Summary

Earth, the third planet from the Sun and the most massive terrestrial planet, is distinguished by its expansive liquid water reserves, covering over 71% of its surface. This abundant water, primarily in the form of oceans, plays a pivotal role in regulating atmospheric gases and climate dynamics. It serves as both the origin and sustenance for an incredibly diverse array of life forms, from microscopic phytoplankton to the majestic blue whale. The study of marine biology intricately intertwines functional biology and marine ecology, where each field informs and shapes the other.

The historical roots of marine biology can be traced back to ancient times, notably with Aristotle's keen observations and Carl Linnaeus' seminal taxonomic classifications. The 19th century witnessed significant strides forward, propelled by Edward Forbes' pioneering hypothesis on marine life depth limits and Charles Darwin's transformative contributions stemming from his voyage aboard the H. M. S. Beagle, which laid foundational principles for evolutionary theory. The groundbreaking Challenger expedition further advanced understanding of global marine diversity, documenting a vast array of marine life across diverse habitats.

Modern marine biology builds upon this rich historical foundation, leveraging advanced technologies such as genomics and remote sensing to explore and unravel the complexities of marine ecosystems. Research continues to uncover intricate ecological interactions and adaptive mechanisms, underscoring the critical role of oceans in maintaining global ecological balance.

Marine biodiversity is exceptionally rich, with estimates suggesting that 50-80% of all life resides beneath the ocean's surface. This biodiversity is influenced by various factors including temperature, salinity, light availability, and habitat diversity. Molluscs, a highly diverse and adaptable phylum, inhabit nearly every marine habitat, contributing significantly to marine biodiversity. In India, the study of molluscan diversity and distribution holds particular significance due to their ecological importance and economic value. Gujarat, with its extensive coastline and diverse marine habitats, supports a rich variety of Molluscan species.

The Saurashtra coast in Gujarat exemplifies this diversity, featuring a mosaic of habitats including rocky shores, sandy beaches, coral reefs, and seagrass beds. These varied ecosystems provide specialized niches that support a wide range of molluscan species. The intertidal zones along this coast, characterized by nutrient-rich waters and periodic exposure to air, are particularly conducive to supporting diverse molluscan communities.

The thesis aims to comprehensively explore molluscan diversity and distribution along the Saurashtra coast, examining their habitats and adaptations. The research also includes a bibliometric analysis to provide a panoramic view of global trends in molluscan research and influential studies.

Bibliometric analysis offers a systematic exploration of scientific literature, revealing trends, identifying gaps, and highlighting influential contributions. It provides valuable insights into the collaborative networks driving molluscan research, guiding future research directions and enhancing our understanding of this vital field.

The study utilized the Science Citation Index (SCI) database within Scopus to retrieve and analyse research articles on Molluscs published from 1969 to 2024. A total of 2,276 articles were identified and analysed based on various publishing metrics, employing tools like R Studio and VOS viewer for data analysis.

The results of the bibliometric analysis revealed dynamic fluctuations in article production over time, with a notable increase observed from the 1990s onwards. Leading countries in molluscan research included the United States, China, Germany, France, and the United Kingdom, showcasing robust global collaboration and contribution. Geographic distribution highlighted significant research outputs from various countries across the world, emphasizing the international scope and interdisciplinary nature of molluscan research.

Keywords analysis identified interconnected themes such as biodiversity, phylogeny, paleoecology, pollution, and more, reflecting the breadth of research interests within molluscan studies. Trend topics underscored the importance of understanding community structure, benthos, and molecular techniques like microsatellites in advancing knowledge within the field. The discussion emphasized the ecological and economic significance of molluscan research along the South Saurashtra coast of Gujarat, India. It underscored the role of molluscs as bioindicators of ecosystem health, their responses to environmental stressors, and their importance in benthic ecosystems. The study identified gaps in research, particularly in certain coastal areas, highlighting the need for more systematic and comprehensive studies to enhance our understanding of marine biodiversity and conservation efforts.

The research conducted along the South Saurashtra coastline of Gujarat, India, explored diverse locations known for their unique coastal characteristics and significant molluscan habitats. Gujarat boasts India's longest coastline, stretching approximately 1,600 kilometers and encompassing 21% of the country's total coastline. Within this expansive region, the study focused on three distinct sites: Mangrol, Adri, and Veraval, each selected for their specific environmental attributes conducive to molluscan diversity.

