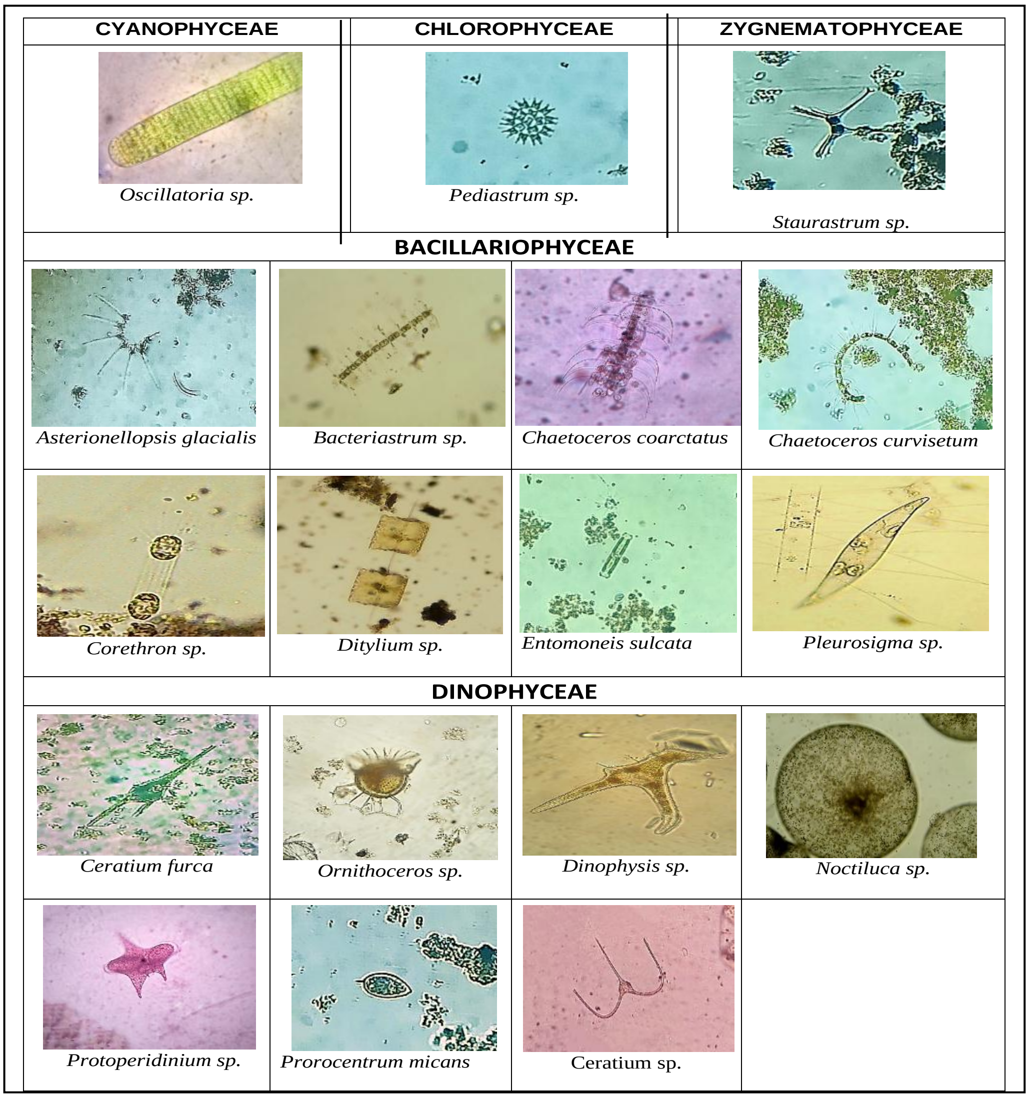

Fig 2: Phytoplankton observed along the estuaries of Karnataka. (Magnification X 40 and X 100)

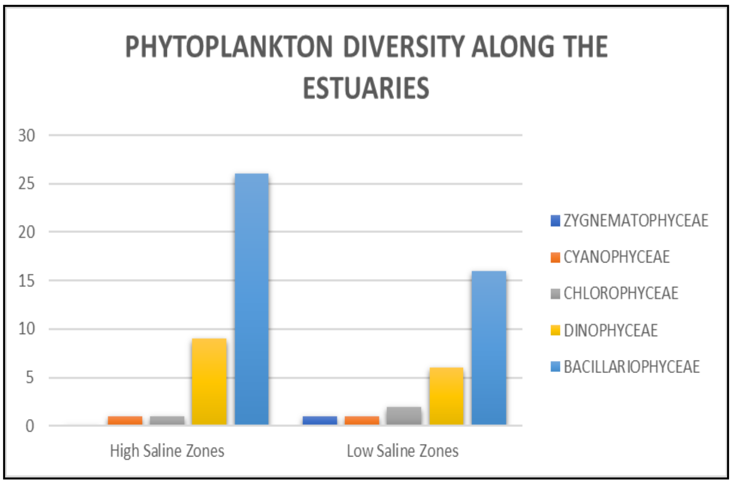

Chart 1 : Phytoplankton Abundance in High and Low Saline Zones of estuaries.

The dominant phytoplankton distribution revealed 40 species belonging to 5 taxonomic groups respectively across the studied estuaries. Of these taxa 1 species belonged to class cynophyceae, 1 species belonged to Zygnematophyceae, 27 species belonged to class Bacillariophyceae (23 genera, 27 species),9 species representing Dinophyceae (7 genera, 9 species). Among the class Bacillariophyceae centrals were predominant (16 centrales and 11 pennales). The total number of species in high saline regions of the estuaries is 37, while the total number of species in low saline zones represented 26.

Major phytoplankton species belonging to the class Bacillariophyceae are *Chaetoceros curvisetum*, *Chaetoceros pseudocurvisetum* and *Pleurosigma sp.* representing in all the studied estuaries. Also, other species like *Asterionella glacialis, Bacteriastrum sp. Corethron sp., Guinardia sp., Laudaria annulata, Navicula sp., Pseudo-nitzschia sp., Protoperidinium sp., and Prorocentrum micans* were observed in salinity (9ppt) low as well from the salinity as high as 28 ppt.

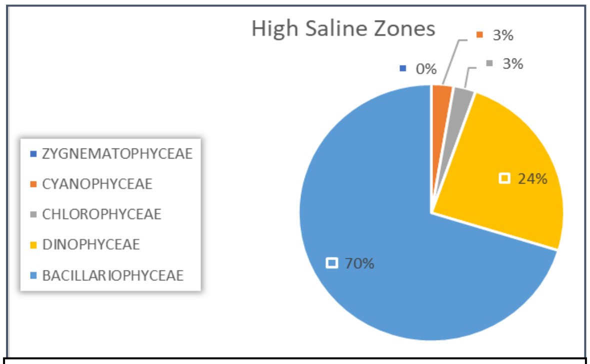

Chart 2: Percentage composition of Phytoplankton species in High Saline zone of Estuaries

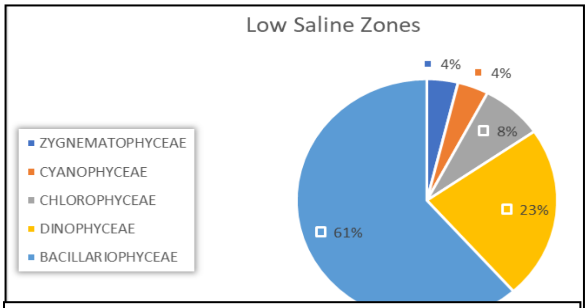

Chart 3: Percentage composition of Phytoplankton species in Low Saline zone of Estuaries

Chart 1 show that the high saline estuaries constituted about 70% of the class Bacillariophyceae, 24% of class Dinophyceae, 3% of Chlorophyceae as well as 3% of Cyanophyceae.

Chart 2 shows that the low saline estuaries constituted about 61% of the class Bacillariophyceae, 23% of class Dinophyceae, 4% of Cyanophyceae, 4% of Zygnamatophyceae and 8% of Chlorophyceae.

Several biotic and abiotic factors are known to regulate the dynamics of phytoplankton community in response to changing estuarine gradients (Martin *et al*., 2007). In the present study 40 dominantly available phytoplankton were recorded which comparatively fewer compared to Mandovi estuarine diversity 209 species (Pednekar *et al*., 2014). These variations may also reflect the sampling strategy as similar documentation representing 82 species (Devassy and Goes, 1988) and 49 species by Krishna Kumari *et al*. (2002) from the Mondovi estuary. Bacillariophyta was a dominant group among the plankton community representing all the major estuaries (Bharati *et al*., 2019) followed by Dinophyta. Similar observations were recorded during the present study where diatoms and dinoflagellates were the most abundant groups of marine phytoplanktons. Abundance of *Chaetoceros sps* and *Bacteriastrum sps* were observed in the low saline zones along the west Bengal coast (Trigueros and Orivi, 2001). Dominance of pinnate diatom like *Nitzschia sps* have been reported from the low saline regions while *Coscinodiscus sps* were abundant in the high saline zones of Zuari and Mandovi estuary (Matondkar *et al*., 2006). In the present study *Ceratium sps, Ornithocercus sps, Prorocentrum* and *protoperidinium sps* were observed in both high and low saline regions representing its euryhaline adaptations.

Similarly, among the Bacillariophyceae, *Asteranella, Bactriastrum, Cheatocerous, Ditylum, Pleurosigma, Pseudonitzschia sps, Skeletonema, Thalassiosira* are dominant euryhaline species. The presence of *Pseudonitzschia* is of concern because it produces neurotoxic domoic acid (Leelong *et al*., 2012). Potentially toxic *Alexandrium* was observed in the high saline zone known to cause paralytic shellfish poisoning in a bloom condition (Munday *et al*., 2012).

Present study concludes that the phytoplankton communities showed spatial adaptability to salinity representing the entire studied estuary. *Noctiluca scintillans* blooms were restricted to the high saline zones of the northern estuary like Kali, Gangavali and Agnashini indicates its higher salinity preference. Hence the present study reveals that phytoplankton diversity and distribution are ample along the high saline zones and less at low saline zones indicating the salinity as a major limiting factor.

References

Anil, A. C., Venkat, K., Sawant, S. S., Dileepkumar, M., Dhargalkar, V. K., Ramaiah, N., Harkantra, S. N. & Ansari, Z. A. 2002. Marine Bioinvasion: Concern for ecology and shipping, Curr. Sci., 83, 214–218.

Ansari, Z. A. and Parulekar, A. H. 1998. Community structure of meiobenthos from a tropical estuary. Indian J. Mar. Sci., 27: 362-366.

Bharathi, M.D., Sarma, V., Ramaneswari, K. 2018. Intra-annual variations in phytoplankton biomass and its composition in the tropical estuary: Influence of river discharge. Mar. Pollut. Bull. 129, 14–25.

Devassy, V.P. and Goes, J. I. 1988. Phytoplankton community structure and succession in a tropical estuarine complex (central west coast of India). Estuar. Coast Shelf. S. 27: 671–685.

Krishna Kumari, L, Bhattathiri, P.M.A., Matondkar, S.G.P,, & John, J. 2002. Primary productivity in Mandovi-Zuari estuaries in Goa. J. Mar. Biol. Assoc. India. 44: 1–13.

Lelong, A., Hégaret, H., Soudant, P., & Bates, S. S. 2012. Pseudo-nitzschia (Bacillariophyceae) species, domoic acid and amnesic shellfish poisoning: revisiting previous paradigms. Phycologia 51: 168– 216.

Martin, G.D., Vijay, JG, Laluraj CM, Madhu NV, Joseph T, Nair M, Gupta GVM, Balachandran KK (2007). Fresh water influence on nutrient stoichiometry in a tropical estuary, South west coast of India. Appl. Ecol. Env. Res., 6: 57–64.

Matondkar, P.S.G., Gomes, H.D., Parab, S.G., Pednekar, S., & Goes, J.I. 2007. Phytoplankton diversity, biomass and production. In: Shetye SR, Kumar D, Shankar D, editors. The Mandovi and Zuari Estuaries. Dona Paula, Goa, India: National Institute of Oceanography, pp. 67–81.

Munday, R., Quilliam, M. A., LeBlanc, P., Lewis, N., Gallant, P., Sperker, S. A., Ewart, H. S., & MacKinnon, S. L. 2012. Investigations into the toxicology of spirolides, a group of marine phycotoxins. Toxins 4: 1–14

Pednekar, S. M., Kerkar, V. & Matondkar S, G. P. 2014. Spatiotemporal distribution in phytoplankton community with distinct salinity regimes along the Mandovi estuary, Goa, India. Turk. J. Bot., 38: 800-818.

Reynolds, C. S. 2006. The ecology of phytoplanktons. Cambridge, UK: Cambridge University Press.

Sarma, V., Krishna, M.S., Prasad, V.R., Kumar, B.S.K., Naidu, S. A., Rao, G.D., Vishwanadham, R., Sridevi, T., Kumar, P.P. and Reddy, N.P.C. 2014. Distribution and sources of particulate organic matter in the Indian monsoonal estuaries during monsoon. *J. Geophys. Res. Biogeosci*. 119: 2095-2111.

Thomas, C. R. 1996. Identifying marine diatoms and dinoflagellates.

Trigueros, J. M., & Orive, E. 2001. Seasonal variations of diatoms and dinofl agellates in a shallow, temperate estuary, with emphasis on neritic assemblages. Hydrobiologia, 444 : 119–133.

Ansari, Z.A. & Parulekar, A.H., Community structure of meiobenthos from a tropical estuary, Indian J. Mar. Sci., 27
(1998) 362–366.

Ansari, Z.A. & Parulekar, A.H., Community structure of meiobenthos from a tropical estuary, Indian J. Mar. Sci., 27 (1998) 362–366.

SESSION 3: Marine Pollution and Climate Change (Code: MPCC)

MPCC – 301- OR

Major Threats Disrupting the Magnificent Marine Environment

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Abstract

Our pristine marine ecosystem is facing multitude of threats ranging from micro-plastics to macro-baleen beaching. As per SDG 14 life below water, given by united nations to augment sustainable development in marine sector and to implement the efficient measures what has to be taken to conserve this priceless habitat worldwide within the time frame of 15 years (2015-2030). As a matter of Fact, several never-ending crises exist which includes the rise in sea-level on the average of 3.3mm per year. Hence as a result 36 million Indians will become homeless and will lose their livelihoods at the end of 2050.we all know that seafood is the rich source of nutrition not only for humans but also for livestock as well as for the aquatic organisms. During the past 10 years global marine fisheries production is stagnant with the maximum during 2018- 96.4 million tonnes. Outbreak of covid has again accelerated the single-use plastics in the form of masks, gloves and recently its seen marine animals getting strangulated because of improper disposal of these medical waste. These incidents display that nature is giving us clean chit to restore this fragile-ecosystems like coral-reefs, mangroves and our actions should be towards the betterment of nature for our future. Every human should remember that sustainability should not be the lip service rather a saviour that's going to sustain our future generations to come and should act accordingly at present.

Keywords: sustainability, conservation, threats, marine environment, fisheries

Introduction

Treating the ocean as a common good for humanity has led to tragedy of the commons with maximal and unsustainable exploitation. Ocean is not something that is very distinct or apart from us. Our life depends on the ocean their life depends on our decision towards them. Ocean is the magnanimous ecosystem with extra-ordinary diversity of life and natural resources from the shallowest shoreline to the deepest trench. Excruciating pressure on the wild stocks and technological advances has instigated several threats to the marine life and most of them are at the verge of collapse.

Big thumbs up to the United Nations for formulating the specialized rescue package for the life below water in the form of SDG14. As per sustainable development report 2021 for the decade of action for the sustainable development goals Finland stands first in the SDG index scores whereas India stands at 120th rank among 165 countries. Right from the 2015 when the

SDG goals came into the force, as of now only 0.1 percentage points progress in global SDG14 which is very less when compared with other SDGs progress. With this minuscule progress its very clear that threats have taken the deeper roots because of unsustainable practices and consumption added one should have an thorough knowledge on the threats to get into conservation and restoration.

Threats to the marine ecosystem:

Infinite threats posing havoc to this pristine environment. Some of the threats to the biodiversity Includes Overfishing, Ghost fishing, IUU, Pollution, Sewage disposal, Oil spill, Microplastics and their ingestion by animals, Climate change, Global warming, Rise in sea level, Ocean acidification, Habitat destruction of fragile ecosystem (mangroves, sea grass, salt pans, coral reefs) etc.

High acidity in the ocean water triggers coral bleaching. Because of pollution and exponential rise of global temperature, High percentage of the world coral reef are at risky condition. Every year coral reefs are subjected to massive bleaching events. Again in 2021 the mass bleaching event happened in the great barrier reef of Australia is a clean chit and UNESCO has even made a notice that this world heritage site may enter the danger list soon which shows our earth is at the dangerous pinch point.

Ocean Acidification

According to the UNESCO report that each day of about 20-25 million tons of Co_2 are being added to the ocean. This unknown amount of Co_2 will increase the acidity of the water and will threaten many of the marine species' survival especially those animals having a shell which is damaged by the increased acidity.

Acidification of ocean is expected to occur more in temperate than tropical region. The effect of ocean acidification is distinct in species, some algae can make use of Co_2 for photosynthesis and make use of it for growth. Whereas, other species such as mollusc, corals and some varieties of plankton will be in insecurity and at the verge of extinction.

Climate change

Increase of ocean temperature promoting acidification and making it difficult for animals to breath because of oxygen dead zones. One of the notable examples for oxygen dead zones could be the Baltic Sea (i.e) largest brackish water area in the world with 20-fold expansion of zero oxygen zones in the past 100 years. A small raise in sea temperature can have large impact on marine ecosystem. Around 40 % food security of coastal communities and their livelihood economy are threatened because of the degradation of coastal and marine ecosystems. Melting of ice through the change in ocean temperature which in turn affect the ocean current, weather patterns and sea level.

Pollution

Shipment generates significant threats to the marine ecosystem by means of pollutants such as oil, gas, waste and garbage disposal. It pollutes the sea water and badly affects the marine life. One of the most underrated yet crucial one is the nutrient pollution which leads to the sudden outbreak of toxic blooms by blue-green algae and results in bivalve toxicity to the human who consume them.

Noise generated from the shipping operation is harmful to the marine mammals and it has been scientifically proved. Every year around 8 million tons of plastics enter our ocean and

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by 2050 we would witness more plastic than fish in the water bodies. Pollution and climate change affect the life of killer whales and other marine animals and that's the reason we notice breaching of these animals often in the shoreline.

Overfishing

According to the FAO report Over 70% of the world fish stocks are either fully exploited or depleted. Cycle of decline pressure on resources, technological advances, poor governance pushing the ocean system to the point of collapse.

The marine mammals and entire ecosystem are destroyed by the destructive fishing practices though they are banned. Trawl fishing extends below 2200 meters across all the ocean and affect nearly 15 million km2 of sea floor every year. UN-FAO estimated 2/3 of the wild stocks are exploited to the Maximum Sustainable Yield whereas 1/3 beyond MSY.

Particularly large sized fishes such as tunas, sword fish, sharks etc, almost 90 percent of their population were gone. Illegal Unreported and Unregulated (IUU) fishing is the one that's is fueling the overfishing on the other hand and contribute to 20% of global marine catch. People have less awareness when it comes to marine ecosystem, that's the reason June 5 is celebrated every year as the international day against IUU fishing added FAO agreement on post- state measures was formulated to fight against IUU fishing. World bank have estimated that because of IUU fishing loss of 235$BN/Year to the world economy.

Invasive species

Invasion can be both intentional and accidental, but the risk is same. Invasive species can enlarge the production and value, but at the same time they can also have a profound and devastating impact on the ecosystem. Human might have either intentionally or unintentionally introduced invasive species into geographical areas where they have not occurred before.

Introduction of exotics can have significant impacts upon native species by the direct or indirect activity. Direct impacts involve the predation or competition, as a vector of novel parasite causing diseases to the native species. Indirectly alters the ecological community structure and functions as a result of establishment of invasive species. Up to 80% of the species regard as endangered are at risk due to the pressure of non-native species. Some examples for marine menace were red- sea jellyfish in the Mediterranean Sea and zebra mussel in North America.

On the whole in-order to conserve and protect this magnanimous environment we should focus on reversing oxygen degradation, promoting reef restoration in our seas, moving towards sustainable aquaculture system and its high time to restore ocean health.

Now-a-days sustainability is the popular buzz word and it should not be the lip service and it's the actual balance of people, planet and profit without leaving anyone behind. Along with government, NGOs, it's the responsibility of each and every individual to understand we have One planet, one ocean and only one life to restore them.

References

Airoldi, L. and Beck, M. (2007). Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology: An Annual Review 45: 345-405

Boyd,C.E.,Glencross,B.D (2019). Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. Journal of the World Aquaculture Society.56pp

Douglas McCauley (2018). Here are 5 of the biggest threats to our ocean, and how we can slove them Professor, University of California Santa Barbara; Member of Friends of Ocean Action; Director, Benioff Ocean Initiative. Published by World Economic Forum.

Ducrotoy J.P. and Elliott M. (2006). Recent Developments in estuarine ecology and management. Marine Pollution Bulletin 53:1-4

Eggleton, J. and Thomas, K. V. (2004). A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. Environment International 30:973-980

FAO (2020).The State of World Fisheries and Aquaculture. Sustainability in action.Rome,FAO 224pp

Nicholls, R. J. (2008). Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates, OECD Environment Working Papers, No. 1, OECD Publishing

Ragupathy kanan and Douglas A.James (2009).Effect of climate changes on Global biodiversity. Journal of Science direct.39pp

Sustainable development report 2021, the decade of action for the sustainable development goals, page 9-28.

MPCC – 306 -PO

Important pollution impacts in the marine and coastal zone which cause climate changes

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Introduction

In modern environment, marine pollution is a major issue. Oil spills, plastic litter, algal blooms, metal pollution, POPs, and other factors which damage the ocean. Several industries, sewages, poisonous smokes, plastic waste, and other sources contribute to this pollution. Pollution affects not only marine creatures, but also marine vegetation such as mangroves, seaweeds, sea grass, salt marshes, and coral reefs. Over 1 billion gallons of oil have been leaked globally in the last decade, with 6 million tonnes entering the oceans each year. Oil spills in Ocean that causes numerous economic losses, disrupt ecological equilibrium, and result in the death of marine species like, fishes, Marine mammals, sea birds, sea reptiles. The oil starts to build inside the breathing roots of mangroves, blocking the oxygen supply from the atmosphere. Planktonic creatures absorb micro plastics arrow worms, larval fish, (Carpenter et al., 1972; Moore et al., 2001), and copepods and invertebrate larvae consume plastic microspheres (0.01–0.07 mm) in laboratory feeding trials (Wilson, 1973). (trochophores: Bolton and Havenhand, 1998; echinoderm echinoplutei, ophioplutei, bipinnaria and auricularia: Hart, 1991). Changes in ecological balance are caused by pollution. Carbon emissions will have an impact on air quality, leading to global warming, earthquakes, ozone layer depletion, air pollution, irregular cyclonic activities, hurricanes, as well as other ecological disruptions. Vehicles, the burning of plastic properties such as tyres, polythene bags, and other plastic materials, the burning of coal, and harmful industrial gases are the main sources of carbon emissions. This will result in significant carbon emissions into the atmosphere. Plastic debris can trap or ingest fish, seagulls, sea turtles, and marine mammals, causing suffocation, malnutrition, and drowning. Plastic pollution is so widespread on many beaches that it's hurting turtle reproduction rates by changing the temperature of the sand where incubation takes place. Pesticides, herbicides, fertilisers, detergents, oil, industrial chemicals, and sewage are all examples of man-made contaminants that end up in the ocean.

Heavy metals

Heavy metals are a prominent anthropogenic pollutant in coastal and marine habitats all over the world (Ruilian et al., 2008). Because of their toxicity, durability, and bioaccumulation features, they constitute a major hazard to human health, living species, and natural ecosystems (De Forest et al. 2007). Heavy metals in aquatic settings are a global problem due to their persistence and subsequent Bio build-up in aquatic habitats, which then enters the food chain and has a severe impact on human health. Alternatively, they may accumulate

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directly in macro algae, for example, or via food chain's various trophic levels, eventually affecting humans. Runoff can transport heavy metals into the drainage system, where they will eventually build in the sediments. Heavy metal pollution has an impact on marine organisms such as fish, planktons, coral reefs, fishes, sea birds, mammals etc. The following are some of the heavy metal bands, organised by their classification:

Heavy Metal that is biologically necessary: Copper (Cu), Nickel (Ni), Zinc (Zn), and Iron (Fe).

Heavy Metals that isn't biologically necessary: Lead (Pb), Mercury (Hg), Cadmium (Cd), and Tin (Sn).

Toxicity Levels Range from Mild to High: Cobalt (Co), Chromium (Cr), Aluminium (Au), Copper (Cu), Cadmium (Cd), Nickel (Ni), Zinc (Zn), Lead (Pb), and Mercury (Hg).

Heavy Metals' Effects on the Marine Environment:

Heavy metals accumulate in marine organisms, posing a number of threats to the organisms. In layman's terms, it was described as a slow poison. Trace metals accumulate in various organs of fish and cause problems. It causes a decrease in growth development, a decrease in fish mortality rates, and an increase in the development of anomalies. Metals deposit in phytoplankton and zooplankton, slowing their growth rates. Heavy metal consumption by benthic, pelagic, and marine invertebrates results in bio accumulation, suffocation death, and antibody suppression. In fish, it causes gill epithelium damage and death. It inhibits spawning in fish and invertebrates and increases egg production. Heavy metal accumulation and bio magnification spread throughout the food chain and food web. Human consequences included kidney and liver damage, anaemia, skin irritation, ulcers, and other damages. Sources from oil exploration, mining, industrial activities, acid rain, fertilizers, pesticides , from paints, pharmaceutical industries plays an important role in increasing heavy metal loads in marine environment. Large industries discharge wastewater containing a wide range of chemicals, including heavy metals, hydrocarbon compounds, and nutrients. Oil and greases, phenols, sulphides, ammonia, suspended solids, and heavy metals such as chromium, iron, nickel, copper, molybdenum, selenium, vanadium, and zinc are all found in petroleum refinery waste waters (Wake, 2005).

Some Metal Pollution Surveys in Oman and Tamil Nadu:

Every year, approximately 25,000 tankers pass through the Strait of Hormuz, carrying more than half of the world's crude oil from the Gulf to the Sea of Oman.

In the early 1980s, ROPME conducted a major survey of heavy metals and organic contaminants in the Gulf and Sea of Oman in collaboration with the International Atomic Energy Agency's (IAEA) contaminant screening projects (Burns et al. 1982). The Cd levels were consistently high, ranging from 11 to 30mg/kg dry weight, far exceeding the threshold limit of 1 mg/kg dry weight for shellfish (Nauen 1983). Energy-dispersive X-ray fluorescence is one of the analytical methods used to determine the concentration of heavy metals in sediments. The EDXRF was chosen since it requires little processing time to be accurate, is relatively inexpensive with lower limits, is simple to use, and is quick for multi-elemental analysis (Harikrishnan et al., 2015). Some surveys from Tamil Nadu were used to identify heavy metals: Parangipettai to Periyakalapet (Harikrishnan et al., 2015). Molluscs and algae are used as biosensors to detect heavy metals.

Micro Plastics

The current epoch in human history has been dubbed the "Plastic Age" (Yarsley et al. 1945). However, the widespread use of plastic items and their quick disposal has resulted in a noticeable build-up of plastic trash. Although large quantities of floating plastic debris have been recorded in the central North Atlantic and Pacific Oceans (Goldstein et al. 2012; Eriksen et al. 2013), oceanic circulation models predict probable accumulation sites in all five subtropical ocean gyres (Maximenko et al. 2012). Plastic pollution on the sea floor is dominated by particles less than 1 cm in diameter (Hidalgo-Ruz et al. 2012), also known as micro plastics. Plastic items on the surface of the water are photo degraded, embrittled, and fragmented by wave movement after being exposed to sun radiation. We estimate the amount of plastic on the open ocean surface to be between 7,000 and 35,000 tonnes based on the high and low ranges of spatial concentrations detected within 15 main convergence/divergence zones in the global ocean. Although the plastic concentrations per surface area were comparable throughout the five accumulation zones, the North Pacific Ocean contributed significantly to the global plastic burden (between 33 and 35 percent), owing to the magnitude of this gyre. There are two types of plastic pollution: macroplastics and microplastics. Micro plastics are typically smaller than 1cm in length. It is further subdivided into two groups. Primary (<5mm) and secondary (>5mm) microplastics (>5mm). These plastics reach our seas through a variety of channels, including littering, landfill discharge, and lost at sea (Browne 2015). The micro plastic material in the environment is unlikely to dissolve quickly and take many decades to disintegrate. Weathering is a process that breaks down plastic materials in the environment.

Impacts and effects of micro plastics in our environment

Micro plastics have been found in our food and water sources. These micro plastic and Nano plastic particles can be passed up the food chain to higher trophic level species or into the human food chain via different routes. Nano plastics are easily accumulated in tissues and cells due to their persistent nature, producing metabolic problems and local inflammation. Changes in tissue permeability induced by inflammatory illness would greatly enhance the transport and absorption of Nano plastics, increasing the risk of exposure, particularly in patients with intestinal disorders. Plastic pollution has also been shown to lower metabolic rates, reproductive success rates, and zooplankton survival rates, and zooplankton transport carbon to the deep sea (Galloway et al., 2017). Micro plastics can potentially disrupt the functioning of the marine main food chain/web. The study of (Gregory et al., 1996) revealed that micro plastics are found in skin cleaners, hand cleaners as liquid plastic–sand soaps that the average consumer may use on rare occasions. Polyethylene is listed as a component in the majority of face cleansers sold in New Zealand supermarkets, but in varied forms such as micro-beads, micro bead formula, or micro exfoliates. The micro plastics in face and hand cleansers will be rinsed away by water and end up in the ocean. This will endanger planktons, filter-feeding species, and marine ecosystems. Small animals that consume micro plastics are more vulnerable to hunger, reduced food consumption owing to satiation, or intestinal obstruction, which can lead to death. The quantity of greenhouse gases in the global atmosphere has steadily increased since the Great Industrial Revolution. CO_2, CH4, and N_2O concentrations have grown by 41%, 160%, and 20%, respectively (Working Group I of the

IPCC, 2013). Plastic will harm human health, disrupt the natural chain, and increase greenhouse gas emissions. Irregular climate change will result in a significant rise in global warming. The average rise in atmospheric temperature since the mid-nineteenth century has been 0.6 0.2 C. (Solomon et al. 2007). Plastics having a high density sink into the water whereas plastics with a low density float on the ocean's surface. Micro plastics are expected to melt ice in polar areas.

POPs

POPs stand for Persistent Organic Pollutants. It is referred to as a resistance pollutant. Organochlorides pesticides such as DDT, industrial chemicals, polychlorinated biphenyls (PCB), and unintentional by-products of many industrial processes, particularly polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF), are the most commonly encountered POPs. They have a significant impact on both the environment and human beings. Coastal marine ecosystems, which include estuaries, sea grass beds, salt marshes, tidal flats, mangroves, coral reefs, and shelves, provide a variety of benefits such as nutrient cycling, pollutant detoxification, food production, raw materials and habitats, storm-induced disturbance regulation, and recreational and entertainment activities (Costanza et al., 1997). When agricultural runoff, industrial activities, and other activities come into contact with rivers and the ocean, they cause ocean acidification, changes in water content, colour, odour, and the spread of several diseases. Cholera, typhoid, and other diseases.

Eutrophication

Eutrophication is the gradual increase in phosphorus, nitrogen, and other plant nutrients in an over aged aquatic ecosystem, including a lake. As the amount of organic material that can be broken down into nutrients increases, so does the ecosystem's productivity or fertility. Due to these excess nutrients, algal blooms are farmed on the surface of the ocean, which completely cut off the oxygen supply to the fishes. Algal blooms are decomposed, and bacteria are generated as a result. These bacteria produce biomass by respiring anaerobically. The fish in that area will die as a result of this process. Algal blooms are defined as a rapid growth of algae in a marine or freshwater environment. Eutrophication is the primary cause of the algal bloom.

Sources

Pesticides used in agricultural forms, as well as inappropriate treatment of industrial water and wastes, are the main sources for this pollution was shown in (fig. 2).

In many coastal ecosystems, agricultural runoff is the most significant source of nitrogen pollution. Deforestation, human waste, and aquaculture waste have all contributed to the flow of nutrients into coastal habitats. The reduction of sea grasses, coral reefs, mangroves, and salt marshes is also attributed to land reclamation and aquaculture activities, as well as nutrient over-enrichment. Increased nutrient loading also reduces biological diversity, makes ecosystems more susceptible to shocks, and reduces ecosystem services. Some of these halogenated organic chemicals, including legacy contaminants like organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), and polybromo diphenyl ethers (PBDEs), and emerging pollutants like hexabromo diphenyl ethers (PBDEs), have been listed as persistent organic pollutants (POPs) in the Stockholm Convention due to their properties of stable structure, bioaccumulation, and long-range (Kim and Yoon, 2014; Han and Currell, 2016; Mwangi et al. 2016; Meng et al. 2017).

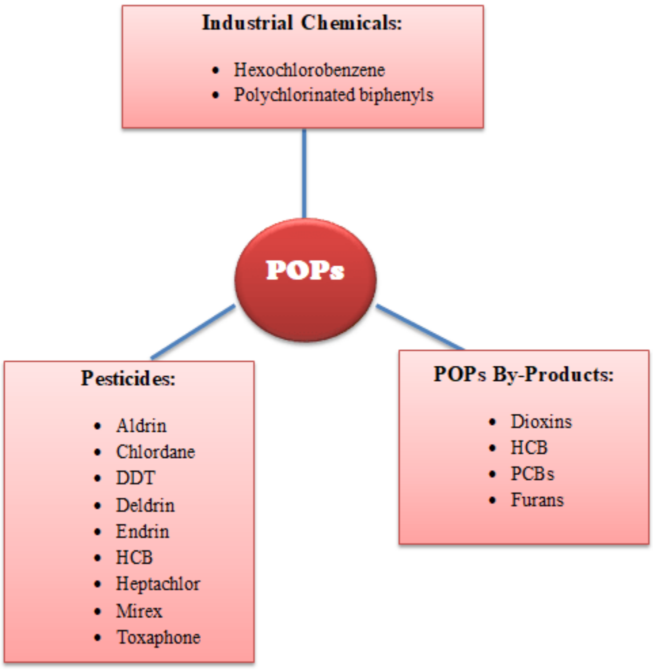

Fig.2: Sources of POPs

Oil Spill

The term "marine oil spill" refers to the discharge of liquid petroleum hydrocarbons into the ocean or coastal regions as a result of human activity. Spills can occur for a variety of causes during the exploration, extraction, and transportation operations, including over pressing, mechanical failure, pipeline corrosion, and ship collision, among others (Lee et al. 2015). Most oil spills 72 % happen on tiny scales, and the total quantity of these minor spills represents for 1% of the spillage (Fingas et al. 2011). Spills of more than 30 tons are uncommon 0.1 % of occurrences, but account for approximately 60% of the total quantity spilled (Fingas et al. 2011). The consequences of hydrocarbon spilt at sea are determined by the location of the occurrence and its subsequent closeness to ecologically sensitive regions and species, as well as the magnitude of external physical forces acting on the spilled oil (Lee et al. 2015). Oil spill cleanup, as well as its impacts on marine ecosystems, is heavily reliant on a thorough understanding of the chemical composition and bulk characteristics of the spilled oil, as well as the oil weathering processes that govern the behavior and fate of spilled oil (Lee et al., 2015).

Oil Weathering In the Marine Environment:

Weathering is the physical, chemical, and biological breakdown of an oil spill in the marine environment into smaller particles. Lighter, more volatile hydrocarbons tend to evaporate, while photosensitive hydrocarbons are oxidized by solar radiation, and processes of density-driven stratification and segregation occur within the water column, as well as droplet condensation and solidification of marine tar residuals after contact with suspended particulates, as well as surface emulsification, dissolution within the water column, and microbial digestion of oil components. Evaporation and aerosolization are more common in lighter fuels and medium crude oils, which include more volatile hydrocarbons, generally saturates of less than C15 mono aromatics, and lighter Poly Aromatic Hydrocarbons (PAHs) (Weitkamp et al. 2007). Photo oxidation happens most commonly with PAHs and aromatic N-S- and O- hetero cycles, which react with oxygen under the influence of sun radiation to create oxygenated products that are more water soluble and resistant to biodegradation than their respective parents (Marty & Potter, 2014). Emulsification occurs by the mixing of oil and water in such a way that by integrating between 60% and 80% water, the stable emulsion volumetrically increases the spilt oil surface by a factor of two to five times and raises the viscosity of oil by up to 1000-fold. Natural dispersion is the natural physical breakdown of oil caused by generated energy and turbidity.

The Effect of Oil Pollution in Marine Life

First, the oil prevents the passage of air oxygen into the water, threatening the respiration of all organisms (Potters et al., 2013). All crude oils include significant concentrations of PAHs as well as several heavy metals, posing significant toxicity risks to human and marine biota (Lee et al. 2015). Oil toxicity affects benthic creatures such as invertebrates and crabs. In the last 60 years, there have been at least 238 large oil spills near mangrove-dominated shorelines across the world.

The effect of oil pollution in seawater and their impact on marine organisms are shown in fig. 3.

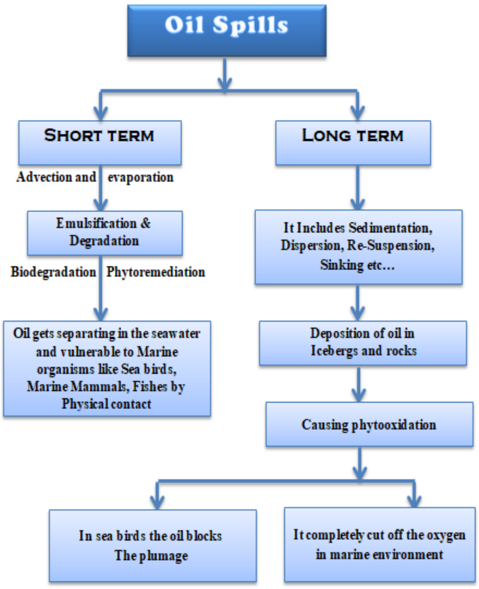

Fig. 3: Oil Spill effects and Responses

Since 1958, these incidents have resulted in the direct discharge of about 5.5 million tons of oil, impacting up to 1.94 million hectares of mangrove habitat and killing at least 126,000 ha of mangrove ecosystems (Sheppard, 2000). In the mangrove ecosystem, oil coats the breathing roots, stems, and sediments of the mangrove; the oil also affects burrowing animals. Oil spill operations in shallow areas have an impact on coral reefs. Following oil contact, there is substantial coral damage and mortality, as well as effects on sub tidal coral abundance, reproductive health, and recruitment. The leak has an impact for turtles, walruses, sea cows, and other animals. Physical contact with oil has been found to have significant detrimental and fatal consequences on many different types of marine mammals, while the long-term implications of consuming petroleum-laden food sources are still being studied (Geraci et al. 2012). During this spill, seabird losses were larger inshore and along island passages, which were thought to be related with attempted feeding areas, with estimates of outright fatality totaling 250,000 sea birds. Commercial fisheries and the aquaculture sector are impacted in this capacity by the loss of economic resources and potential due to direct mortality, habitat degradation, harvesting restrictions, and fishery closures.

Climate Change and Mitigation

Oceans play an important role in global circulation, ecological balance, wind and storm generation, and heat fluxes. The ocean produces up to 60% of the oxygen in the atmosphere and absorbs several billions of tonnes of CO_2. Certain climate variations are caused by a polluted environment. The primary GHG is 411 ppm, the highest in 800,000 years (IPCC, 2018; NASA, 2019). Global warming is expected to reach 1.5 degrees Celsius between 2030 and 2052 if GHG emissions continue at the same rate as in the previous decade (Intergovernmental Panel on Climate Change) (IPCC). These hazards are mostly determined by the pattern and speed of climate change, as well as geographic location, socioeconomic development, resilience and vulnerability, and the implementation of adaptation and mitigation measures (IPCC, 2018; NASA, 2019). According to the US Environmental Protection Agency, recycling 3.17 million tonnes of plastic trash in 2014 may save about 3.2 million tonnes of CO_2e, the equivalent of 670,000 vehicles on the road in a year, and recycling plastic packaging into new goods might save 1.4 million tonnes of CO_2e (US EPA, 2016). Climate change is anticipated to alter the patterns of numerous environmental exposures and catastrophes, such as excessive temperatures, heat waves, wildfires, droughts, and floods, in the future decades, with potentially catastrophic repercussions for many people. These occurrences may also create stress and mental diseases, putting a significant strain on the community (Haines and Ebi, 2019) Furthermore, climate change increases the risk of ocean warming, acidity, and unpredictable wind patterns. Irregular wind patterns will result in cyclonic activity and insufficient rainfall. Some diseases are also caused by sudden changes in weather and temperature. Since the pre-industrial era, the global average atmospheric carbon dioxide (CO_2) concentration has increased from 278 to > 400 parts per million (ppm), resulting in a variety of changes in ocean conditions. Since pre-industrial times, the acidity of the ocean's surface has grown by about 30%. As the twenty-first century advances, global warming is expected to lower oxygen content, reduce sea ice extent, and raise sea level (Gattuso et al., 2015). PCBs disrupt the physiology and metabolism of thyroid hormones, which affects the metabolic rate of marine mammals. Overfishing and habitat degradation are both threats to the global fisheries economy, as do pollution and climate change (Sumaila et al. 2011).

Conclusion

The ocean is polluted by a variety of sources, including oil spills, plastic debris, algal blooms, metal pollution, POPs, and so on. Not only will this pollution harm marine life, but it will also harm our human community and the ecosystem. Toxic gases emitted by businesses

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burning plastic waste, coal burning, and automobiles will emit huge volumes of greenhouse gases and CO_2 into the environment. The ocean has absorbed 50 times more carbon from the atmosphere while generating 60 percent of O_2. The plastics sector contributes significantly to the generation of carbon and greenhouse gases. This plastic will degrade into micro, macro, and Nano-particles in the water. Marine creatures devour these micro plastics. Many turtles were killed when they ate the plastic bags, mistaking them for jellyfish. Plastic must be recycled using incineration and recycling processes. And we must raise public understanding about the need of using biodegradable plastics and organic materials. The government should take measures to raise public awareness about the need of not disposing of rubbish in public spaces. They should be instructed on how to properly dispose of garbage. Make people aware of the danger of greenhouse gas emissions. The most crucial aspect of controlling the oil leak is checking. Oil tanks, pipes, and drillers should be assessed to see whether there are any holes or oil breaks in the tanks. Bacteria are being employed to reduce pollution in the current scenario. Oil pollution is a major problem. Before they enter the ocean, industrial and sewage waters must be adequately treated using a treatment process. Pesticides and fertilisers come into touch with several substances and should be avoided. Sorbents are materials that drain liquids through adsorption drawing in through pores or absorption pulling in through pores forming a layer on the surface. Through bioremediation, bacteria can be utilised to clean up oil spills in the ocean. Pesticides employed on agricultural fields were primarily responsible for the formation of POPs. Pesticide chemical concentrations must be decreased. Our small-scale changes will result in a large-scale green revolution. Humans bear the duty for protecting our environment and resources.