Mangrol, situated at latitude 21°07' N and longitude 70°07' E within the Junagadh district, features an extensive rocky intertidal zone ideal for various mollusc species. This location spans a coastline divided by Juni-Jetty into two sections, totalling 7.5 to 8 kilometers. The left side, less affected by human activities, contrasts with the more impacted right side, influenced by fishing-related operations. The rocky terrain, occasionally interspersed with sand and devoid of mud or silt, shapes a habitat rich in Molluscan diversity. In contrast, Adri, located along the southern part of the Saurashtra Coast, presents a narrower expanse spanning 1.5 to 3 kilometres. Its predominantly rocky shore, interspersed with sandy patches and a relatively gentle gradient, supports a diverse intertidal zone extending over 60 to 70 meters. Human activities, moderated

by the presence of a temple, interact with this coastal ecosystem, influencing its ecological dynamics. Veraval, positioned on the southwest coast of Saurashtra near the Somnath Mahadev Temple, is renowned as a significant fishing hub and fish landing center. The study site near Veraval Fisheries College and Chowpati lighthouse offers insights into molluscan habitats within an intertidal zone exposed during low tide, crucial for understanding species distribution dynamics in this bustling marine environment.

The research spanned from February 2021 to March 2023, commencing with a pilot survey to identify suitable study sites in February to April 2021. Monthly visits from April 2021 onward facilitated comprehensive data collection on Molluscan diversity, while intensive population ecology assessments from November 2021 to October 2022 captured seasonal variations in species dynamics. Additional validation visits until March 2023 ensured robust data reliability across different seasons winter, summer, and monsoon critical for understanding how environmental factors shape molluscan distribution patterns.

Sampling methodologies employed a systematic hand-collection approach, preserving specimens in 70% ethanol for subsequent morphological identification and database cross-referencing. Morphometric measurements, including shell dimensions and weight, provided detailed species characterization essential for biodiversity assessments and ecological studies.

The study meticulously categorized Molluscan species across upper, middle, and lower intertidal zones, emphasizing substratum preferences and zonation adaptations crucial for species survival. Quadrat sampling, conducted in a zig-zag pattern with 1 m^2 quadrates, quantified species abundance per square meter, supplemented by visual observation and photo-interpretation to ensure comprehensive habitat coverage and data accuracy.

Advanced methodologies included species distribution models (SDMs), integrating environmental data from Bio-Oracle encompassing variables like salinity, chlorophyll-a concentration, and sea surface temperature. Models—Maxent, BIOMOD, Bayesian approaches, and Random Forest—were employed in ensemble to predict habitat suitability, guiding conservation strategies and sustainable aquaculture practices along the Gujarat coast.

Gonadal sampling of dominant species further elucidated reproductive biology through microscopic analysis of preserved samples, enriching ecological insights into population dynamics and life history traits. Data analysis encompassed diverse biodiversity indices—Shannon-Weiner, Simpson Diversity, Pielou's Evenness, Menhinick, and Margalef—coupled with population ecology metrics and statistical tools (e.g., one-way ANOVA) to assess data reliability and ecological significance.

The study delves into the diversity of marine molluscs along Gujarat's South Saurashtra Coast, emphasizing their ecological, economic, and conservation significance. Across the study sites Mangrol, Adri, and Veraval; a total of 59 molluscan species were meticulously catalogued, representing 4 classes, 14 orders, and 26 families. Gastropods

emerged as the predominant class, followed by Bivalvia, Polyplacophora, and Cephalopoda, highlighting their dominance across all three locations.

Each site exhibited distinct species compositions: Mangrol recorded 37 species, predominantly comprised of gastropods making up 95.46% of the population. Adri followed with 32 species, where gastropods constituted 97.26%. Veraval boasted the highest species diversity with 51 species, where gastropods accounted for 93.49%, showcasing its role as a biodiversity hotspot along the coast.

Among the dominant species identified were Gastropod species like *Cerithium caeruleum*, *Lunella coronatus*, *Peronia verruculata*, and *Trochus radiatus*, underscoring their prevalence and ecological significance within these coastal ecosystems.

The study illuminated the influence of varied habitats from rocky shores to mangroves on molluscan diversity, with Veraval emerging as the most diverse site. This observation was corroborated by comprehensive diversity indices (Shannon-Wiener, Simpson's, Margalef, and Menhinick), which consistently ranked Veraval highest, followed by Mangrol and Adri, underscoring their respective ecological roles and conservation value.