References

Bolton, T.F., Havenhand, J.N., 1998. Physiological versus viscosity-induced effects of an acute reduction in water temperature on microsphere ingestion by trochophore larvae of the serpulid polychaete Galeolaria caespitosa. J. Plankton Res. 20, 2153–2164.

Browne MA. 2015. Sources and pathways of microplastic to habitats. In: Bergmann M, Gutow L, Klages M, editors. Marine anthropogenic litter. Berlin (DE): Springer International Publishing. p 229–244.

Burns KA, Villeneuve JP, Anderlini VC, Fowler SW (1982) Survey of tar, hydrocarbon and metal pollution in the coastal waters of Oman. Mar Pollut Bull 7:240–247 .

Carpenter, E.J., Anderson, S.J., Harvey, G.R., Miklas, H.P., Peck, B.B., 1972. Polystyrene spherules in coastal waters. Science 178, 749–750.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253e260.

DeForest, D., Brix, K., Adams, W., 2007. Assessing metal bioaccumulation in aquatic environments: The inverse relationship between bioaccumulation factors, trophic transfer factors and exposure concentration. Aquat. Toxicol. 84, 236–246.

Eriksen M, et al. (2013) Plastic pollution in the South Pacific subtropical gyre. Mar Pollut Bull 68(1–2):71–76.

Fingas, M. (2011). Evaporation modeling. In M. F. Fingas (Ed.), Oil spill science and technology: Prevention, response, and cleanup (Chapter 9, pp. 201–242). Gulf Professional Publication: Elsevier.

Fu, J., Zhao, C.P., Luo, Y.P., Liu, C.S., Kyzas, G.Z., Luo, Y., Zhao, D.Y., An, S.Q., Zhu, H.L., 2014. Heavy metals in surface sediments of the Jialu River, China: their relations to environmental factors. J. Hazard. Mater. 270, 102–109.

Galloway, T.S., Cole, M., Lewis, C., 2017. Interactions of microplastic debris throughout the marine ecosystem. Nat. Ecol. Evol. 1

https://doi.org/10.1038/s41559-017-0116, 0116.

Gattuso JP, Magnan A, Bille R et al. 2015. Contrasting futures for ocean and society from different anthropogenic CO2 emissions scenarios. Science, 349(6243): aac4722. doi:10.1126/science.aac47 22.

Geraci, J. (2012). Sea mammals and oil: Confronting the risks. San Diego: Elsevier. ISBN: 9780323157124.

Goldstein MC, Rosenberg M, Cheng L (2012) Increased oceanic microplastic debris enhances oviposition in an endemic pelagic insect. Biol Lett 8(5):817–820.

Gregory, M.R., 1996. Plastic 'scrubbers' in hand-cleansers: a further (and minor) source for marine pollution identified. Mar. Pollut. Bull. 32, 867–871.

Gregory, M.R., 1996. Plastic 'scrubbers' in hand-cleansers: a further (and minor) source for marine pollution identified. Mar. Pollut. Bull. 32, 867–871.

Haines, A., Ebi, K., 2019. The imperative for climate action to protect health. N. Engl. J. Med. 380, 263–273.

Hale, R.L., Grimm, N.B., Vor € osmarty, C.J., Fekete, B., 2015. Nitrogen and phosphorus € fluxes from watersheds of the northeast US from 1930 to 2000: role of anthropogenic nutrient inputs, infrastructure, and runoff. Global Biogeochem. Cycles 29 (3), 341e356.

Han, D., Currell, M.J., 2016. Persistent organic pollutants in China's surface water systems. Sci. Total Environ. 580, 602e625.

Harikrishnan, N., Suresh Gandhi, M., Chandrasekaran, A., Ravisankar, R., 2015. Assessment of heavy metal pollution and potential ecological risk of sediments of East Coast of Tamilnadu by energy dispersive X-ray fluorescence spectroscopy (EDXRF) and sediment quality guidelines (SQGS). J. Heavy Metal Tox. Dis. 1 (1:3), 1–5.

Hart, M.W., 1991. Particle captures and the method of suspension-feeding by echinoderm larvae. Biol. Bull. 180, 12–27.

Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M (2012) Microplastics in the marineenvironment: A review of the methods used for identification and quantification. Environ SciTechnol 46(6):3060–3075.

Hosono, T., Su, C., Delinom, R., Umezawa, Y., Toyota, T., Kaneko, S., Taniguchi, M., 2011. Decline in heavy metal contamination in marine sediments in Jakarta Bay, Indonesia due to increasing environmental regulations. Estuar. Coast. Shelf Sci. 92, 297–306.

Intergovernmental Panel on Climate Change (IPCC), 2018. Global Warming of 1.5 °C. http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf, Accessed date: 28 November 2018.

Kim, S.-K., Yoon, J., 2014. Chronological trends of emission, environmental level and human exposure of POPs over the last 10 years (1999-2010) in Korea: implication to science and policy. Sci. Total Environ. 470, 1346e1361.

Lee, K., Boufadel, M., Chen, B., Foght, J., Hodson, P., Swanson, S., et al. (2015). The behaviour and environmental impacts of crude oil released into aqueous environments. Ottawa: The Royal Society of Canada.

Marty, J., Potter, S. (2014). Risk assessment for marine spills in Canadian Waters, phase 1: Oil spills south of the 60th parallel, Presented to Transportation Canada by WSP Canada Inc.

Maximenko N, Hafner J, Niiler P (2012) Pathways of marine debris derived from trajectories of Lagrangian drifters. Mar Pollut Bull 65(1–3):51–62.

Meng, J., Hong, S., Wang, T., Li, Q., Yoon, S.J., Lu, Y., Giesy, J.P., Khim, J.S., 2017. Traditional and new POPs in environments along the Bohai and Yellow seas: an overview of China and South Korea. Chemosphere 169, 503e515.

Moore, C.J., Moore, S.L., Leecaster, M.K., Weisberg, S.B., 2001. A comparison of plastic and plankton in the North Pacific Central Gyre. Mar. Pollut. Bull. 42, 1297–1300.

Mwangi, J.K., Lee, W.-J., Wang, L.-C., Sung, P.-J., Fang, L.-S., Lee, Y.-Y., ChangChien, G.P., 2016. Persistent organic pollutants in the Antarctic coastal environment and their bioaccumulation in penguins. Environ. Pollut. 216, 924e934.

NASA, 2019. https://climate.nasa.gov/vital-signs/carbon-dioxide/, Accessed date: 26 March 2019.

Nauen CE (1983) Compilation of legal limits for hazardous substances in fish and fishery products. Food and Agricultural Organization of the United Nations, Rome, 106 p.

Posen, I.D., Jaramillo, P., Landis, A.E., Griffin, W.M., 2017. Greenhouse gas mitigation for US plastics production: energy first, feedstocks later. Environ. Res. Lett. 12. https://doi.org/10.1088/1748-9326/aa60a7, 034024.

Ruilian, Y., Xing, Y., Yuanhui, Z., Gongren, H., Xianglin, T., 2008. Heavy metal pollution in intertidal sediments from Quanzhou Bay, China. J. Environ. Sci. 20, 664–669.

Satapathy, K.K., 2015. Statistical assessment of heavy metal pollution in sediments of east coast of Tamilnadu using Energy Dispersive X-ray Fluorescence Spectroscopy (EDXRF). Appl. Radiat. Isot. 102, 42–47.

Sheppard, C. R. C. (2000). Seas at the millennium: An environmental evaluation (1st ed.). Oxford: Elsevier Science Ltd. ISBN-10: 0080432077.

Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors. 2007. Climate change 2007: The physical science basis. Working Group I contribution to the Fourth Assessment Report of the IPCC. Vol V 4 Cambridge (UK): Cambridge University Press.996 p.

Sumaila UR, Cheung WWL, Lam VWY, Pauly P, Herrick S (2011) Climate change impacts on the biophysics and economics of world fisheries. Nature Climate Change, 1, 449–456.

Sun, R.X., Luo, X.J., Tan, X.X., Tang, B., Li, Z.R., Mai, B.X., 2015. Legacy and emerging halogenated organic pollutants in marine organisms from the Pearl River Estuary, South China. Chemosphere 139, 565e571.

Taylor, S.M., 2009. Transformative ocean science through the VENUS and NEPTUNE Canada ocean observing systems. Nucl. Instrum. Methods Phys. Res. Sect. A Accel. Spectrom. Detect. Assoc. Equip. 602 (1), 63e67.

US EPA, 2016. Advancing sustainable materials management: 2014 fact sheet.
https://www.epa.gov/sites/production/files/201611/documents/2014_smmfactsheet_508.pdf.

Wake, H., 2005. Oil refineries: a review of their ecological impacts on the aquatic environment. Estuar. Coast. Shelf Sci. 62, 131–140.

Weitkamp, E. A., Sage, A. M., Pierce, J. R., Donahue, N. M., & Robinson, A. L. (2007). Organic aerosol formation from photochemical oxidation of diesel exhaust in a smog chamber. Environmental Science & Technology, 41, 6969–6975.

Wilson, D.S., 1973. Food size selection among copepods. Ecology 54, 909–914.

Working Group I of the IPCC, 2013. Climate Change 2013: The Physical Science Basis. Contr Work, 43, pp. 866e871. http://climatechange2013.org.

Yarsley VE, Couzens EG (1945) Plastics (Penguin, London).

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A review on the impact of COVID-19 pandemic on macroplastic pollution in aquatic ecosystem

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Abstract

Plastic products take part a crucial role in protecting humans during the COVID- 19 pandemic. It leads to the extensive use of personal protective equipment's (PPE) such as gloves, masks, face shield, gowns, shoe cover etc. This increases the medical plastic waste production in the healthcare system. Single use of sanitizer bottles also increases the waste production and accumulation. Mismanagement of these single use products leads to the aggregation of plastics in the terrestrial and aquatic ecosystem. The greenhouse gases emitted from plastics also lead to climate change. Pigmentation of water due to plastics results the unavailability of light which has a direct impact on aquatic productivity. These plastics can transfer the pathogens, chemicals and also act as a reservoir for antimicrobial and metal resistance genes. So, it become a severe hazard to human and animal health. This review points out the increase in accumulation of plastics as a result of effects of COVID-19 preventive measures and how it affects the aquatic life and human health.

Keywords: Macroplastics, pathogens, COVID 19, aquatic ecosystem, climate change

Introduction

COVID-19 pandemic, caused by SARS-CoV-2, affects the world since December 2019. This enveloped, + sense RNA viruses are mainly transmitted through respiratory droplets and is spread to others during coughing, sneezing, and on direct contact with infected patients. To control the outbreak and transmission of virus, in addition to the social distancing, peoples have to wear various types of personal protective equipment's which are made up of plastics. So, COVID 19 pandemic indirectly increase the use and accumulation of plastics in the environment. These plastic products are carried by various natural processes and man-made activities from land to aquatic ecosystem.

The plastic pollution in aquatic environment leads to the formation of new ecological niches (Zettler *et al.*, 2013). The plastisphere or the new niches on plastics are influenced by location of the plastic product, its particle size, substrate type and environmental conditions. The plastisphere contains anaerobic and aerobic organisms. (Rogers *et al.*, 2020; McCormick *et al.*, 2014). This diverse microbial composition of aquatic biofilms can lead to interspecies interactions such as gene transfer, competition, symbiosis, colonization and degradation of plastics (Oberbeckmann and Labrenz, 2020). Over years, the macroplastics are degraded and transformed into microplastics which then act as a vector for the transport of pathogens in the aquatic environment. Due to the high durability of plastics, associated microorganisms are able to travel longer distances vertically as well as horizontally in the oceans. The organisms on the surface of plastics aid in the spread of antimicrobial resistance and metal resistance genes (Yang *et al.*, 2019).

Impact of COVID 19 on increased use of plastics

The COVID-19 pandemic has prompted the use of plastic products (Silva *et al.*, 2020). All humans work together to ensure the safety of our lives. As part of these changes, the use of single use plastics has been increased. Personal protective equipment's (PPE) such as gloves, face masks, face shield, surgical masks, long sleeved gowns, shoe cover, aprons, eye goggles etc become a new source of plastic pollution. PPEs are the products which provides protection to our body from various injuries and infection. The spreading and transmission of COVID- 19 from an infected person to a normal person occurs rapidly. So, people have to take various protective measures for maintaining good health. The transmission of corona virus results from direct contact (contact with aerosols or respiratory droplets) or through indirect contact, such as contact with contaminated surfaces or supplies. Several personal protective equipment's are now being used for the efficient prevention of transmission of the infection (Wong *et al*., 2020; Paterlini, 2020). Since all individuals need these PPEs as a part of disease prevention and personal protection, the demand of them were increased by several folds in the market. People in the health care sector have to use these PPE kits every time when they come in contact with patients.

PPEs provide best health protection but at the same time its impact on our environmental real. They are of one time use, so it has to be treated as waste which increases the plastic pollution in our environment. These waste products are not reusable. If the single-use PPE are not discarded properly it may end up as litter and enters into our aquatic ecosystem. In a study conducted by Fadare and Okoffo, found plastic face masks as a major source of microplastics in the environment (Fadare and Okoffo, 2020). The large scale production and accumulation of plastics release greenhouse gases which results in climate change (Chandegara *et al*., 2015).

Macroplastics in aquatic environments

All types of living organisms in aquatic ecosystem interact or they ingest the plastics. This may cause adverse effects such as malnourishment, fertility problems, animals become entrapped in plastic waste causing several physical injuries (van and Schwarz, 2019). Toxic chemicals from the plastics may leach out into the surrounding habitat which affects the life forms in that environment (Bucci *et al*., 2020). Plastic wastes in terrestrial ecosystem are transported through the rivers into the marine ecosystem. 80 percentage of plastic pollution in ocean actually originates form river and the rate of plastic pollution in fresh water ecosystem and marine ecosystem are comparable (Dris *et al*., 2015).

Freshwater ecosystem gets these plastics through different ways such as, by the leakage from landfills, industrial effluents and scraps, improper waste treatment methods, litter etc. plastic waste pieces of size >5 mm are called macroplastics. The major plastic pollutants are food wrappers, bottle caps, toys, rubber particles, polymers, packing straps, beverage and freshwater bottles and lids, and plastic bags ((Bletter *et. al.*, 2018). Over time, wind, rain,

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waves, etc cause macroplastics to break down into microplastics and they also enter into aquatic ecosystem. Plastics are found in different zones of the aquatic ecosystem depending on their velocity (Mountford and Morales, 2019). Varying intensities surface current makes the objects to transport through aquatic system and get accumulated in water column, shorelines (Andrady, 2011).

Effects of macroplastic on environment and health

Macroplastics exist for longer duration in the environment and are broken down into small microplastics which can be easily ingested by the aquatic life forms (Arthur *et al*., 2008; Galgani *et al*., 2010; Andrady, 2011). This affects their growth, feeding and reproduction (Lee *et al*., 2013; Sussarellu *et al*., 2016; Lo and Chan, 2018). Thus, the plastic pollution reduced the lifespan of aquatic organisms as evidenced by the high mortality rate of codepods (Lee *et al*., 2013). Some aquatic lifeforms (e.g., coral, fishes, sea cucumbers, zooplankton etc.) are capable to expel the ingested plastics whereas some others mobilize these substances in circulation (Imhof *et al*., 2013; Hall *et al*., 2015). Plastic accumulates in the tissues of marine animals and finally they reaches the higher organisms including humans (Teuten *et al*., 2009). V*ibrio* like organisms can form biofilm on plastics (Quilliam *et al.*, 2014) which leads to water borne diseases. Biofouling intensify the plastic deposition to the bottom of the marine ecosystem where it come in contact with zooplanktons (Kooi *et al*., 2017) and damage the food web. Studies on zebrafish showed some changes in several genes coding for transcriptional factors, oxidative stress (Choi *et al*., 2018), changes in the ERK and JNK pathways (Tang *et al*., 2018), disturbance in lipid metabolism (Lu, *et al*., 2016) (Karami *et al*., 2016).

Conclusion

Personal protective equipment's played a critical role in protecting humans from COVID-19. The extensive use of these plastic products creates major waste disposal problem they end up in marine ecosystem. The plastic wastes produced and accumulated during COVID-19 will elevate the treats of aquatic life. Aquatic ecosystem facilities grant prosperity to human societies. The plastic pollution reduces the efficiency and productivity of aquatic ecosystem. Plastics in a given habitat reduces the number aquatic fauna and flora in that area and also reduces the quality of water. The chemicals and other toxins released from plastics cause severe metabolic disorders and other health problems. The biofilm formation leads to transfer of antimicrobial and metal resistance genes. So, it is the need of the current situation for the innovation of reusable plastics or acquiring new waste management strategies for reducing the plastic wastes generated during the pandemic.

References

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine pollution bulletin*, *62*(8), 1596-1605.

Arthur, C., Baker, J. E., & Bamford, H. A. (2009). Proceedings of the International Research Workshop on the Occurrence, Effects, and Fate of Microplastic Marine Debris, September 9-11, 2008, University of Washington Tacoma, Tacoma, WA, USA.

Blettler, M. C., Abrial, E., Khan, F. R., Sivri, N., & Espinola, L. A. (2018). Freshwater plastic pollution: Recognizing research biases and identifying knowledge gaps. *Water research*, *143*, 416-424.

Bucci, K., Tulio, M., & Rochman, C. M. (2020). What is known and unknown about the effects of plastic pollution: A meta-analysis and systematic review. *Ecological Applications*, *30*(2), e02044.

Chandegara, V. K., Cholera, S. P., Nandasana, J. N., Kumpavat, M. T., & Patel, K. C. (2015). Plastic Packaging Waste Impact on Climate Change and its Mitigation. *Subbaiah R, Prajapati GV, Water management and climate smart agriculture. Adaptation of Climatic Resilient Water Management and Agriculture, Gyan Publishing House, New Delhi, India*, *3*, 404-15.

Choi, J. S., Jung, Y. J., Hong, N. H., Hong, S. H., & Park, J. W. (2018). Toxicological effects of irregularly shaped and spherical microplastics in a marine teleost, the sheepshead minnow (Cyprinodon variegatus). *Marine pollution bulletin*, *129*(1), 231-240.

Dris, R., Imhof, H., Sanchez, W., Gasperi, J., Galgani, F., Tassin, B., & Laforsch, C. (2015). Beyond the ocean: contamination of freshwater ecosystems with (micro-) plastic particles. *Environmental chemistry*, *12*(5), 539-550.

Fadare, O. O., & Okoffo, E. D. (2020). Covid-19 face masks: A potential source of microplastic fibers in the environment. *The Science of the total environment*, *737*, 140279.

Galgani, F., Fleet, D., Van Franeker, J. A., Katsanevakis, S., Maes, T., Mouat, J., ... & Janssen, C. (2010). *Marine Strategy Framework directive-Task Group 10 Report marine litter do not cause harm to the coastal and marine environment. Report on the identification of descriptors for the Good Environmental Status of European Seas regarding marine litter under the Marine Strategy Framework Directive*. Office for Official Publications of the European Communities.

Hall, N. M., Berry, K. L. E., Rintoul, L., & Hoogenboom, M. O. (2015). Microplastic ingestion by scleractinian corals. *Marine Biology*, *162*(3), 725-732.

Imhof, H. K., Ivleva, N. P., Schmid, J., Niessner, R., & Laforsch, C. (2013). Supplemental information: Beyond the ocean: Contamination of beach sediments of a subalpine lake with microplastic particles.

Karami, A., Romano, N., Galloway, T., & Hamzah, H. (2016). Virgin microplastics cause toxicity and modulate the impacts of phenanthrene on biomarker responses in African catfish (Clarias gariepinus). *Environmental research*, *151*, 58-70.

Kooi, M., Nes, E. H. V., Scheffer, M., & Koelmans, A. A. (2017). Ups and downs in the ocean: effects of biofouling on vertical transport of microplastics. *Environmental science & technology*, *51*(14), 7963-7971.

Lee, K. W., Shim, W. J., Kwon, O. Y., & Kang, J. H. (2013). Size-dependent effects of micro polystyrene particles in the marine copepod Tigriopus japonicus. *Environmental science & technology*, *47*(19), 11278-11283.

Lo, H. K. A., & Chan, K. Y. K. (2018). Negative effects of microplastic exposure on growth and development of Crepidula onyx. *Environmental Pollution*, *233*, 588-595.

Lu, Y., Zhang, Y., Deng, Y., Jiang, W., Zhao, Y., Geng, J., ... & Ren, H. (2016). Uptake and accumulation of polystyrene microplastics in zebrafish (Danio rerio) and toxic effects in liver. *Environmental science & technology*, *50*(7), 4054-4060.