Ecologically, gastropods play pivotal roles in nutrient cycling, sediment stabilization, and habitat structuring within marine environments. Their predatory activities on encrusting organisms further highlight their integral position in the marine food web. Economically, Molluscs like oysters, mussels, and clams support local fisheries and aquaculture industries, sustaining livelihoods for coastal communities and underlining their economic importance beyond ecological considerations. Conservation efforts hinge on understanding and preserving molluscan diversity, crucial for sustainable resource management. These species serve as vital indicators of environmental health, necessitating ongoing research and monitoring to safeguard marine biodiversity in this unique coastal region

The South Saurashtra Coast in Gujarat, India, hosts a diverse range of marine habitats, from estuaries to coral reefs, which support a rich mosaic of molluscan species. This biodiversity not only plays crucial ecological roles but also supports local fisheries and aquaculture, contributing significantly to socio-economic development. However, these molluscan populations are increasingly threatened by overexploitation, habitat destruction, pollution, and climate change, highlighting the urgent need for effective conservation measures. Gujarat's expansive coastline encompasses diverse environments, including mudflats, mangroves, and both sandy and rocky shores, each fostering unique molluscan communities. These species, such as clams, oysters, mussels, and squids, are integral to marine food webs and serve as important bioindicators of ecosystem health, reflecting the overall condition of coastal environments.

Despite their ecological and economic importance, Molluscan populations face significant challenges. Overexploitation from fishing activities, habitat loss due to coastal development, pollution from industrial and agricultural runoff, and the impacts of climate change, including ocean acidification and sea level rise, threaten their sustainability. Effective conservation strategies are essential to mitigate these threats and ensure the long-term viability of Molluscan species.

To address these challenges, the study employed Species Distribution Models (SDMs), sophisticated tools that integrate species occurrence data with environmental variables to predict habitat suitability and distribution patterns. By utilizing machine learning models like MaxEnt, BIOMOD, Bayesian models, and Random Forest, the research analyzed how factors such as salinity, chlorophyll concentration, and water temperature influence molluscan distribution along the South Saurashtra Coast. The findings revealed a diverse array of 59 molluscan species across different intertidal zones, illustrating their adaptive capabilities to varying environmental conditions. Species like *Trochus radiatus* and *Tibia insulaechorab* demonstrated versatility by inhabiting multiple zones, while *Cerithium caeruleum* and *Lunella coronatus* showed specific habitat preferences, indicating niche specialization within their environments.

MaxEnt emerged as the most accurate model, achieving the highest AUC value of 0.63, signifying moderate predictive capability. BIOMOD, Bayesian models, and Random Forest exhibited lower accuracy, reflecting the complexity of predicting species distributions based on environmental variables.

The study also identified key environmental drivers influencing molluscan habitats: salinity levels averaging 35.80 PSU significantly influenced distribution, while chlorophyll concentration (average 5.02 mg/m^3) indicated areas with abundant food resources, crucial for molluscan populations. Water temperature, averaging 18.73°C, was highlighted as critical for molluscan growth and distribution, with strong correlations observed between temperature and growth probability.

Understanding the density, abundance, and frequency of mollusc populations is crucial for evaluating biomass, health, and habitat productivity. This knowledge is pivotal for monitoring population dynamics, reproductive success, and survival rates. The study specifically examines key species such as *Cerithium caeruleum* (CC), *Lunella coronatus* (LC), *Peronia verruculata* (PV), and *Trochus radiatus* (TR), with a focused investigation into the gonadal cycles of CC and LC.

Examining density, abundance, and frequency across different intertidal zones reveals distinct patterns: *Cerithium caeruleum* (CC) exhibits significant density variations in the Upper Intertidal Zone (UIZ) and Middle Intertidal Zone (MIZ), influenced by air exposure and tidal conditions. Abundance varies notably in the MIZ, while frequency shows significant variation in the UIZ. *Trochus radiatus* (TR) displays density and abundance variations in the UIZ and LIZ, influenced by environmental stressors and stable submersion conditions. Frequency fluctuates significantly in response to air exposure, wave action, and predation.

Peronia verruculata (PV) maintains uniform density and abundance across all zones, indicating broad environmental tolerance, yet shows selective habitat preferences in terms of frequency in the UIZ and MIZ. *Lunella coronatus* (LC) exhibits density and abundance variations in the UIZ and LIZ, reflecting sensitivity to air exposure, wave action, and predation.

The reproductive cycles of *Lunella coronatus* and *Cerithium caeruleum* reveal seasonal variations in activity and histological changes across different seasons. LC shows peak reproductive activity in summer, reduced in winter, and transitional phases

during the monsoon. CC demonstrates heightened spermatogenic activity during the monsoon and significant oocyte development in summer.