McCormick, A., Hoellein, T. J., Mason, S. A., Schluep, J., & Kelly, J. J. (2014). Microplastic is an abundant and distinct microbial habitat in an urban river. *Environmental science & technology*, *48*(20), 11863-11871.

Mountford, A. S., & Morales Maqueda, M. A. (2019). Eulerian modeling of the three‐dimensional distribution of seven popular microplastic types in the global ocean. *Journal of Geophysical Research: Oceans*, *124*(12), 8558-8573.

Oberbeckmann, S., Löder, M. G., & Labrenz, M. (2015). Marine microplastic-associated biofilms–a review. *Environmental chemistry*, *12*(5), 551-562.

Paterlini, M. (2020). On the front lines of coronavirus: the Italian response to covid-19. *Bmj*, *368*.

Quilliam, R. S., Jamieson, J., & Oliver, D. M. (2014). Seaweeds and plastic debris can influence the survival of faecal indicator organisms in beach environments. *Marine pollution bulletin*, *84*(1-2), 201-207.

Rogers, K. L., Carreres‐Calabuig, J. A., Gorokhova, E., & Posth, N. R. (2020). Micro‐by‐micro interactions: How microorganisms influence the fate of marine microplastics. *Limnology and Oceanography Letters*, *5*(1), 18-36.

Silva, A. L. P., Prata, J. C., Walker, T. R., Duarte, A. C., Ouyang, W., Barcelò, D., & Rocha-Santos, T. (2020). Increased plastic pollution due to COVID-19 pandemic: Challenges and recommendations. *Chemical Engineering Journal*, 126683.

Sussarellu, R., Suquet, M., Thomas, Y., Lambert, C., Fabioux, C., Pernet, M. E. J., ... & Huvet, A. (2016). Oyster reproduction is affected by exposure to polystyrene microplastics. *Proceedings of the National Academy of Sciences*, *113*(9), 2430-2435.

Tang, J., Ni, X., Zhou, Z., Wang, L., & Lin, S. (2018). Acute microplastic exposure raises stress response and suppresses detoxification and immune capacities in the scleractinian coral Pocillopora damicornis. *Environmental pollution*, *243*, 66-74.

Teuten, E. L., Saquing, J. M., Knappe, D. R., Barlaz, M. A., Jonsson, S., Björn, A., ... & Takada, H. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2027-2045.

van Emmerik, T., & Schwarz, A. (2020). Plastic debris in rivers. *Wiley Interdisciplinary Reviews: Water*, *7*(1), e1398.

Wong, J., Goh, Q. Y., Tan, Z., Lie, S. A., Tay, Y. C., Ng, S. Y., & Soh, C. R. (2020). Preparing for a COVID-19 pandemic: a review of operating room outbreak response measures in a large tertiary hospital in Singapore. *Canadian Journal of Anesthesia/Journal canadien d'anesthésie*, *67*(6), 732-745.

Yang, Y., Liu, G., Song, W., Ye, C., Lin, H., Li, Z., & Liu, W. (2019). Plastics in the marine environment are reservoirs for antibiotic and metal resistance genes. *Environment international*, *123*, 79-86.

Zettler, E. R., Mincer, T. J., & Amaral-Zettler, L. A. (2013). Life in the “plastisphere”: microbial communities on plastic marine debris. *Environmental science & technology*, *47*(13), 7137-7146.

MPCC – 308 - OR

Seasonal variation in the *Chaetomorpha antennina* associated fauna from rocky intertidal zone of Covelong, Chennai

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Abstract

Seasonal variation in the diversity and abundance of *Chaetomorpha antennina* associated faunal communities were assessed from June’19 to March’20 on the intertidal rocks of Covelong, Chennai, India. A total of 10 groups of macro faunal communities were documented during the study period. The percentage abundance of associated communities was represented by 46% amphipods, 36% mussels, 12% isopods, 3% polychaetes, 2% gastropods. Nematodes, copepods, flatworm, ribbon worms, and nudibranchs, combinedly, comprised less than 1% of total abundance. The Shannon diversity index was similar for summer (0.98), monsoon (0.95) and post-monsoon (1.09). Dominance index was also comparable for summer (0.46), monsoon (0.48) and post-monsoon (0.43). However, Evenness index was higher for summer (0.74), followed by monsoon (0.56) and post-monsoon (0.49). The density (fauna/gm of thalli) was highest in post monsoon followed by monsoon and summer, dominated by amphipods and mussels. Seasonal variation in the richness, abundance and diversity of associated faunal communities could be linked with the abiotic and biotic factors.

Keywords: Seaweeds, habitat, intertidal ecology, invertebrate, diversity

Introduction

Seaweeds are the key players in the coastal food web owing due to their substantial abundance and diversity. They are the most important primary producers with enormous ecological and socioeconomic importance. They support enormous invertebrate communities by considerable production of organic matter and thus providing major energy source and nutrients in the coastal food web. They also provide protective habitat against predators and feeding and breeding ground for the marine faunal species (Salovius et al., 2005).

Seaweeds create biogenic environment, due to their complex morphology, it provides suitable substratum and physical environment for wide variety of benthic marine invertebrate communities of size range from 0.2 mm to 30.0 mm (Rodriguez et al., 2021). Mobile invertebrate communities also get benefited from seaweed beds. It also offers a significant relationship to the higher tropic level organisms such as fishes (Andrew and Jones, 1990). The species diversity and abundance of seaweed associated communities depends highly on their preference, vegetation and physical environment (Emilio et al., 2007). The seaweed beds provide not only feeding and breeding ground, but also protection from predators. Some of the common faunal group includes crustaceans, mollusks, nematodes and polychaetes (Gallardo et al., 2021).

Green seaweed *Chaetomorpha antennina* (Bory) Kützing 1847 (Ulvophyceae: Cladophoraceae) is abundantly present on the intertidal rocks of covelong, Chennai. *Chaetomorpha* spp. also known as green hair algae are fast-growing seaweed, found abundant in both marine water and brackish waters (Frei and Preston, 1961). They provide habitat structure for associated faunal communities and support in maintaining coastal biodiversity.

In the recent decades, seaweed communities are experiencing additional stress due to global climate change and anthropogenic pressures (Harley et al., 2012). These kinds of stressors may also have implications on the associated invertebrate communities. These changes ultimately reflect in the ecological pattern like marine food web. Henceforth, it is important to understand the faunal diversity associated with the seaweeds in the intertidal zone. In the present study, we have documented the major faunal group associated with *C. antennina* in the rocky intertidal zone of Covelong, Chennai with respect to seasonal changes.

Materials and Methods

Study area and sample collection

The study was conducted at the Covelong coast (12°47’31’’N; 80°15’04’’E - 12°46’42’’N; 80°15’15’’E), located 40 km south of Chennai. The coast comprises of rocky and sandy intertidal zones harboring diverse life forms. We have selected three intertidal rocks, dominated by *Chaetomorpha* spp. within distance of 500 m along the coast. The sampling was conducted during June 2019 to March 2020 and categorized as summer (June - September), monsoon (October – December) and post-monsoon (January – March). We have placed 25 * 25 cm quadrats, randomly on each intertidal rocks and counted total of number of thalli of *C. antennina.* The thalli were covered with sample bottle and then scrapped using scalpel so as to avoid the escape of active organisms. Three thalli each on each of the three rocks were collected and preserved in a cool box for subsequent analysis in the laboratory.

Laboratory processing of the samples

On arrival of samples to the climate change research facility at Centre for Climate Change Studies, Sathyabama Institute of Science and Technology, Chennai, the thalli were carefully rinsed in seawater to separate associated communities and stored in 5% seawater formalin for further identification. The macrofauna were sorted using stereomicroscope (Motic, SMZ 168 fitted with Moticam 10 MP camera) upto group levels.

Statistical analysis

The Shannon diversity, dominance and evenness for faunal diversity for each month and principal component analysis were calculated using PAST 3.22 (Hammer et al., 2018).

Results and Discussion

The intertidal rocks along Covelong coast is one of the unique habitat for the marine organisms, which has gained least attention till date. During the study period, we observed seasonal influence on the abundance of *C. antennina*. During summer and pre monsoon (May onwards), intertidal rocks are at same level to sand due to high depositions of sediments in these months. However, post-monsoon (January onwards), the intertidal rocks are more exposed and above the sand level. We also found that lesser abundance and diversity of seaweeds during the summer months of April - August. Further, September onwards, we observed a significant increase in germling settlings of *C. antennina.*

We observed that *C. antennina* supports wide range of associated communities. A total of 2013 individuals belonging to 10 groups were identified. Overall, the relative abundance of associated communities was represented by 46% amphipods, 36% mussels, 12% isopods, 3% polychaetes, 2% gastropods. Also, lesser representations (< 1 %) of nemertean, nematodes, flatworms, sea slug and copepod were found during the sampling period (figure 1). The density (fauna/gm of thalli) was highest in post monsoon (16 individuals/gm) followed by monsoon (5 individuals/gm) and summer (2 individuals/gm) (figure 1). The high density in post-monsoon was due to abundance of amphipods and mussels (contributing ~85%). Settlement of macro faunal communities are linked with abiotic and biotic factors including light, temperature, tides, nutrients and trophic interaction (Den Hartog et al., 2006). The associated communities also vary among patches of algae on the rocky intertidal shores (Whorff et al., 1995). The density of associated communities can also be due to higher abundance of seaweeds on intertidal rocks in the post-monsoon. Seasonal variations may also be because of higher anthropogenic pressure due to tourism on these rocks during summer months.

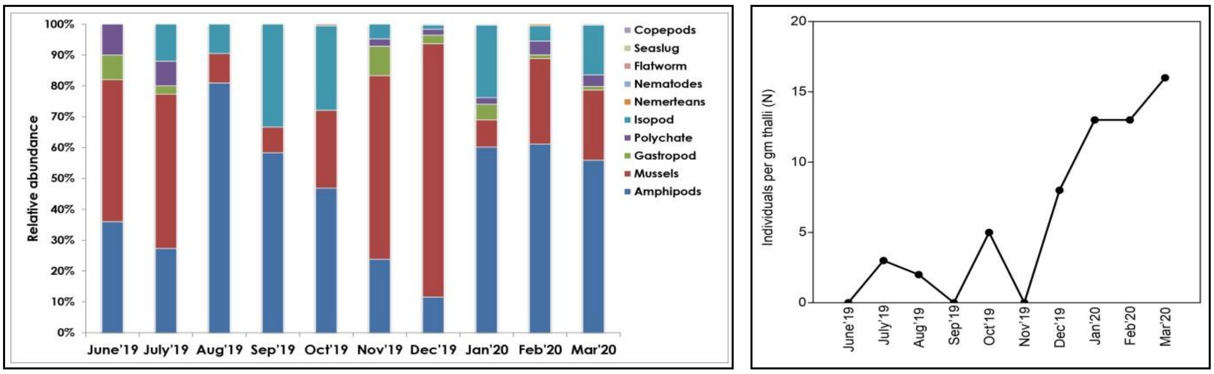

Figure 1: Relative abundance and density of faunal communities associated with *C. antennina*

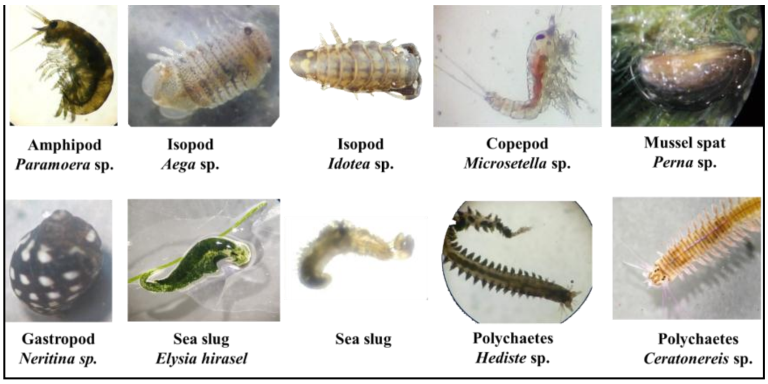

Figure 2: Common or abundant fauna identified during sampling period

The most common or abundant fauna includes: *Paramoera* sp. (amphipods, based on COI gene sequences), *Aega* sp. and *Idotea* sp. (Isopods), *Hediste* sp. and *Ceratoneris* sp. (polychaetes), *Neritina* sp. (gastropods), *Perna* sp. (mussel spats) and *Elysia hirasei* (sea slug), *Microsetella* sp (copepods) (figure 2). Previous study by Muralikrishnamurty, (1983) showed that invertebrate communities including amphipods, isopods, gastropods and polychaetes were present abundantly in the intertidal *Chaetomorpha* sp.

The Shannon diversity index was similar for summer (0.98), monsoon (0.95) and post-monsoon (1.09). Dominance index was also comparable for summer (0.46), monsoon (0.48) and post-monsoon (0.43). However, Evenness index was higher for summer (0.74), followed by monsoon (0.56) and post-monsoon (0.49) (Figure 3).

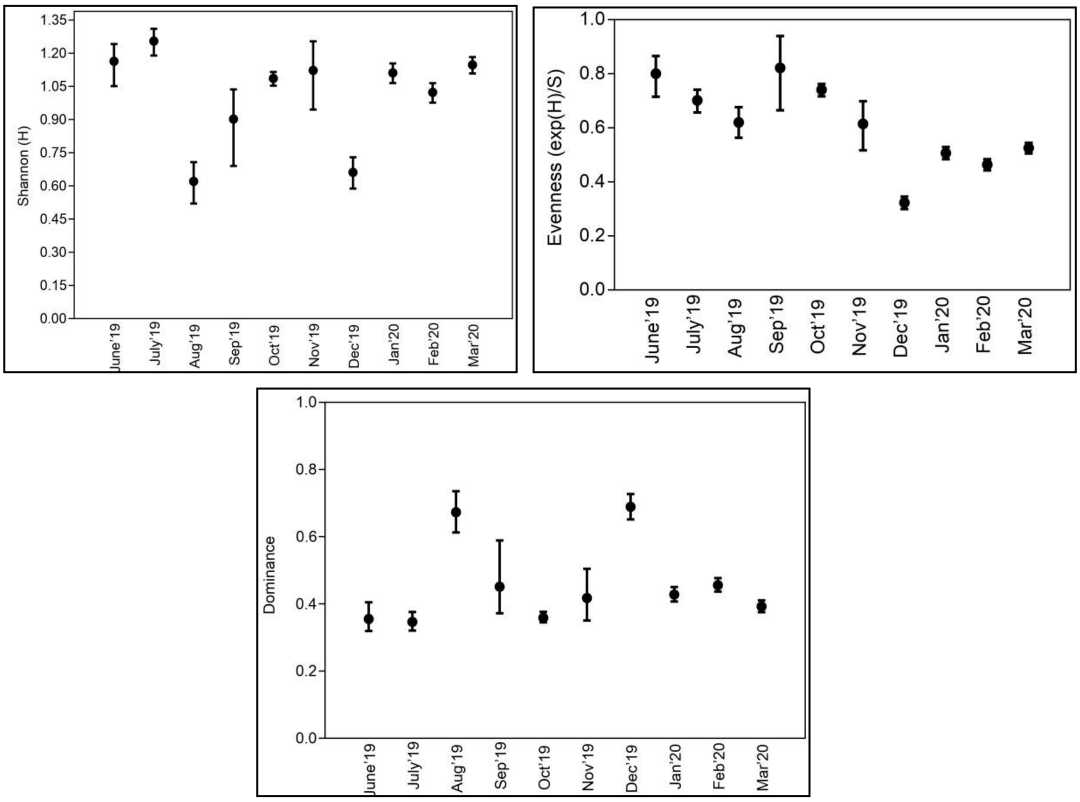

Fig. 3: Shannon diversity, Evenness and Dominance of associated faunal communities

Further, the first two principal components (PC1 and PC2) accounted for 97.47% variance in principal component analysis (PCA). A clear distinguished separation was observed for the abundance occurred in various months during the sampling period. PCA also revealed that abundance of invertebrate communities was mostly related to post-monsoon season. January'20 had positive correlation with abundance of amphipods and isopods. February'20 and March'20 were positively correlated to the polychaetes and mussels.

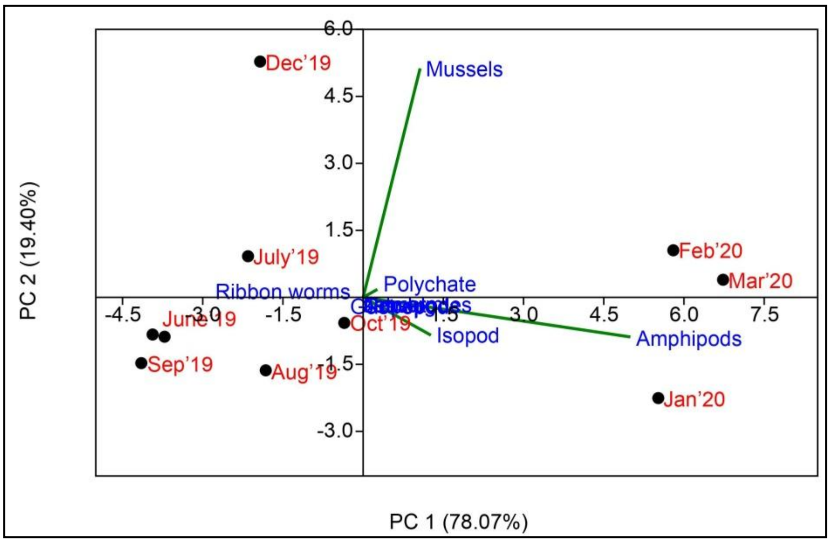

Fig. 4: Principal Component Analysis (PCA) based on months and C. antennina *associated faunal communities*

This study gave the baseline understanding of the invertebrate species associated with the *C. antennina* from rocky intertidal coast of Covelong. As *C. antennina* was involved in supporting huge diversity of invertebrate species on the intertidal rocks and are linked with the transfer of energy to the higher tropic level in the marine food web. Henceforth, it is necessary to protect the seaweeds in the intertidal zone, which in turn conserves and protect the macro fauna associated to it.

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References:

Andrew, N. L., & Jones, G. P. (1990). Patch formation by herbivorous fish in a temperate Australian kelp forest. *Oecologia*, *85*(1), 57-68.

Den Hartog, C., Kuo, J., Larkum, A. W. D., Orth, R. J., & Duarte, C. M. (2006). Seagrasses: biology, ecology and conservation.

Emilio Sánchez-Moyano, J., García-Asencio, I., & Carlos García-Gómez, J. (2007). Effects of temporal variation of the seaweed *Caulerpa prolifera* cover on the associated crustacean community. *Marine Ecology*, *28*(2), 324-337.

Frei, E., & Preston, R. D. (1961). Cell wall organization and wall growth in the filamentous green algae *Cladophora* and *Chaetomorpha*-I. The basic structure and its formation. *Proceedings of the Royal Society of London. Series B. Biological Sciences*, *154*(954), 70-94.

Gallardo, D., Oliva, F., & Ballesteros, M. (2021). Marine invertebrate epibionts on photophilic seaweeds: importance of algal architecture. *Marine Biodiversity*, *51*(1), 1-18.

Muralikrishnamurty, P. V. (1983). Intertidal phytal fauna off Gangavaram, east coast of India.

Rodriguez, I. D., Marina, T. I., Schloss, I. R., & Saravia, L. A. (2021). Marine food webs are more complex but less stable in sub-Antarctic than in Antarctic regions. *bioRxiv*.

Salovius, S., Nyqvist, M., & Bonsdorff, E. (2005). Life in the fast lane: macrobenthos use temporary drifting algal habitats. *Journal of Sea Research*, *53*(3), 169-180.

Whorff, J. S., Whorff, L. L., & Sweet, M. H. (1995). Spatial variation in an algal turf community with respect to substratum slope and wave height. *Journal of the Marine Biological Association of the United Kingdom*, *75*(2), 429-444.

Harley, C. D., Anderson, K. M., Demes, K. W., Jorve, J. P., Kordas, R. L., Coyle, T. A., & Graham, M. H. (2012). Effects of climate change on global seaweed communities. *Journal of Phycology*, *48*(5), 1064-1078.

Hammer, Ø., Harper, D. A., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontologia electronica, 4(1) 9.

SESSION 4: Marine Microbial Ecology and Bioprospecting (Code: MMEB)

MMEB – 402 – OR

Enumeration of the foodborne pathogens from highly preferred seafoods, Karwar, Karnataka, West coast of India

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Abstract

Seafood consumption is becoming more popular due to their purity and nutritional supplements. Subsequently, fisheries products pose greater human health hazards due to foodborne disease outbreaks. In order to assess the prevalence of sea foodborne pathogens the present study carried out at coastal town Karwar, Karnataka. Finfish representing different category of habitat (pelagic and benthic) was purchased from retail fish market and shellfish collected from estuarine open market for the period of six months from October 2020 to March 2021. Six types of foodborne pathogens were identified using conventional culture methods. Approximately 56% of fish samples and 40% of shellfish samples were tested positive for *Salmonella spp*. A substantially higher rate of contamination of *E. coli* was observed in shellfish samples (45%) than in fish sample (26%). Three different *Vibrio* species were obtained from fish and shellfish samples. Approximately 36% of fish samples tested were found to be contaminated with *Shigella spp*. Detection of harmful pathogens from the studied fish and shellfish may indicates the hygienic status of aquatic environments as well poor post-harvest processing practices.

Keywords: Karwar, Seafood, Pathogens, Vibrio and Fish product

Introduction

Fishing is a chief economic activity in the countries having a coastline. Approximately 45% of the fish used for human consumption is sold fresh, 30% frozen, 14% canned, and 12% cured (Gram *et al*., 2002; Huss *et al*., 2003). The seafood's are rich in protein, essential micro and macro nutrients hence, considered as staple human diet. Moreover, essential low fat and beneficial omega-3 polyunsaturated fatty acids are vital for healthy human life. Besides fishery products also pose health hazards being reservoirs of food borne pathogens and may leads to disease outbreak (Kromhout *et al.,* 1985). According to Food and Agriculture organization (FAO) seafood-borne pathogenic bacteria may conveniently divided into three groups, depending on their ecology and origin: (1) indigenous to an aquatic environment and naturally present on fish, (2) indigenous to multiple environments and frequently found on seafood, and (3) found on the outer and inner surfaces of diseased or asymptomatic animal/human carriers (Huss *et al*., 2003).

Seafood products are vectors for disease causing pathogenic bacteria like *Vibrio cholerae, Salmonella, Vibrio parahaemolyticus, Listeria monocytogenes, Staphylococcus aureus* and *Clostridium botulinum*. As per U. S. Food and Administration (USFDA), during 1996-2006, seafood contributed 21.6% of total outbreaks due to foodborne diseases and 11.3% of total foodborne illnesses. A glance on the actual causes of foodborne disease outbreaks in USA reveals that 87% are bacterial origin, 8.5% are viral origin and <1% by parasites. The figures of import refusals and rejection of export consignment by importing countries like USA, EU and Japan provide an indirect estimate of the current level of hazards in Indian seafood. During 2010-2011, USFDA refused 65 consignments from Indian seafood which representing 37 *Salmonella* contamination. During the same period, there were two RASFF (Rapid Alert System for Food and Feed) alert notifications on *Salmonella* and one on *Vibrio cholerae* for seafoods exported to European Union (Panda SK, 2019). In India, an outbreak of foodborne illness due to *Salmonella weltevreden* was recorded as early as in 1985 (Aggarwal *et al*., 1985). In 2009 an outbreak of gastroenteritis among 34 female nursing students due to *S. Weltevreden* has been reported in Mangalore, India (Antony *et al*., 2009) due to the consumption of fish. Not much data is available regarding prevalence of pathogenic bacteria from locally available seafood in Karwar. Hence, the main aim of this study was to isolate and identify foodborne pathogenic bacteria from highly preferred edible fish and shellfish.

Materials and methods

The port town Karwar being the border area of two states demarcating Karnataka from Goa which is indeed a commercial hub of seafood's trade, attracts plentiful people from all over, to enjoy the lingering taste of a wide variety of coastal cuisines. The seafood is one of the major reasons with outbreaks of foodborne diseases. Hence, this study was carried out to check the microbial load of seafoods representing different realms of ocean. We selected pelagic fishes viz., Mackerel (*Rastrelliger kanagurta*) and False trevally (*Lactarius lactarius*), benthic fish like Tongue sole (*Cynoglossus macrostomus*) and sedentary shellfishes were *Meretrix casta* and *Saccostrea cucullata*.

Collection of samples

150 seafood samples were randomly collected. Each sampling comprised of 15 fish samples purchased from retail fish market and 10 shellfish samples (each shellfish sample comprised about 10 individuals of same batch) collected from estuarine open market. A total of 90 fishes and 60 shellfish samples were analysed for the period of six months from October 2020 to March 2021. The samples were aseptically collected and transported to the laboratory in a sterile bag containing ice for the analysis.

Preparation of samples:

The samples were rinsed in sterile distilled water to remove any debris. Fishes were dissected to obtain flesh, gills and gut for analysis. Shellfishes were aseptically dissected and the flesh was obtained. 10 g of flesh of fish and shellfish samples and 1g of gills and gut portion of fish were individually homogenised and 10-fold dilutions were prepared in sterile buffered peptone water as per standard protocol.

Total aerobic bacterial counting was done according to spread plate count method using standard plate count agar (Swanson *et al*., 2001). For the isolation of *Salmonella spp.*, *Shigella spp.*, *Vibrio parahaemolyticus*, *Vibrio cholerae*, *Vibrio vulnificus* and *E.coli* were plated on their respective selective media as per standard microbiological methods (Neusely da silva *et al*., 2013; Yagoub S., 2009). Suspected colonies from each of these plates were selected, purified and identified by subsequent biochemical test.

Results

A total of 150 seafood samples comprising of fishes and shellfishes were analysed. Total aerobic plate count of fish and shellfish are presented in Table 1. The total count ranged from 10^3 to 10^9 cfu/g in fish samples and 10^4 to 10^6 cfu/g in shellfish samples. Fish gill samples showed highest bacterial load. Out of 150 seafood samples analysed 75 seafood samples were tested positive for *Salmonella spp*., Out of which that tested positive, 51 were fish samples and the remaining 24 were shellfishes. Among three different *Vibrio spp*. isolated, *Vibrio parahaemolyticus* was dominant. The number and percentage of bacterial species which were isolated from fishes and shellfishes are shown in Table 2.

Table 1: Total aerobic count in fish and shellfish

Tested seafood	**Parts analysed (cfu/g)**		
Fish	**Muscle**	**Intestine**	**Gills**
Rastrelliger kanagurta	$2 \times 10^4 – 1.3\ 10^6$	$1 \times 10^5 – 2.7 \times 10^8$	$1.6 \times 10^5 – 2.4 \times 10^9$
Cynoglossus macrostomus	$1.7 \times 10^4 – 4.2 \times 10^5$	$1.4 \times 10^4 – 2.3 \times 10^8$	$1.2 \times 10^5 – 1.7 \times 10^9$
Lactarius lactarius	$4 \times 10^3 – 2.1 \times 10^4$	$1.2 \times 10^4 – 8 \times 10^7$	$1 \times 10^4 – 4 \times 10^8$
Shellfish			
Meretrix casta	$2.1 \times 10^4 – 4 \times 10^6$		
Saccostrea cucullata	$2.4 \times 10^4 – 3.1 \times 10^5$		

Table 2: Occurrence of pathogenic bacteria in fish and shellfish

Tested seafood	***Salmonella***	***Shigella***	***E.coli***	***V. parahaemolyticus***	***V. cholerae***	***V. vulnificus***
Fish (n= 90)						
Rastrelliger kanagurta	18 (20%)	6 (6%)	9 (10%)	21 (23%)	3 (3%)	12 (13%)
Cynoglossus macrostomus	24 (26%)	21(23%)	12(13%)	24(26%)	6(6%)	6(6%)
Lactarius lactarius	9(10%)	6(6%)	3(3%)	3(3%)	3(3%)	3(3%)
Total	51 (56%)	33(36%)	24(26%)	48(53%)	12(13%)	21(23%)
Shellfish (n=60)						
Meretrix casta	12(20%)	6(10%)	12(20%)	18(30%)	3(5%)	3(5%)
Saccostrea cucullata	12(20%)	9(15%)	15(25%)	15(25%)	6(10%)	3(5%)
Total	24 (40%)	15(25%)	27(45%)	33(55%)	9(15%)	6(10%)

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Discussion

In this study finfish representing different category of habitat like pelagic and benthic fishes were analysed for pathogenic bacteria assuming pelagic fish could be more prone to contamination as near shore waters are highly polluted by domestic effluents. But almost similar incidence of pathogenic bacteria was isolated between pelagic and benthic fishes. Similar kind of studies carried out by Prabhakar P. *et al*. (2020) between pelagic and demersal fishes observed that the fish catches washed in near shore water before distribution to different retailers resulted in pathogen contamination of freshly caught seafood. Around 30 seafood samples showed high Aerobic plate count ($\geq 10^5$ cfu/g) in muscle depicting poor bacteriological quality. Fish and shellfish of good quality will have counts less than 10^5 per gram of tissue (Ghada Mahamed Mohamed, 2012; Bandekar *et al*., 2004). In the present study, Enterobacteriaceae such as *Salmonella spp.*, *Shigella spp. and E.coli* were isolated. Yagoub (2009) isolated similar pathogenic bacteria from raw fishes. *Salmonella* was isolated from 56% of fish samples and 40% of shellfish samples. In India, Kumar *et al*. (2009), detected *salmonella* in clam (34.2%) followed by mussel (31%), fish (28.2%) and oyster (12.5%). Much higher results were obtained by Shabarinath *et al*. (2007), who examined 100 fish and shellfish samples obtained from the market and fish landing centre in India, where *salmonella* was detected in 70% of fish, 59% of shrimp and 30% of oyster samples. Among *Vibrio spp.*, *V. cholerae*, *V. vulnificus*, and *V. parahaemolyticus* has been implicated in human vibrioses associated with the consumption of fish and shellfish (Senderovich *et al*., 2010). The present study of fish and shellfish revealed the presence of *Vibrio parahaemolyticus*, *V. cholerae and V. vulnificus* where in *V. parahaemolyticus* was dominant. This results are similar to published data from other parts of the world (Robert-Pillot *et al*., 2014; Rosec *et al*., 2012; Serracca *et al*., 2011; Yang *et al*., 2017).

The presence of foodborne pathogen in fish and shellfish in present study reflects the contamination of water bodies due to anthropogenic activity, domestic effluents and also poor post-harvest process.

Reference

Aggarwal, P., Singh, S.M. and Bhattacharya, M.M. 1985. An outbreak of food poisoning in a family due to Salmonella Weltevreden at Delhi. *J. Diarrhoeal Dis. Res*. 3: 224-225.

Antony, B., Dias, M., Shetty, A.K. and Rekha, B. 2009. Food poisoning due to Salmonella enterica serotype Weltevreden in Mangalore. *Indian J. Med. Microbiol*. 27: 257-258.

Bandekar, J. R., A.S. Kamat, M. Karani, V. Dhokane, R. Shashidhar, A. Kakatkar, N. Ghadge, A. Bhat, V. Venugopal and S.B. Warner. 2004. Bacteriological Quality of Farmed Freshwater Fish and Shellfish Meant for Export. *Fishery Technology* , 41(1): 57-62.

Ghada Mahamed Mohamed. 2012. Comparative study between raw and cooked fish sold in Assiut city on the incidence of some foodborne pathogens. *Assiut Vet.Med.J.* 58(133):99-108.

Gram L, Ravn L, Rasch M, Bruhn JB, Christensen AB, Givskov M. 2002. Food spoilage: interactions between food spoilage bacteria. *Int J Food Microbiol*, 78:79–97.

Huss HH, Ababouch L, Gram L. 2003. Assessment and Management of Seafood Safety and Quality. *FAO Fisheries Technical Paper*, 444. FAO, Rome.

Kromhout D, Bosschieter EB and de Lezenne CC.1985. The inverse relation between fish consumption and 20-year mortality from coronary heart disease. *N. Engl. J. Med*. 312:1205–1209.

Kumar, R., P. K. Surendran and N. Thampuran. 2008. Distribution and genotypic characterization of *Salmonella* serovars isolated from tropical seafood of Cochin, India. Journal of Applied Microbiology, 106: 515-524.

Neusely Da Silva, Marta Hiromi Taniwaki, Valeria Christina Amstalden Junqueira, Neliane Ferraz De Arruda Silveira, Maristela Da Silva Do Nascimento & Renato Abeilar Romeiro Gomes. 2013. A Microbiological Examination Methods of Food and Water: A Laboratory Manaul, CRC Press. Taylor & Francis Group, London. ISBN: 978-0-203-16839-4.

Panda, S.K. 2018. *Quality issues in fishery byproducts*. In: Bindu, J., Sreejith, S. and Sarika, K. (eds.) Protocols for the production of high value secondary products from industrial fish and shell fish processing, ICAR-Central Institute of Fisheries Technology, Cochin Pp. 183-189.

Prabhakar P., Manjusha Lekshmi , Parvathi Ammini, Binaya Bhusan Nayak , Sanath Kumar. 2020. Salmonella Contamination of Seafood in Landing Centers and Retail Markets of Mumbai, India. *Journal of AOAC International*, 103 (5): 1361 -1365.

Robert-Pillot, A., Copin, S., Himber, C., Gay, M., & Quilici, M. L. 2014. Occurrence of the three major Vibrio species pathogenic for human in seafood products consumed in France using real-time PCR. *International Journal of Food Microbiology*, 189: 75–81.

Rosec, J. P., Causse, V., Cruz, B., Rauzier, J., & Carnat, L. 2012. The international standard ISO/TS 21872-1 to study the occurrence of total and pathogenic *Vibrio parahaemolyticus* and *Vibrio cholerae* in seafood: Its improvement by use of a chromogenic medium and PCR. *International Journal of Food Microbiology*, 157:189–194.

Senderovich Y, Izhaki I, Halpern M. 2010. Fish as reservoirs and vectors of *Vibrio cholerae*. PLoS One 5, e8607.

Serracca, L., Battistini, R., Rossini, I., Prearo, M., Ottaviani, D., Leoni, F., et al. 2011. Vibrio virulence genes in fishes collected from estuarine waters in Italy. *Letters in Applied Microbiology*, 53: 403–408.

Shabarinath, S., Kumar, H. S., Khushiramani, R., Karunasagar, I. and Karunasagar, I. 2007. Detection and characterization of Salmonella associated with tropical seafood. *Inte. J. Food Microbiol.* 114: 227-233.

Swanson, K.M.J, Petran, R.L. & Handling, J.H. *Culture methods for enumeration of microorganisms*. 2001. In: Downes, F.P. & Ito, K. (eds.) Compendium of Methods for the Microbiological Examination of Foods. 4th edition. Washington, American Public Health Association. Pp. 53–67. ISBN: 087553175X

Yagoub, O.S. 2009. Isolation of Enterobacteriaceae and *Pseudomonas spp*. from raw fish sold in fish market in Khartoum state. Journal of Bacteriology Research, 1(7): 085-088.

Yang, J. H., Mok, J. S., Jung, Y. J., Lee, K. J., Kwon, J. Y., Park, K. 2017. Distribution and antimicrobial susceptibility of Vibrio species associated with zooplankton in coastal area of Korea. *Marine Pollution Bulletin*, 125: 39-44.

MMEB – 403- OR

Nutraceuticals from marine microorganisms - a review

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Abstract

Sustaining a good and healthy lifestyle is a basic need for most people. It is thoroughly known that good health is firmly associated with diet and many other factors such as lifestyle habits, genetics, environment, physical activity etc. Nutraceuticals are significant regular bioactive mixtures that give health promoting and medical benefits to people. There is a pressing need to find new medication elements because of expanded frequency of serious infections as disease and neurodegenerative pathologies and the diminishing viability of existing anti-infection agents and there is a recharged interest in investigating the marine environment for new drugs. The oceans have been the earth's most abundant wellspring of food. Awareness about marine microorganisms was not proper and restricted knowledge about their bioactive possibilities. Marine environment affords an abundance of bioactive compounds with unique properties and remarkable potentials. A lot of those compounds can be used as nutraceuticals, functional food ingredients, dietary supplements, prebiotics, natural preservatives, pigments, stabilizers, gelling agents etc. There is high opportunity for studies and survey to discover the capacity of marine microorganisms as creators of new medicines. Marine life comprises practically 80% of the world's biota with a huge number of bioactive mixtures and auxiliary metabolites .These bioactive particles and metabolites can act as antimicrobial, antiparasitic, antiviral, antioxidative and immunosuppressive agents. Microbial platforms like the most widely used *Escherichia coli* and *Saccharomyces cerevisiae* have been engineered as versatile cell factories for the production of diverse and complex value added chemicals such as nutraceuticals, phytochemicals, probiotics, and polysaccharides. This review highlights the progress in the biological production of value added nutraceuticals from marine microorganisms.

Keywords: Marine microorganisms, nutraceuticals

Introduction

The term Nutraceuticals was coined by d by Dr. Stephen L. Defelice, from combining the concepts "Nutrition" and "Pharmaceutical" in 1989. It is the functional foods that contain biologically active molecules which supply health benefits including the prohibition and therapeutical usage against ailments (Palthur *et al*., 2010). Marine microbial flora contributes to large amounts of bioactive compounds which can be used as drugs, food supplements. Nutraceuticals contain diverse products that promise novel solution to health-related issues.

Stenotrophomonas strains isolated from deep sea invertebrates have remarkable antifungal and antimicrobial activity.

A fungal genus *Pseudallescheria* derived from marine habitat was stated to produce novel compound, dioxopiperazine, methylthio gliotoxin which has antibacterial activity. All these compounds exhibit activity against methicillin resistant *Staphylococcus aureus* (Li *et al*., 2006). These microorganisms are halophiles. Marine microorganisms show vital part in earth system: they affect our climate, they are the major primary producers in the ocean, dictate much of the movement of energy and nutrients in marine habitat and provide us with a basis of medications and natural products. Marine microorganisms have sole properties since they have to acclimatize to risky environmental conditions such as extreme temperature, pressure, alkalinity, or acidity and substrate scarcity in deep seawater (Romanenko[b] *et al*., 2008).

Nutraceuticals have colossal market potential. Nutraceutical items are prevalent all through the world particularly in developed nations, including the Asia Pacific, United States of America (USA), Middle East, Japan, Latin America and Europe. This is promptly growing industry (7-12 % each year) with more than a huge number of individuals on the planet utilizing these natural items. People with healthy ways of life are all the more normally the clients of nutraceutical items (Brower, 2008).

Nutraceuticals

The term Nutraceuticals was coined by d by Dr. Stephen L. Defelice, from combing the concepts "Nutrition" and "Pharmaceutical" in 1989. It is the functional food that contain biologically active molecules which supply health benefits including the prohibition and therapeutical usage against ailments (Palthur *et al*., 2010). Nutraceuticals contain diverse products that promise novel solution to health-related issues. At present more than 470 nutraceutical and useful food items are accessible with documented health benefits (Brower, 1999). There are various products that may fall under classification of nutraceuticals they include dietary supplements, functional foods, medical foods, pharmaceuticals etc. Nutraceuticals mainly include vitamins, minerals probiotics, prebiotics carotenoids, hydrolysed proteins, dietary enzymes like papain bromelain etc.

Potential health benefits of Nutraceuticals

- Helps to lessen the danger of malignancy, heart ailment and other disorders.
- Helps to avoid or treat hypertension diabetics, arthritis, cataracts and menopausal symptoms etc.
- Helps to avoid particular medications.
- Helps in boosted energy and power to remain active throughout the day.
- They facilitate various biological processes cell proliferation, antioxidant defences, gene expression, and safeguarding mitochondrial integrity.
- Plays an important role in enhancing the immune system and anti-allergic powers.

Marine microorganisms

Marine microorganisms are normally halophiles. They show vital part in earth system affect our climate, are the major primary producers in the ocean dictate much of the movement of marine energy and nutrients and provide us with a basis of medications and natural products. They comprise bacteria, algae, fungi, plankton & viruses. The extreme complexity of the marine environment including high salinity, elevated pressure, low temperature and unique

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lighting conditions, may provide some significant properties in marine microbes than the homologous terrestrial microorganisms (Gupta & Prakash, 2019). **Marine Bacteria**

Stenotrophomonas strain isolated from different marine derived specimens exhibited notable antifungal and antimicrobial action. *Pseudoalteromonas tunicata* produces a yellow pigment that possesses antifungal activity. *Pseudoalteromonas luteoviolacea* have been shown to inhibit the growth of protists (Gupta & Prakash, 2019).

Marine Fungi

Marine Fungi been identified to yield a wide variety of novel metabolites that possess antibacterial, anticancer, antiviral and anti-inflmmatory action, because of the presence of some exceptional and distinctive carbon skeleton in them. *Ampelomyces*, *a m*arine fungal species that owns powerful antifouling and antimicrobial activity and another specimen of marine-derived fungus *Cladosporium* sp. also has same property. Another marine-derived fungus *Fusarium* sp. also possesses some novel antifungal activity from its ethanol extracts (Gupta & Prakash, 2019).

Phytoplanktons and Algae

Through photosynthesis phytoplanktons are able to convert carbon dioxide and inorganic nutrients into usable organic compounds such as vitamins, proteins, fatty acids and carbohydrates (Li *et al*., 2009). Macroalgae or seaweeds are the utmost kind of algae in the nutraceutical industry as it offers a large diversity of food and its ingredients in different Asian countries like China, Japan & Korea (Indegaard & Minsaas, 1991). The marketed products are mainly based on some strains, ie. *Spirulina*, *Chlorella* etc. (Aumeerun *et al*., 2019).

Nutraceuticals from marine microorganisms

Ocean has the world's richest source of microbial diversity and has novel microorganisms which have not yet been discovered and have vast scope for developing many beneficial compounds for human needs. It can be used as antioxidants, antibiotics, immunosuppressant's, vitamins and as food supplements. Marine microbial flora contributes to large amounts of bioactive compounds which can be used as drugs, food supplements. Many studies show that microalgae is a rich source of polyunsaturated fatty acids, astaxanthin, polysaccharides and vitamins like A, B, C, E, H (Grobbelaar & Bornman, 2004). These extracted compounds are usually used as preservatives in food, infant milk and in other dietary products (Volkman, 2003). Many bacteria like *Pseudomonas* specially KMM 3042, bacterial strain produce diverse bioactive compounds including pyrroles, phenanthrene, quinolone, phenazine, zafrin. Some of these compounds are antimicrobial agents (Romanenko[a] *et al*., 2008). *Stenotrophomonas* strains isolated from deep sea invertebrates have remarkable antifungal and antimicrobial activity (Romanenko[b] *et al*., 2008). *Pseudoalteromonas phenolica* is described to have inhibition activity against *Staphylococcus aureus* that shows methicillin resistance, due to the occurrence of a brominated biphenyl compound (Isnansetyo & Kamei, 2003). Yellow pigment of *Pseudoalteromonas tunicate* has antifungal, antimicrobial, antitumorigenic, immunosuppressive and antiproliferative activities (Bhatnagar & Kim, 2010; Egan *et al*., 2002). All these compounds exhibit activity against methicillin resistant *Staphylococcus aureus* (Li *et al*., 2006). Various compounds extracted from marine environment showed nutraceutical potentials. Some compounds are listed below:

Lipids

Lipids take out from microalgae of marine origin are utilized in larval nutriment of aquaculture, mostly for the improvement of live feeds. They have other biological potentials include anti-inflammatory, antiviral, antiallergic and therapeutic. Some important microalgal fatty acids or lipids that have biological potentials include Gamma-amino-butyric acid, Gamma-linolenic acid, Docosahexaenoic acid, Eicosapentaenoic acid, Okadaic acid etc.

Polysaccharides

The exopolysaccharides (EPS) extracted from the marine bacteria have many applications in different industries like food processing, pharmaceuticals etc. EPS mainly acts as coagulating, adhesive, gelling and thickening agents, stabilizers etc. They have the ability to resist extremes of environmental conditions like temperature, pH, and salinity. These properties enhance their potential to be used as a friendly resource from nature (Satpute *et al*., 2010). In a previous study, EPS have shown to possess antiviral and immunomodulatory properties from a marine bacterium *Geobacillus thermodenitrificans* and it was isolated from a shallow marine vent (Arena *et al*., 2009).

Probiotics: marine lactic acid bacteria (LAB)

Marine microbial diversity is enormous and can be helpful to introduce very effective probiotics. Novel probiotics from marine habitats can be an effective resource against antibiotic resistance. Diverse strains of probiotic bacteria from marine environment are *Lactobacillus* sp. (*L. acidophilus, L. casei*), *Bifidobacterium* (*B. bifidum, B. longum, B. breve*), *Leuconostoc* sp. and *Streptococcus* sp. (*S. salivarius subsp. thermophiles*) (Chalova *et al*., 2008).

Pigments

Apart from polysaccharides and lipids, algae from marine environment also impart some types of natural bioactive pigments. These pigments have significant role in photosynthesis process and impart the pigmentation property. These pigments from natural environment display countless health profits, thus useful for the synthesis of novel nutraceuticals. Some pigments like Lutein, Chlorophyll-a,, zeaxanthin, and canthaxanthin have antimutagenic properties (Ande *et al*., 2017).

Current market of neutraceuticals

Nutraceuticals possess high retail value in markets. The market value has been rise tremendously in year 2020 (Suleria *et al*., 2015). Nutraceutical items are prevalent all through the world particularly in developed nations including the Latin America, USA, Middle East, Asia Pacific, Europe and Japan. This is promptly growing industry (7-12 % each year) with more than a huge number of individuals on the planet utilizing these natural items. In Asia, nutraceutical item exchange, Japan addresses the biggest buyer, traced by China. Nutraceutical items have a remarkably competitive market and cost contrasted to traditional treatments. The Indian customer's mindfulness about traditional nutraceutical ordering is seriously restricted and nutraceutical assembling's need to take up the reason and spread mindfulness about their items to the Indian masses (Suleria *et al*., 2015). In India, drinks and useful food are expected to observe a lot higher development rates when

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contrasted with dietary enhancement. India's the functional food market is estimated to record moderate development, with useful food varieties and drinks, guess to represent practically 71% of the dietary enhancement area (Rovira *et al*., 2013).

Nutraceuticals came into the therapeutic organization, for example, tablet, or powder in an endorsed portion while current nutraceuticals are accessible as types of food or remembered for food varieties or as entire food itself, for example, probiotic drink and yogurt. The level of the utilization shifted by the age of the customers like the utilization of nutraceutical items was more normal in the older people as contrasted and the more youthful age. There is a solid conviction that in the coming years, the nutraceutical market industry with flying colours in Asian nations like China and India. It is a result of more prominent customer mindfulness toward their wellbeing, expanding pay levels, and more prominent trust in customary and free prescriptions. In the areas where nutraceutical item utilization is high, various dietary enhancements, clinical food sources, food supplements, and utilitarian food varieties have attacked the food and wellbeing market fully intent on keeping up wellbeing and averting sickness. Inside these regions, utilization paces of these items change with the nation, age, and sex of the people (Gupta & Prakash, 2015).

Consumption of nutraceuticals greatly differs with life routines of individuals, like large intake of fruits and dietary fibres, high physical activity are connected with the usage of nutraceutical products. The individuals those following healthy life routine are the main consumers of nutraceuticals and associated products (Gupta & Prakash, 2019). Aged people are more susceptible to many health issues and deficiencies of essential nutrients. So it is mandatory for consuming nutraceuticals at old age to stay healthy and lead a healthy life.

Conclusion

From the above analysis, it is very proper to infer that the marine environment values a variety of microbial vegetation that can deliver a wide assortment of bioactive metabolites that can be utilized both in nourishment and drugs to plan new medications that are viable against different medication safe microorganisms. Oceans are a rich source of biodiversity. Since marine microorganisms are present in extremely harsh conditions. They are adapted to harsh conditions like temperature, pressure, pH etc. They have potentially active bioactive compounds which can be used as nutritional food supplements and effective drugs for treatment of ailments .Marine nutraceuticals are creating great impacts on our life by adding up new mixtures of therapeutical effects. Accordingly, use of marine biodiversity and their bioactive metabolites are very useful for finding effective nutraceuticals. The worldwide market is as of now encountering a time of development post downturn even delayed consequence of downturn blurs, the nutraceutical market is probably going to stay in the development stage which is driven by developing business sector of nations like India, China, Brazil and so forth.

References

Ande, M. P., Syamala, K., Srinivasa Rao, P., MuraliMohan, K., & Lingam, S. S. (2017). Marine nutraceuticals. *Aquaculture times*, *3*(2), 06-09.

Arena, A., Gugliandolo, C., Stassi, G., Pavone, B., Iannello, D., Bisignano, G., & Maugeri, T. L. (2009). An exopolysaccharide produced by Geobacillus thermodenitrificans strain B3-72: antiviral activity on immunocompetent cells. *Immunology letters*, *123*(2), 132-137.

Aumeerun, S., Soulange-Govinden, J., Driver, M. F., Ranga, R. A., Ravishankar, G. A., & Hudaa, N. (2019). Macroalgae and Microalgae: Novel Sources of Functional Food and Feed. In *Handbook of Algal Technologies and Phytochemicals* (pp. 207-219). CRC Press.

Bhatnagar, I., & Kim, S. K. (2010). Immense essence of excellence: marine microbial bioactive compounds. *Marine drugs*, *8*(10), 2673-2701.

Brower, V. (1998). Nutraceuticals: poised for a healthy slice of the healthcare market? *Nature biotechnology*, *16*(8), 728-731.

Chalova, V. I., Lingbeck, J. M., Kwon, Y. M., & Ricke, S. C. (2008). Extracellular antimutagenic activities of selected probiotic Bifidobacterium and Lactobacillus spp. as a function of growth phase. *Journal of Environmental Science and Health, Part B*, *43*(2), 193-198.

Egan, S., James, S., Holmström, C., & Kjelleberg, S. (2002). Correlation between pigmentation and antifouling compounds produced by Pseudoalteromonas tunicata. *Environmental Microbiology*, *4*(8), 433-442.

Grobbelaar, J. U., & Bornman, C. H. (2004). Algal biotechnology: real opportunities for Africa. *South African Journal of Botany*, *70*(1), 140-144.

Gupta, C., & Prakash, D. (2015). Nutraceuticals for geriatrics. *Journal of traditional and complementary medicine*, *5*(1), 5-14.

Gupta, C., & Prakash, D. (2019). Nutraceuticals from Microbes of Marine Sources. *Nutraceuticals-Past, Present and Future*, 99.

Indegaard, M., & Minsaas, J. (1991). Seaweed resources in Europe. Uses and potential. *Animal and human nutrition*, 21-64.

Isnansetyo, A., & Kamei, Y. (2003). MC21-A, a bactericidal antibiotic produced by a new marine bacterium, Pseudoalteromonas phenolica sp. nov. O-BC30T, against methicillin-resistant Staphylococcus aureus. *Antimicrobial agents and chemotherapy*, *47*(2), 480-488.

Li, X., Kim, S. K., Nam, K. W., Kang, J. S., Choi, H. D., & Son, B. W. (2006). A new antibacterial dioxopiperazine alkaloid related to gliotoxin from a marine isolate of the fungus Pseudallescheria. *The Journal of antibiotics*, *59*(4), 248-250.

Li, Y., Qin, J. G., Ball, A. S., & Moore, R. B. (2009). Perspectives on marine phytoplankton as sources of nutrition an bioenergy.

Palthur, M. P., Palthur, S. S., & Chitta, S. K. (2010). Nutraceuticals: Concept and regulatory scenario. *Int. J. Pharm. Pharm. Sci*, *2*(2), 14-20.

Romanenko[a], L. A., Uchino, M., Kalinovskaya, N. I., & Mikhailov, V. V. (2008). Isolation, phylogenetic analysis and screening of marine mollusc-associated bacteria for antimicrobial, hemolytic and surface activities. *Microbiological research*, *163*(6), 633-644.

Romanenko[b], L. A., Uchino, M., Tanaka, N., Frolova, G. M., Slinkina, N. N., & Mikhailov, V. V. (2008). Occurrence and antagonistic potential of Stenotrophomonas strains isolated from deep-sea invertebrates. *Archives of microbiology*, *189*(4), 337-344.

Rovira, M. A., Grau, M., Castañer, O., Covas, M. I., Schröder, H., & REGICOR Investigators. (2013). Dietary supplement use and health-related behaviors in a Mediterranean population. *Journal of nutrition education and behavior*, *45*(5), 386-391.

Satpute, S. K., Banat, I. M., Dhakephalkar, P. K., Banpurkar, A. G., & Chopade, B. A. (2010). Biosurfactants, bioemulsifiers and exopolysaccharides from marine microorganisms. *Biotechnology advances*, *28*(4), 436-450.

Suleria, H. A. R., Osborne, S., Masci, P., & Gobe, G. (2015). Marine-based nutraceuticals: An innovative trend in the food and supplement industries. *Marine drugs*, *13*(10), 6336-6351.

Volkman, J. (2003). Sterols in microorganisms. *Applied microbiology and Biotechnology*, *60*(5), 495-506.

MMEB – 404- OR

Bacterial quorum sensing and bioluminescence in marine environment- A Review

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Abstract
Bioluminescent organisms are present in the marine sediments as well as the surface and gut of marine creatures. In bacteria, it is regulated by Quorum Sensing. Bacterial colonies releases auto inducers into its marine environment until a threshold concentration; quorum level, and these are recognized by specific receptor protein. Bacterial luciferase catalyses light emission from bacteria,luxA and luxB gene encode the α and β subunits. Lux system and Ain system have role for controlling bioluminescence in high and low cell density respectively. Bacterial lux system has been used extensively as a biosensor, to monitor environment pollutants.

Key Words: Bioluminescence, Quorum sensing, Luciferase

Introduction
Many living organism are able to transform chemical energy into visible light, ability know as bioluminescence. Bioluminescence is common in the marine environment, occurring in numerous organisms, from bacteria to invertebrate and fish. In symbiotic bacteria, host organism provides a safe location as well as sufficient nutrients. In exchange, the host used the light producing bacteria for attracting prey and mate. Majority of Bioluminescent bacteria belonged to gammaproteobacteria families such as Enterobacteriaceae, vibronaceae and shewanellaceae (Dunlap and Urbanczyk, 2013). Luciferase enzyme catalyses light emission from bacteria. Luciferase is a rather stable enzyme (Suadee *et al*., 2007)
Quorum sensing control light production in the bioluminescent bacteria. Bacterial bioluminescence occurs as a continuous glow in the presence of oxygen at cell concentrations exceeding quorum sensing levels. Several different physiology and biochemical function of bacterial bioluminescence include enhanced DNA repair, UV resistance, anti oxidative activity. This phenomenon has a huge impact on a variety of marine microbial systems.
Vibrio fischeri is a bacterial species that has been reported to posses' bioluminescence. In *V.fischeri*, the autoregulatory feedback seems to be dependent on *luxR* and *luxI* (Sayut *et al*., 2007). The genus *photobacterium* possess *luxF genes* (Mancini *et al*.,1989;Ast and Dunlap, 2004). They posess another set of genes called rib genes responsible for the riboflavin syntharase enzyme production.(Lee *et al*., 1994; Lin *et al*., 2001)

Bioluminescence in marine environment

Bioluminescence is a major functional trait in the ocean, with three quarters of pelagic macro oraganisms (Martini *et al*.,2017) and about a third of epibenthic organisms known to have such capacity (Martini, Kuhunz, Mallefet and Haddock; 2019). Bioluminescent marine bacteria can be freefloating, sessile or in symbiosis with other organisms and is occured by autoinducer accumulation.(Nealson *et al*., 1970, Rosson and Nealson, 1981).

Genes and enzymes involved

The lux operon codes for the genes luxCDABEG leading to light production by the bacteria. The *lux A & luxB* genes code for the alpha & beta subunit of enzyme luciferase while the fatty acid reductase enzyme complex is coded by *luxc, lux D and lux E* genes. The promoter for rib genes are upstream of lux C gene(Sung and Lee, 2004).The first gene of the lux operon encoding luciferase LuxC belongs to the class I genes (Waters and Bassler, 2006). The luxR is a regulator protein of a large number of quorum sensing regulated genes . (Mok *et al*.,2003; Lenz *et al*.,2004; Pompeani *et al*., 2008)

Quorum sensing and bioluminuscence

Bacteria communicate with one another by quorum sensing (QS), this enables bacteria to adapt their behaviour so that the whole community survives. Biofilm formation, virulence factor synthesis, production of protease and siderophore production (Heilmann *et al*., 2015) come under this. Bacterial colonies releases autoinducer (AI), an extracellular receptor which is released according to cell density (Papenfort and Bassler, 2016). Bacteria adapt on the basis of cell density and environment surrounding them. AHLs and AI-2 mediated QS are being targeted by recently identified QQ enzymes. AHL signals are degraded by enzymes like phosphotriesterase-like lactonases (PLLs), oxidoreductase and lactonase(Fetzner, 2015) . Both Gram negative and Gram positive bacteria uses a furanosyl borate diester named AI-2. (Chen *et al*., 2002;))

QS is induced by autoinducing peptides (AIPs) in certain gram positive bacteria like *Staphylococcus* spp., *Clostridium* spp., or *Enterococcus* spp., (Monnet *et al*., 2016). A different class of autoinducrrs called as actl-homoserine lactones (AHLs) composed of a varying length aliphatic acyl chain and a lactone ring was found in many Gram-negative bacteria like *Pseudomonas* spp., *Acinetobacter* spp., or *Burkholderia* spp.(Schuster *et al*., 2013)

QS is essential for biofilm formation & antibiotic tolerance. In a study the application of benzamide- bezimidazole decreased biofilm formation & restored antibiotic susceptibility in *Pseudomonas aeruginosa* by inhibiting the QS regulator MvfR.(Starkey *et al*., 2014; Maura and Rahme, 2017). The natural furanone compounds, as well as many synthesised deriatives have been shown to effectively inhibit quorum sensing in both in vitro (Martinelli *et al*; 2004) and in vivo (Wu *et al*; 2004). QS was discovered by studying bacterial bioluminescence (Kemper and Hanson, 1968)

Conclusion

Bioluminescence is a form of cheminescence; where the light-yielding reaction is derived from a nuturally catalyzed process, such as the enzymatic reactions found in luminous bacteria. These bacteria which possess luciferase enzyme exhibit bioluminescence property in the marine environment only with the help of quorum sensing. In recent years these bacteria have been used as biosensors for the detection and measurement of pollution in the Marine environment.

Reference

Ast, J. C., and Dunlap, P. V. (2004). Phylogenetic analysis of the lux operon distinguishes two evolutionarily distinct clades of *Photobacterium leiognathi*. *Arch. Microbiol.* 181, 352–361. doi: 10.1007/s00203-004-0663-7

Bassler, B. L., Greenberg, E. P., and Stevens, A. M. (1997). Cross-species induction of luminescence in the quorum- sensing bacterium *Vibrio harveyi*. *J. Bacteriol.* 179, 4043–4045. doi: 10.1128/jb.179.12.4043-4045.1997

Chen, X., Schauder, S., Potier, N., Van Dorsselaer, A., Pelczer, I., Bassler, B. L., et al. (2002). Structural identification of a bacterial quorum-sensing signal containing boron. *Nature* 415, 545–549. doi: 10.1038/415545a

Defoirdt, T., Boon, N., Sorgeloos, P., Verstraete, W., and Bossier, P. (2008). Quorum sensing and quorum quenching in Vibrio harveyi: lessons learned from in vivo work. *ISME J.* 2, 19–26. doi: 10.1038/ismej.2007.92

Dunlap, P. V., and Urbanczyk, H. (2013). "Luminous bacteria," in *The Prokaryotes*, eds E. F. DeLong, S. Lory, E. Stackebrandt, and F. Thompson (Berlin: Springer), 495–528. doi: 10.1007/978-3-642-30141-4_75

Fetzner, S. (2015). Quorum quenching enzymes. *J. Biotechnol.* 201, 2–14. doi: 10.1016/j.jbiotec.2014.09.001

Heilmann, S., Krishna, S., and Kerr, B. (2015). Why do bacteria regulate public goods by quorum sensing?—how the shapes of cost and benefit functions determine the form of optimal regulation. *Front. Microbiol.* 6:767. doi: 10.3389/fmicb.2015.00767

Kempner, E. S., and Hanson, F. E. (1968). Aspects of light production by *Photobacterium fischeri*. *J. Bacteriol.* 95, 975–979.

Lee, C. Y., O'Kane, D. J., and Meighen, E. A. (1994). Riboflavin synthesis genes are linked with the lux operon of *Photobacterium phosphoreum*. *J. Bacteriol.* 176, 2100–2104. doi: 10.1128/jb.176.7.2100-2104.1994

Lin, J. W., Chao, Y. F., and Weng, S. F. (2001). Riboflavin synthesis genes ribE, ribB, ribH, ribA reside in the lux operon of *Photobacterium leiognathi*. *Biochem. Biophys. Res. Commun.* 284, 587–595. doi: 10.1006/bbrc.2001.5013

Mancini, J. A., Boylan, M., Soly, R., Ferri, S., Szittner, R., and Meighen, E. A. (1989). Organization of the lux genes of *Photobacterium phosphoreum*. *J. Bioluminesc. Chemiluminesc.* 3, 201–205. doi: 10.1002/bio.1170030407

Martini, S.,Kuhunz, L., Mallefet, J.,and Haddock, S. H. D.(2019) Distribution and quantification of bioluminescence as an ecological trait in tge deep sea benthos. Sci. Rep. 9,1-11. doi:10.1038/s41598-091-50961-z

Martini,S.,and Haddock, S.H.D.(2017).Quantification of bioluminescence from the surface of deep sea demonstrates its predominance as an ecological trait .Sci.Rep.7;45750.doi; 10.1038/srep45750

Maura, D., and Rahme, L. G. (2017). Pharmacological inhibition of the *Pseudomonas aeruginosa* MvfR quorum sensing system interferes with biofilm formation and potentiates antibiotic-mediated biofilm disruption. *Antimicrob. Agents Chemother.* 61:e01362-17. doi: 10.1128/AAC.01362-17

Miller, M. B., and Bassler, B. L. (2001). Quorum sensing in bacteria. *Annu. Rev. Microbiol.* 55, 165–199. doi: 10.1146/annurev.micro.55.1.165

Monnet, V., Juillard, V., and Gardan, R. (2016). Peptide conversations in Gram-positive bacteria. *Crit. Rev. Microbiol.* 42, 339–351. doi: 10.3109/1040841X.2014.948804

Schuster, M., Sexton, D. J., Diggle, S. P., and Greenberg, E. P. (2013). Acyl-homoserine lactone quorum sensing: from evolution to application. *Annu. Rev. Microbiol.* 67, 43–63. doi: 10.1146/annurev-micro-092412-155635

Starkey, M., Lepine, F., Maura, D., Bandyopadhaya, A., Lesic, B., He, J., et al. (2014). Identification of anti-virulence compounds that disrupt quorum-sensing regulated acute and persistent pathogenicity. *PLoS Pathog.* 10:e1004321. doi: 10.1371/journal.ppat.1004321

Sung, N. D., and Lee, C. Y. (2004). Coregulation of lux genes and riboflavin genes in bioluminescent bacteria of *Photobacterium phosphoreum*. *J. Microbiol.* 42, 194–199.

Waters,C.m.,and Bassler,B.L.(2005) QUORUM SENSING: cell-to-cell communication in bacteria.*annu. rev. cell Dev .Biol.*21, 319-346. Doi:10.1146/annurev.cellbio.21.012704.131001

Whitehead, N. A., Barnard, A. M. L., Slater, H., Simpson, N. J. L., and Salmond, G. P. C. (2001). Quorum-sensing in gram-negative bacteria. *FEMS Microbiol. Rev.* 25, 365–404. doi: 10.1111/j.1574-6976.2001.tb00583.x

Nealson, K. H.; Hastings, J. W. (1979-12-01). "Bacterial bioluminescence: its control and ecological significance". Microbiological Reviews. 43 (4): 496–518. doi:10.1128/mmbr.43.4.496-518.1979. ISSN 0146-0749. PMC 281490. PMID 396467

McFall-Ngai, Margaret; Heath-Heckman, Elizabeth A.C.; Gillette, Amani A.; Peyer, Suzanne M.; Harvie, Elizabeth A. (2012). "The secret languages of coevolved symbioses: Insights from the Euprymna scolopes–Vibrio fischeri symbiosis". Seminars in Immunology. 24 (1): 3–8. doi:10.1016/j.smim.2011.11.006. PMC 3288948. PMID 22154556.

Waters, Christopher M.; Bassler, Bonnie L. (2005-10-07). "QUORUM SENSING: Cell-to-Cell Communication in Bacteria". Annual Review of Cell and Developmental Biology. 21 (1): 319–346. doi:10.1146/annurev.cellbio.21.012704.131001. PMID 16212498.

MMEB – 405 - OR

Biological potential of chitinolytic marine bacteria - a review

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Abstract

Chitin is a major naturally occurring polymer that acts as rich source of carbon and nitrogen. Whose structure constitute of N-acetylglucosamine linked by β-1,4 bonds. This naturally occurring polysaccharide mostly found in the extra cellular matrix of higher fungi, sponges, molluscs, nematodes, exoskeletons of insects and shells of crustaceans. It is a renewable source. Majority of the food processing industries contain chitin as the processed wastes. These wastes may cause major environmental problems due to its easy deterioration. Chemical procedures are usually used to degrade these wastes and it may cause hazardous and corrosive problems. Being more eco-friendly and cost effective method when compared to the chemical method for chitin degradation, the enzymatic method can be adopted as an alternative. The hydrolysis method is mainly mediated by some chitinolytic enzymes that allow the microorganism to use chitin as the sole source of carbon and nitrogen. In the field of medicine, agriculture and various other fields' chitinase or chitinolytic enzyme have a significant role. This property can be exploited for the production of some novel chitin derived products, for the degradation of shell fish waste containing chitin by using as carbon resource in microbial fermentation etc. In ocean chitin degradation is a vital step for the phenomenon of nutrient cycle to be occurring. This is mediated by chitinolytic bacteria. Plant diseases due to harmful fungi are of great concern in agriculture and it may cause large losses in the fields. Chitin contributes as a major component of fungal cell call thereby decaying chitin by chitinolytic bacteria thus fungal growth is inhibited. Hence the chitinolytic enzymes can be used as natural fungicides by replacing the deleterious chemical fungicides. Thus, a better application of this property is as an effective biocontrol agent. The major strains of chitinolytic marine bacteria include *Photobacteriumgalatheae* S2753, *Pseudoalteromonaspiscicida* S2040 and S2724, *Stenotrophomonasmaltophilia*etc.

Keywords: Chitin, chitinase, marine bacteria, biocontrol agent

Introduction

Chitin is a most profuse polymer found in marine environment (Paulsen *et al.*, 2019). Chitin is degraded frequently by chemical pathway and biotechnological pathway to give chitin oligosaccharides (Salas-Ovilla *et al.*, 2019). In biotechnological pathway chitin is degraded by chitinase enzyme that cleave the β- 1,4 bond of N-acetyl glucosamine. The shrimp production in India was estimated 70000 ton in 2019.The Shrimp waste Consist of 40% chitin

(Younes & Rinaudo, 2015). The screening of chitinase producers has become an important area in research field. A large number of studies indicate that marine biota is rich in chitinase enzyme. Bacteria often secrete many chitinases and they degraded different form of chitin. The chitinase is believed to be the primary enzyme used in breakdown of fungal chitin (Kawase *et al*., 2014; Orikoshi *et al.*, 2005). Lytic polysaccharide monooxygenase were first described in 2010 (Vaaje-Kolstad *et al*., 2010) for the breakdown of chitin. Chitinolytic marine bacteria have the ability to inhibit the fungi by chitin degradation (Kawase *et al*., 2014). The fungal plant diseases are the cause of large loses in field of agriculture and it affects world's food production (Pitt & Hocking, 2009). Fungal contamination and mycotoxin production are major problem (Andersen *et al*.,2017). Natural fungicide such as chitinase can replace chemical fungicide and potentially give biocontrol (Brzezinska *et al.*, 2014*).* Present scenario concentrated on the mycolytic activity of chitinase enzyme, which can be used as an alternative for chemical pesticides in an effective manner. This is an eco friendly method for controlling pests in agriculture instead of chemicals that cause hazardous environmental impacts (John & Thangavel, 2015). Chitinase producing organisms could either be used directly in biological control of microorganisms or indirectly using their purified protein or through gene manipulation (Gupta *et al*., 1995; Singh *et al*., 1999). Enzymes generated by marine bacterial strains are important in different biological fields because of their extraordinary features (Debashish*et al*., 2005). Some are extremely resistant to salt and heat, the major characteristics that are usually very important in several industrial processes.

Chitinolytic bacteria

Chitinolytic Bacteria mostly found in marine environment. These are capable of decomposing the chitin under aerobic and anaerobic conditions. These are found in environment with High amount of chitin (such as shrimp shell) (Brzezinska*et al*., 2014). Chitinolytic bacteria comprise only 4% of total heterotrophic bacteria (Swiontek & Donderski, 2006). Chitin degrading bacteria isolated from soil include *flavobacterium, Bacillus, cytophaga, pseudomonas (*Souza *et al.*, 2011*)*. In aquatic environment include aerobic genera *flavobacterium, enterobacter, Bacillus, Ervinia, Vibrio* (Swiontek & Donderski, 2006; Donderski & Trzebiatowska, 2000). Marine microbial varieties have been attracting more and more surveillance as a reserve for new novel enzymes, because enzymes from microorganisms are comparatively more active and stable than the corresponding ones derived from animal or plant sources. The extreme complexity of the marine environment including high salinity, elevated pressure, low temperature and unique lighting conditions, may provide some significant properties in enzymes from marine microbes than the homologous enzyme produced by terrestrial microorganisms, leading to the recent development of marine microbial enzyme technology and the establishment of precious products (John & Salim, 2020). Clostridium *is* anaerobic genus that has been described in marine environment (TsujiboH *et al.,* 1999). *Cellulomonas* (ATCC 21 399) is capable of degrading chitin in both aerobically and anaerobically (Sturz & Robinson, 1986). Some researchers identified organisms such as *Eubacterium, Streptococcus,* and *Clostridium* from residue of whale (Olsen *et al.*, 1999), *Serratia* and *Streptomyces* from crustaceans (Castro *et al.*, 2011) and *Bacillus licheniformis* and *Bacillus amyloliquefaciens* from food industry and

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shrimp respectively (Laribi-Habchi *et al.,* 2015; Setia., 2015). Due to their aerobic character they are mostly isolated from terrain rather than aquatic environment (Salas-Ovilla *et al.,* 2019*).*

Biocontrol potential of chitinolytic bacteria

Microorganisms producing chitinase enzymes have the ability to inhibit many fungal growths that poses a serious threat to agricultural crops. Diverse microorganisms produce and excrete lytic enzymes that can hydrolyze wide variety of polymeric compounds, inclusive of proteins, cellulose, hemicellulose, DNA and chitin (Vivekananthan *et al*., 2004) therefore, contributing to the direct suppression of phytopathogens. Lytic enzymes can destroy various components present in the cell walls of oomycetes and fungi (Chet & Inbar, 1994).The fungal plant pathogens are conventionally destroyed with the use of chemical fungicides, which has caused acceleration in environmental pollution and destruction. Also, these chemicals can be lethal to many beneficial insects and microorganisms populating in soil environment (Budi *et al*., 2000). In such context, biocontrol, the use of microorganisms in plant disease control, offers an effective alternative and eco-friendly strategy. Chitinase producers are the most commonly studied and attractive alternative to chemical pesticides because of the safety they offer and lower environmental impact. Some of the most important plant pathogens are *Fusarium, Penicillium, Alternaria, Aspergillus* etc. Studies have shown that chitinase enzyme of bacterial origin are found to be more fungicidal (Brzezinska *et al*., 2014). Some researchers isolated chitinolytic bacteria from sea dumb and screened for chitinolytic activity on the basis of formation of zone of clearance (Gohel *et al*., 2004). The screened culture was further studied for their potential as antifungal agent. As the fungal cell wall is made up of chitin as a major component, the chitinase enzyme produced by the culture lyses the cell and also causes inhibition of hyphal elongation of fungi.

Chitinolytic bacteria in waste management

Usage of chitinases is an ecofriendly way of clearing sea shell waste (Das *et al*., 2012). Chitinous waste can be effectively used in microbial production of chitinases (Gohel *et al.*, 2006). In a previous study, 40 strains of bacteria were tested to know their potentiality to degrade chitin (Sabry, 1992). The most active organisms were reported from *Alcaligenes* and *Bacillus* species. Sea shell is rich in protein and chitin so its disposal is a serious environmental issue, some researchers characterized a new chitinase - deficient *Bacillus licheniformis* strain able to deproteinate shrimp shell waste (Waldeck *et al*., 2006). Molecular biological tools such as rDNA technology can be used in the degradation of sea shell waste and convert them to eco friendly products (Das *et al*., 2012).

Chitinase in food and fermentation industry

Various studies have been carried out in analyzing the chitinolytic bacterial enzymes in a wide range of applications like the food and fermentation industry. In a study (Le *et al*., 2*018*), they isolated potential chitinolytic strains from salt fermented shrimp. The isolated strains were identified as *Salinovibrio* sp. *Salinovibrio* sp. in the in vitro screening results suggested the wide use of these strains as a new candidate in seafood fermentation and chitin hydrolysis. The isolation of bacteria with strong chitinase activity is important for enhancing the commercial quality of fermented foods and developing novel enzymes with industrial potential (Le *et al*., 2018). In recent years, chitinases produced by bacteria have been received increased attention due to a wide spectrum of properties and activities (Yan and Fong, 2015). Advanced study was carried out on the isolation and characterization of chitinase producing *Bacillus* and *Paenibacillus* strain from the salted and fermented shrimp shows the high chitinase activity and play a functional role in the chitin bioconversion of sea crustacean food (Han *etal* 2014). The antimicrobial activity of the chitinolytic strains can be determined by performing the disc diffusion method on nutrient agar (Bauer *et al.*, 1966). Safety assessment like biogenic amine production, mucin degradation, and hemolytic activity can be thoroughly examined (Bovercid *et al*., 1999; Zhou *et al*., 200; Semedo *et al*., 2003).

Conclusion

Chitinolytic Bacteria mostly found in marine environments. These are capable of decomposing the chitin under aerobic and anaerobic conditions. For particular biotechnological needs chitinolytic microorganisms can be grown in suitable natural environmental conditions. Microorganisms in aquatic environment include aerobic genera *Flavobacterium, Enterobacter, Bacillus, Ervinia ,Vibrio* etc. Their applications are not limited but show a broad spectrum. Numerous studies carried out, demonstrated that the effect of some fungal phytopathogens can be resisted by chitinolytic enzymes with anti fungal activity. The conventional use of chemical fungicide caused acceleration in environmental pollution and destruction which also can be lethal to many beneficial insect and microorganism populating in soil environment. In such context, biocontrol, the use of microorganisms in plant disease control, offers an effective alternative and eco-friendly strategy. Chitinases can utilize chitinous waste in the environment, also chitin waste can be used for production of microbial chitinase which is a cost effective method. Various studies have provided development in the field of fermentation studies and bio conversion of chitin. These chitinolytic bacterial in vitro screening results suggested that they could be widely used as new candidates for chitin hydrolyzation and seafood fermentation. The potential of these strains for inhibiting foodborne pathogens and the in vitro safety are also identified.

References

Andersen, B., Dosen, I., Lewinska, A. M., & Nielsen, K. F. (2017). Pre‐ contamination of new gypsum wallboard with potentially harmful fungal species. *Indoor Air*, *27*(1), 6-12.

Bauer A.W, Kirby W.M, Sherris J.C, TurckM . 1966. Antibiotic susceptibility testing by a standardized single disk method. Am J ClinPathol 45: 493

Bover-Cid, S., & Holzapfel, W. H. (1999). Improved screening procedure for biogenic amine production by lactic acid bacteria. *International journal of food microbiology*, *53*(1), 33-41.

Brzezinska, M. S., Jankiewicz, U., Burkowska, A., &Walczak, M. (2014). Chitinolytic microorganisms and their possible application in environmental protection. *Current microbiology*, *68*(1), 71-81

Budi, S. W., van Tuinen, D., Arnould, C., Dumas-Gaudot, E., Gianinazzi-Pearson, V., &Gianinazzi, S. (2000). Hydrolytic enzyme activity of Paenibacillus sp. strain B2 and effects of the antagonistic bacterium on cell integrity of two soil-borne pathogenic fungi. *Applied Soil Ecology*, *15*(2), 191-199.

Castro, R., Álvarez, A., Machado, E., Mendoza, M., Gómez, R., &García, P. (2011). Characterization of a extracellular chitinase produced by Serratia sp. BIOMI-363706 using colloidal chitin as substrate. *Rev. Soc. Quím. Perú*, *77*, 101-108.

Chet, I., &Inbar, J. (1994). Biological control of fungal pathogens. *Applied Biochemistry and Biotechnology*, *48*(1), 37-43.

Das, S. N., Neeraja, C., Sarma, P. V. S. R. N., Prakash, J. M., Purushotham, P., Kaur, M., ... &Podile, A. R. (2012). Microbial chitinases for chitin waste management. In *Microorganisms in Environmental Management* (pp. 135-150). Springer, Dordrecht.

Debashish, G., Malay, S., Barindra, S., &Joydeep, M. (2005). Marine enzymes. *Marine Biotechnology*,*96*, 189-218.

Donderski, W., &Trzebiatowska, M. (2000). Influence of physical and chemical factors on the activity of chitinases produced by planktonic bacteria isolated from Jeziorak Lake. *Polish Journal of Environmental Studies*, *9*(2), 77-82.

Gohel, V., Singh, A., Vimal, M., Ashwini, P., &Chhatpar, H. S. (2006). Bioprospecting and antifungal potential of chitinolytic microorganisms. *African Journal of Biotechnology*, *5*(2), 54-72.

Gupta, R., Saxena, R. K., Chaturvedi, P., &Virdi, J. S. (1995). Chitinase production by *Streptomyces viridificans*: its potential in fungal cell wall lysis. *Journal of Applied Bacteriology*, *78*(4), 378-383.

Han, K. I., Patnaik, B. B., Kim, Y. H., Kwon, H. J., Han, Y. S., & Han, M. D. (2014). Isolation and characterization of chitinase‐ producing Bacillus and Paenibacillus strains from salted and fermented shrimp, Acetesjaponicus. *Journal of food science*, *79*(4), M665-M674.

John, N., &Salim, R. (2020). A study on major plant growth promoting traits of bacteria isolated from marine environment. *Materials Today: Proceedings*, *25*, 269-273.

John, N., &Thangavel, M. (2015). Isolation, screening and identification of marine bacteria for the plant growth promoting activities. *Global journal for research analysis*, *4*(1), 65-68.

Kawase, T., Yokokawa, S., Saito, A., Fujii, T., Nikaidou, N., Miyashita, K., & Watanabe, T. (2006). Comparison of enzymatic and antifungal properties between family 18 and 19 chitinases from S. coelicolor A3 (2). *Bioscience, biotechnology, and biochemistry*, *70*(4), 988-998.

Laribi-Habchi, H., Bouanane-Darenfed, A., Drouiche, N., Pauss, A., &Mameri, N. (2015). Purification, characterization, and molecular cloning of an extracellular chitinase from Bacillus licheniformis stain LHH100 isolated from wastewater samples in Algeria. *International Journal of Biological Macromolecules*, *72*, 1117-1128.

Le, B., Chung, G., & Yang, S. H. (2018). Chitinase-producing Salinivibrio bacteria isolated from salt-fermented shrimp with antimicrobial and safety assessments. *Journal of Applied Biological Chemistry*, *61*(3), 233-238.

Olsen, M. A., Blix, A. S., Utsi, T. H. A., Sørmo, W., &Mathiesen, S. D. (1999). Chitinolytic bacteria in the minke whale forestomach. *Canadian journal of microbiology*, *46*(1), 85-94.

Orikoshi, H., Nakayama, S., Miyamoto, K., Hanato, C., Yasuda, M., Inamori, Y., &Tsujibo, H. (2005). Roles of four chitinases (ChiA, ChiB, ChiC, and ChiD) in the chitin degradation system of marine bacterium Alteromonas sp. strain O-7. *Applied and environmental microbiology*, *71*(4), 1811-1815.

Paulsen, S. S., Andersen, B., Gram, L., & Machado, H. (2016). Biological potential of chitinolytic marine bacteria. *Marine drugs*, *14*(12), 230.

Pitt, J. I., & Hocking, A. D. (2009). *Fungi and food spoilage* (Vol. 519, p. 388). New York: Springer.

Sabry, S. A. (1992). Microbial degradation of shrimp‐ shell waste. *Journal of basic microbiology*, *32*(2), 107-111.

Salas-Ovilla, R., Gálvez-López, D., Vázquez-Ovando, A., Salvador-Figueroa, M., & Rosas-Quijano, R. (2019). Isolation and identification of marine strains of Stenotrophomonamaltophilia with high chitinolytic activity. *PeerJ*, *7*, e6102.

Semedo, T., Almeida Santos, M., Martins, P., Silva Lopes, M. F., Figueiredo Marques, J. J., Tenreiro, R., & Barreto Crespo, M. T. (2003). Comparative study using type strains and clinical and food isolates to examine hemolytic activity and occurrence of the cyl operon in enterococci. *Journal of Clinical Microbiology*, *41*(6), 2569-2576.

Setia, I. N. (2015). Chitinolytic assay and identification of bacteria isolated from shrimp waste based on 16S rDNA sequences. *Advances in Microbiology*, *5*(07), 541.

Singh, P. P., Shin, Y. C., Park, C. S., & Chung, Y. R. (1999). Biological control of *Fusarium* wilt of cucumber by chitinolytic bacteria. *Phytopathology*, *89*(1), 92-99.

Souza, C. P., Almeida, B. C., Colwell, R. R., & Rivera, I. N. (2011). The importance of chitin in the marine environment. *Marine biotechnology*, *13*(5), 823.

Sturz, H., & Robinson, J. (1986). Anaerobic decomposition of chitin in freshwater sediments. In *Chitin in nature and technology* (pp. 531-538). Springer, Boston, MA.

Suresh, P. V. (2012). Biodegradation of shrimp processing bio-waste and concomitant production of chitinase enzyme and N-acetyl-D-glucosamine by marine bacteria: production and process optimization. *World Journal of Microbiology and Biotechnology*, *28*(10), 2945-2962.

Swiontek, B. M., &Donderski, W. (2006). Chitinolytic bacteria in two lakes of different trophic status. *Polish Journal of Ecology*, *2*(54).

Vaaje-Kolstad, G., Westereng, B., Horn, S. J., Liu, Z., Zhai, H., Sørlie, M., &Eijsink, V. G. (2010). An oxidative enzyme boosting the enzymatic conversion of recalcitrant polysaccharides. *Science*, *330*(6001), 219-222.

VipulGohel, Tejas Chaudhary, Pravav Vyas, H. S. Chhatpar. 2004. Isolation and identification of marine chitinolytic bacteria and their potential in antifungal biocontrol. *Indian Journal Of Experimental Biology* vol 42, July 2004, pp 715-720

Vivekananthan, R., Ravi, M., Ramanathan, A., &Samiyappan, R. (2004). Lytic enzymes induced by *Pseudomonas fluorescens* and other biocontrol organisms mediate defence against the anthracnose pathogen in mango. *World Journal of Microbiology and Biotechnology*, *20*(3), 235-244.

Waldeck, J., Daum, G., Bisping, B., &Meinhardt, F. (2006). Isolation and molecular characterization of chitinase-deficient Bacillus licheniformis strains capable of deproteinization of shrimp shell waste to obtain highly viscous chitin. *Applied and environmental microbiology*, *72*(12), 7879-7885.

Yan, Q., & Fong, S. S. (2015). Bacterial chitinase: nature and perspectives for sustainable bioproduction. *Bioresources and Bioprocessing*, *2*(1), 1-9.

Younes, I., &Rinaudo, M. (2015). Chitin and chitosan preparation from marine sources. Structure, properties and applications. *Marine drugs*, *13*(3), 1133-1174.

Zhou, J. S., Gopal, P. K., & Gill, H. S. (2001). Potential probiotic lactic acid bacteria Lactobacillus rhamnosus (HN001), Lactobacillus acidophilus (HN017) and Bifidobacterium lactis (HN019) do not degrade gastric mucin in vitro. *International Journal of Food Microbiology*, *63*(1-2), 81-90.

SESSION 5: Coastal and Ornamental Aquaculture (Code: COA)

COA – 509- PO

Wild caught milkfish (*Chanos chanos*) culture in floating sea cages at Olaikuda, Pamban Island, India

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Abstract

Milkfish is an economically important table fish of Southeast Asia. The Philippines, Indonesia, Taiwan are the leading producers as well as consumers of milkfish. In India, despite the small-scale pond-based milkfish culture being practiced widely there is no commercial scale mariculture exists due to the absence of artificial seed propagation facilities. The domestic market value of milkfish ranges between □100 and 150/kg. Availability of large number of wild spawned milkfish seeds across the coastal swamps of the Gulf of Mannar during March to August months appears to be a potential seed source for capture-based aquaculture. The herbivorous nature of milkfish offers an added advantage of growing them with low value plant-based diet. Other traits such as disease resistance, faster growth (reaches 680 g within 8-9 months), acclimatization to higher stocking densities makes this species preferable for low input farming initiatives in the marine environments. In order to assess the growth and cost economics of the milkfish cultivation in sea cages, wild caught milk fish seeds (7- 9 g) were collected and stocked @ 30 nos./m^3 in a 9 m dia floating collar cage deployed at Olaikuda fishing village. The milkfish were fed twice a day with formulated pellet feed consisting of moderate Protein (30-40%), Lipid (7-10%), and Carbohydrate (25%) levels over a period of 250 days with an overwhelming 80% cumulative survival which yielded a significant average daily growth rate of 2.8 g/day resulted an average harvest size of 680 g/fish.

Keywords: Milkfish, *Chanos chanos*, sea cage culture, survival and growth rate, capture based fish culture.

Introduction

Milkfish is the single candidate species representing the family Chanidae belonging to the order Gonorynchiformes and they grow up to 1.8 m, but are most often reported less than 1 m in length (Bagarinao, 1994). Milkfish have no teeth and generally feed on algae and invertebrates (Pantastico et al., 1986; Baliao et al., 1999; Requintina et al., 2008). Based on the morphological characteristic and ecological requirements milkfish show dissimilar phases in their life cycle (Requintina et al., 2008). On the basis of their widespread availability, general hardiness and rapid growth in pond, milkfish are considered as one of the best candidate species for aquaculture (Joseph, 2016; Lingam et al., 2019). Milkfish being an economically important table fish of south-east Asia, widely cultured in tropical and subtropical areas of the Indo-west Pacific Ocean (Biswas et al., 2011; Ravisankar et al., 2005; Requintina et al., 2008). *Chanos chanos* (Forsskal, 1775) could possibly be a top aquaculture commodity in south East Asian countries primarily due to their traits such as easy to culture and its adaptability to wide range of environments ranging from freshwater to marine and even high saline habitats (Barman et al., 2012; Jana et al., 2006; Mandal et al., 2018; Syed Raffic Ali et al., 2019). Juvenile *Chanos chanos* (Forsskal, 1775) thrive primarily on blue-green algae, mangrove and sea grass debris, diatoms and detritus (Kumagai et al., 1985; Luckstadt et al., 2002; Yun A and Takarina, 2019). The milkfish fry season occurs at different times of the year in different parts of the country. In regions affected by monsoon or trade winds, peak fry season typically coincides with one or both of the twice-yearly wind shifts. These seasonal peaks are more or less predictable, but fry abundance may vary from year to year (Jaikumar et al., 2013).

Materials and Methods

Cage design and deployment

The present cage culture experiment was carried out at Olaikuda (9^{o} 20'07.74" N, 79 ^{o}19'47.56 E), Rameshwaram on the southeast coast of India. The site identified earlier for culture demonstration due to its favourable sea conditions such as relatively calm and clear water, pollution free environment, proximity to wild milkfish seed availability. Floating collar cages (HDPE 9 m diameter) with a cultivable volume of 320 m^3 were developed and deployed at a depth of 6-7 m. The cages were positioned with a multipoint grid mooring system capable of keeping the battery of culture systems intact irrespective of the rough monsoonal sea conditions. Ballast weights were added to the fish holding nets in order to avoid the deformation of nets during the high current and wave conditions. The total cultivable volumes of these cages were 320 m^3 and fitted with 8, 16 mm knotless poly ethylene meshes coated with antifouling paints as fish holding nets.

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Fig: -1HDPE Floating collar cage (9 m diameter)

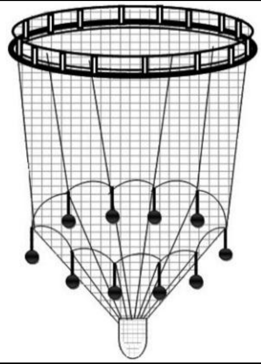

Fig: -2 Drawing of the cage with culture net.

Collection of milkfish fingerlings

Milkfish fingerlings were collected with a help of drag net (40 m long, 10 m wide) made up of mosquito meshes (Locally called "kondadi valai") of 50 m long scare line, on which palmyra leaves were attached ('Olai kayiru') to gather fishes at one direction. Owing to this large net size, six persons were employed to operate this sampling gear. While two persons waded ahead through the water dragging the two ends of the scare line in a semi-circle position and two others dragged the net. Two others standing on either side of the drag net splashed water to scare the fingerlings towards the net. Scared by the Palmyra leaves tied in the dragging scare line disturbed by the bag-like space of the closely flowing net the curved area covered by the drag net was narrowed down as the net was dragged toward the edge of the water-logged area, trapping all fingerlings within the arc (Jaikumar et al., 2013). Fingerling as much as 300-600 numbers per drag amounting 6,000 seeds of size ranging between 60 and 90 mm with the average weight of 6 – 8 g were collected.

Packing and Transportation

Collected fingerlings were transferred using plastic buckets (20 L) from the place of capture to packing site which was at a distance of 300 to 400 m. The bucket holding the seeds was covered with a wet cloth to avoid seed escape. The fingerlings were allowed to acclimatise gradually in one ton FRB tank filled with filtered seawater for 20 to 30 min under a tree shade. Ice bars were added to maintain the water temperature at around 26 $^{\circ}$C. The fingerlings (60-90 mm) were packed in plastic bags (90 × 60 cm; thickness 0.0622 cm) inflated with 1^{-3} water and 2^{-3} oxygen. The densities of fish packed in the plastic bags depended upon its biomass. Packed seeds were then transported using a minivan (Tata Ace) from the collection site (Vedalai) to the culture site (Olaikuda) covering 35 km and further transported in a boat from shore to rearing sea cages (1.8 km). Special attention was given to maintain optimal conditions such as temperature and dissolved oxygen which ensured the high survival rate. Seed collection was carried out at early hours of the day during low tide to avoid the adverse effects such as raising temperature, which is critical for the survival of fingerlings.

Seed Stocking

Milkfish fingerlings were stocked in the open sea cages in the evening hours of the day after a period of acclimatisation to the sea water. The bags containing fingerlings were made to float within the cage for about 30 minutes. After a brief period of acclimatisation, they were slowly released into the cages.

Daily feeding and cage maintenance

The milk fishes were fed with formulated plant-based pellets consisting of 30 - 40 % crude protein, Lipid (7 - 10 %), Carbohydrate (25 %) at the rate of 4 % of biomass per day for the first 2 months. The feeding rate was then reduced to 2 % of their body weight during harvest. The fish were fed twice daily (split feeding) @ 40 % at 06:30 hrs and 60 % at 14:30 hrs. After feeding the fishes in the morning, they were very closely monitored by skin diving in to the cage. Dead fishes, if any, were removed from the mortality bag and documented. The net, HDPE frame and brackets were regularly cleaned to keep them devoid of fouling on weekly basis to ensure the proper water exchange and avoid net damage. Milkfish reared in higher temperatures are reported to have the fastest food intake due to the improved physiological activity. Since the rate of digestion is also highly temperature dependent and can be measured by time elapsing between food intake and defecation (Villaluz and Unggui, 1983).

Water quality and growth rate

Physicochemical parameters such as salinity (‰), temperature (°C), pH and dissolved oxygen (DO; mg L^{-1}) were measured with a water quality probe (YSI Model 563A) on daily basis. Fortnight sampling of fishes was done using scoop net during the entire culture period to assess the growth rate. A total sample size of 15 to 20 fishes was used to measure the total length (TL) and weight (g). Absolute growth (AG), absolute growth rate (AGR), relative growth (RG), relative growth rate (RGR) and specific growth rate (SGR) were assessed twice in a month.

Results and discussion

During the culture period physicochemical parameters (Table - 3) recorded were of the order of average salinity 31 ppt (min 29 max 34, temperature 27 °C (min 26 max 28), pH 8.2 (min 7.8 max 8.7) and dissolved oxygen (DO: mg L^{-1}) average 6.4 (min 5.55 max7.1) includes a seasonal graph. The stocking size of the milkfish in August ranged from 7 to 9 cm (6 to 8 g) with the average size of 8 cm and 7.2 g. The total mortality during the culture period was 900 and among the dead fishes, 90 % of mortality was occurred during the initial 15 days. Remaining 10 % of death happened in between the remaining culture periods. stocked The quantum of feed utilised was in the order of 5576 kg which resulted in the feed conversion ratio (FCR) of 1: 2.05. With 80 % cumulative survival and a significant daily growth rate of 2.8 g day $^{-1}$ which resulted in an average harvest size of 680 g/fish $^{-1}$. Maximum 1050 g weight, length 51 cm and minimum 405 g weight and 31.5 cm were documented. Milkfish were generally reared in the brackishwater ponds due to its ability in tolerating the salinity levels from 0 to 150 ppt and there were no attempts made in the country to rear them in the marine waters (Lin et al., 2003; Cuvin-Aralar et al., 2016). The contemprory brackishwater culture of milkfish in cages attempted by the Central Marine Fisheries Research Institute yielded a biomass of 500 kg with an average weight of 400 g with a feed conversion ratio of 1:2 in 240 days (Imelda Joseph et. al., 2015). When comparing the results of the present pioneering mariculture attempt the growth and survival rate are far better than any other culture methods environmnts but for the slight increase in the feed conversion efficiency against the CMFRI's 1:2 vs our 1: 2.05, which is duly due to the absence of adequate secondary feeding sources in the offshore environments.

Table 1 Summary of cage culture site characteristics corresponding initial stocking density.

Parameters	Olaikuda cage site
Distance from shore (km)	1.8
Depth (m)	8
Bottom profile	Sandy
Cage height (m)	6
Cage width (m)	9
Number of fingerlings stocked	5000
Number of fish harvested (85 %)	4000
Initial stocking density (m^{-3})	30
Days of culture	250

Table 2 Summary of growth parameters used to express results of growth rates of milkfish.

Parameter (unit)	Equation
Absolute growth (g)	AG = W2 − W1
Absolute growth rate (g day $^{-1}$)	AGR = (W2 − W1) / (t2 − t1)
Relative growth	RG = (W2 − W1) / W1
Relative growth rate	RG = (W2−W1) / W1(t2 − t1)
Instantaneous growth rate (g day $^{-1}$)	IGR = (logW2 − log W1) / (t2 − t1)
Specific growth rate (% day $^{-1}$)	SGR = 100* (log W2 − log W1) / (t2 − t1)
FCR	TFC / BI

W1 = initial wet weight of fish during stocking
W2 = the mean final weight of fish during harvest
t2-t1 = represents the grow-out period.
Lt = total length at age t:a and b are constants.
TFC is the total amount of feed consumed (kg) and BI is the biomass increase

Table-3 Summary of cultured period (Aug to May) means and ranges in water quality parameters from cage culture site, Olaikuda.

	Temperature (°C)	Dissolved Oxygen (mg $^{-1}$)	Salinity (g $^{-1}$)	pH
Average	27	6.40	31	8.20
Minimum	26	5.55	29	7.80
Maximum	28	7.10	34	8.70

Conclusion

The present attempt of rearing milkfishes in the sea cages at higher densities is a great success and forecasting the mariculture potential of milkfishes. By expanding the milkfish culture by formulating a low value species specific plant based protein diets and artificial propagation of milk fish seeds will ensure economically viable milk fish farming in the country. In the absence of hatchery produced seeds, and considering the huge wild seed availablity in the Gulf of Mannar region, a seed collection and conditioning facility can be established to support milk fish farming venture in the India. Though, milkfish can be reared completely with plant based formulated diets formulating a species specific diet will enhance its profitability by considerably reducing the days of culture. Consistent production of milkfish in large scale will help to enhance its marketability.

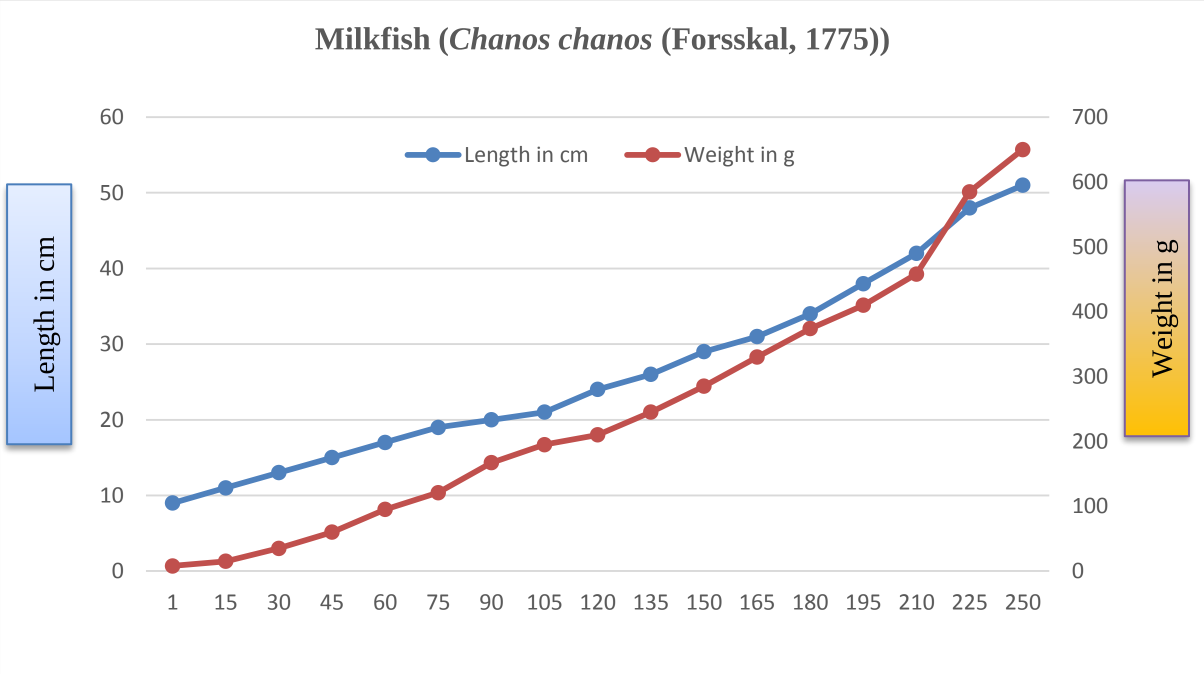

Fig: -3 Milkfish (*Chanos chanos* (Forsskal, 1775)) weight Vs length

References

Biswas, G., J.K. Sundaray., A.R. Thirunavukkarasu., M. Kailasam, 2011. Length-weight relationship and variation in condition of Chanoschanos (Forsskal, 1775) from tide-fed brakishwater ponds of the Sundarbans-India. *Indian Journal of Geo-Marine* Science,40(3), 386-390. http://hdl.handle.net/123456789/12428

Bagarinao, T. 1994. Systematics, distribution, genetics and life history of milkfish, (*Chanos chanos* (Forsskal)), 1775. Environmental Biology of Fishes 39:23–41. https://doi.org/10.1007/BF00004752

Baliao D. D., de los Santos M. A., & Franco N. M. 1999. The modular method: Milkfish pond culture. Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center. http://hdl.handle.net/10862/1545

Barman UK, Garg SK, Bhatnagar A. 2012. Effect of Different Salinity and Ration Levels on Growth Performance and Nutritive Physiology of Milkfish, (*Chanos chanos* (Forsskal, 1775)) -Field and Laboratory Studies. *Fisheries and Aquaculture Journal*, 3, 49-53. https://www.longdom.org/open-access/effect-of-different-salinity-and-ration-levels-on-growth-2150-3508.1000053.pdf

Cuvin-Aralar, M.L.A., Ricafort, C.H., Salvacion, A. 2016. An Overview of Agricultural Pollution in the Philippines The Fisheries Sector. http://hdl.handle.net/10986/29247

Imelda-Joseph., Sarimol C. N., K. M. Venugopalan. 2015. Cage culture of milk fish Chanos chanos in brackishwater pond at Kochi, Kerala Cage Aquaculture in Asia: Proceedings of the Fifth International Symposium on Cage Aquaculture in Asia, Asian Fisheries Society, Malaysia and ICAR-Central Marine Fisheries Research Institute, Kochi, India. pp 215-221. https://www.yumpu.com/en/document/view/55829671/caa5-proceedings

Jaikumar, M., Kumar, C.S., Robin, R.S., Karthikeyan, P., Nagarjuna, A. 2013. Milkfish Culture : Alternative Revenue for Mandapam Fisherfolk , Palk Bay ,. *International Journal of Fisheries and Aquaculture* Sciences. 3:31–43. http://www.irphouse.com/ijfas/ijfasv3n1_05.pdf

Jana, S.N., Garg, S.K., Patra, B.C. 2006. Effect of inland water salinity on growth performance and nutritional physiology in growing milkfish, *Chanos chanos* (Forsskal,1775): Field and laboratory studies. *Journal of Applied Ichthyology* 22:25–34. https://doi.org/10.1111/j.1439-0426.2006.00698.x

Joseph, S. 2016. Different species used for coastal pond farming in India. In: Imelda, Joseph and Ignatius, Boby (Eds.), Course Manual, Winter school on technological advances in mariculture for production enhancement and sustainability. ICAR- Central Marine Fisheries Research Institute, Kochi. pp 231–239. Different species used for coastal pond farming in India. http://eprints.cmfri.org.in/10600/1/PDF-Manual.pdf

Kumagai, S., Bagarinao, T., Unggui, A. 1985. Growth of juvenile milkfish (*Chanos chanos* (Forsskal, 1775)) in a natural habitat. *Marine Ecology Progress Series* 22:1–6. https://doi.org/10.3354/meps022001

Lin, Y.M., Chen, C.N., Lee, T.H. 2003. The expression of gill Na, K-ATPase in milkfish, (*Chanos chanos* (Forsskal, 1775)), acclimated to seawater, brackish water and fresh water. Comparative Biochemistry and Physiology - A Molecular and Integrative Physiology 135:489–497. https://doi.org/10.1016/S1095-6433(03)00136-3

Lingam, S.S., Sawant, P.B., Chadha, N.K., Prasad, K.P., Muralidhar, A.P., Syamala, K., Xavier, K.A.M. 2019. Duration of stunting impacts compensatory growth and carcass quality of farmed milkfish, *Chanos chanos* (Forsskal, 1775) under field conditions. Scientific Reports 9:1–11. https://doi.org/10.1038/s41598-019-53092-7

Luckstadt, C., & Reiti, T. (2002). Investigations on the feeding behavior of juvenile milkfish (*Chanos chanos* (Forsskal, 1775) in brackishwater lagoons on South Tarawa, Kiribati. Verhandlungen der Gesellschaft fur Ichthyologie, 3, 37-43. http://hdl.handle.net/10862/1939

Mandal, B., Bera, A., Kailasam, Padiyar, A., Ambasankar, Alavandi, Vijayan 2018. A Guide to Milkfish (*Chanos chanos* (Forsskal, 1775)) *Aquaculture*. Central Institute of BrackishwaterAquaculture. https://krishi.icar.gov.in/jspui/bitstream/123456789/20213/2/Milkfish%20Aquaculture%20%20-%20book%20let%20inner%20-%202-5-18.pdf

Pantastico, J.B., Baldia, J.P., Reyes, D.M. 1986. Feed preference of milkfish (*Chanos chanos* (Forsskal, 1775) fry given different algal species as natural feed. *Aquaculture* 56:169–178. https://doi.org/10.1016/0044-8486(86)90332-7

Ravisankar, T., Sarada, C., Krishnan, M. 2005. Diversification of Fish Culture and Exports among Major Shrimp-producing Countries of Asia : A Spatial and Temporal Analysis. *Agricultural Economics Research* 18:187–195. DOI: 10.22004/ag.econ.58470

Requintina, E.D., Mmochi, A.J., Msuya, F.E. 2008. A Guide to Milkfish Culture in the Western Indian Ocean Region. WIOMSA. Western Indian Ocean Marine Science Association Institute of Marine Sciences, University of Hawaii, Hilo and the Coastal Resources Center, University of Rhode Island, viii + 36pp. http://www.crc.uri.edu

Syed Raffic Ali, S., Ambasankar, K., Balachandran, S., Ramachandran, K. 2019. Effect of moisture and temperature on the extrudate properties of milkfish (*Chanos chanos* (Forsskal, 1775)) feed. *Indian Journal of Fisheries* 66:112–117. https://doi.org/10.21077/ijf.2019.66.4.75758-14

Villaluz, A.C., Unggui, A. 1983. Effects of temperature on behavior, growth, development and survival in young milkfish, (*Chanos chanos* (Forsskal, 1775)). *Aquaculture* 35:321–330. https://doi.org/10.1016/0044-8486(83)90104-7

Yun, A. Q., Takarina, N.D. 2019. Food preference analysis of milkfish in Blanakan Ponds, Subang, West Java. AIP Conference Proceedings 2168. https://doi.org/10.1063/1.5132510