UNDERWATER SAMPLING METHODS FOR MARINE BIODIVERSITY MONITORING

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Abstract
Marine ecosystems are vital for life on Earth, demanding urgent conservation efforts amidst increasing human encroachment. Sampling, essential for biodiversity monitoring, faces unique challenges in the dynamic underwater realm. This article delves into diverse sampling methods tailored for marine biodiversity monitoring. Traditional trawling and dredging, while informative, can harm sensitive habitats, driving the need for sustainable alternatives like dive-based surveys employing snorkelling and SCUBA techniques. Additionally, underwater videography and advanced technologies like ROVs and AUVs offer unprecedented insights. Citizen science initiatives further enhance data collection, despite quality concerns. Understanding these methods' strengths, limitations, and applications is crucial for effective marine conservation across ecosystems worldwide.

Introduction

Marine ecosystems including coastal and deep-sea habitats are essential for human life and existence of our planet. These ecosystems provide irreplaceable services to human race and human activities increasingly encroach upon marine habitats, the need for comprehensive monitoring and conservation efforts has never been more urgent. The underwater world remains a mystery for many including researchers as these are inhabited by countless species, from tiny plankton to massive whales. Understanding the intricacies of marine biodiversity is crucial not only for the preservation of fragile ecosystems but also for the sustainable management of ocean resources upon which millions of people depend.

At the heart of marine biodiversity monitoring lies the fundamental task of sampling – the systematic collection of data from various locations and depths to gain insights into the composition, distribution, and abundance of species. Scientific information derived from monitoring initiatives focused on marine ecosystems is frequently used to understand ecosystem condition and changing dynamics. Scientific monitoring systems require series of protocols for data gathering and these protocols are basically methods which describe 'how the information is collected'. However, conducting sampling in the dynamic and often remote marine environment poses unique challenges that require specialized techniques and methodologies.

In this article, the realm of underwater sampling methods tailored specifically for monitoring marine biodiversity are briefly described. From the rocky shores of coastal ecosystems to the depths of the open ocean, researchers employ a diverse array of tools and techniques to collect data and unravel the secrets of the sea.

Trapping Survey

Trapping survey is a method used in ecological research to assess the presence, abundance, or diversity of species within a particular area. In trapping surveys, researchers deploy traps or similar devices to capture and sample organisms of interest, such as small mammals, insects, or other animals. These traps are designed to attract target species using bait, pheromones, or other lures, and they are typically checked at regular intervals to collect captured individuals.

Limitation: The major limitation is that the sampling is biased towards species that are attracted to the bait or trap type used.

Trawl and Dredge surveys

Traditional sampling methods, such as trawling and dredging, have long been used to study marine life. These techniques involve dragging nets or dredges along the seafloor to capture organisms, providing valuable insights into the composition of benthic communities.

Limitations: These methods are destructive to sensitive habitats and often result in bycatch of non-target species.

Dive- based surveys

Since traditional methods were destructive to nature, researchers felt the necessity to measure the changes in the ecological processes on spatial and temporal scales, by directly observing the underwater ecosystem. This led to the use of snorkelling and SCUBA based dive techniques to do underwater visual surveys. Method includes the broad-scale insights offered by the Manta Tow and Timed Swim techniques to the nuanced observations facilitated by Transects and Quadrats surveys.

Manta Tow Technique: This technique involves pulling a snorkeler behind a boat at a steady pace, pausing periodically to gather data (each dive last approx. 2 minutes). It offers an excellent means of obtaining a comprehensive understanding of vast reef areas or evaluating notable changes in the abundance and distribution of organisms, along with major disturbances such as cyclones, Crown-of-Thorns starfish, and bleaching incidents. It proves highly effective for tracking variables over significant distances and assisting in the selection of strategic sites.

Fig.1. Manta Tow (Photo credit: Australian Institute for Marine Science (AIMS))

Timed Swim Technique: The Timed Swim technique involves a diver swimming for a set time or distance, giving a complete look at the whole site. It helps us understand where things are and what the area's environment is like.

Transect Methodology: Transects offer information on a medium scale. They are lines marked on the reef floor, where divers count benthic organisms. These lines can be tape measures, ropes, or chains of various lengths, with measurements taken at fixed points or where changes occur, like counting chain links or where benthic species change. The choice of length depends on the abundance and spread of what a researcher is monitoring and the variety of the site's features. Various transect survey methods include:

a. Line Transects: In this method, a straight line is established and followed by observers who record all occurrences of the target organisms or features that intersect the line. This technique provides a standardized and efficient way to collect data on biological communities and their spatial patterns.

Fig. 2. Line Transect (Photo Credit: ICAR-CMFRI)

b. Point Intercept Transects: Point Intercept Transects is a method used in ecological surveys to quantify the abundance and distribution of plant species within a specific area. In this method, transects, or linear paths, are established within the study area, and at regular intervals along these transects, observers record the presence or absence of plant species or other ecological features at predetermined points. The data collected can be used to assess species composition, density, and spatial distribution within the habitat under study.

c. Belt Transects: Belt transects are a method used in ecological studies to sample and measure vegetation or other ecological features within a defined area. In a belt transect, a long, narrow strip of land or water is selected for study. Typically, this strip is marked out with parallel lines or markers. Researchers then systematically record data along the length of the transect. This may involve measuring the abundance, distribution, and characteristics of plants or other organisms within the belt, as well as environmental factors such as soil type, slope, or moisture content. Belt transects are often used to provide more detailed information about ecological communities than point-based methods, as they sample a broader area and provide data on vegetation structure and composition along a continuous gradient. Belt transect is facilitated by structures like PVC poles or T-bars.

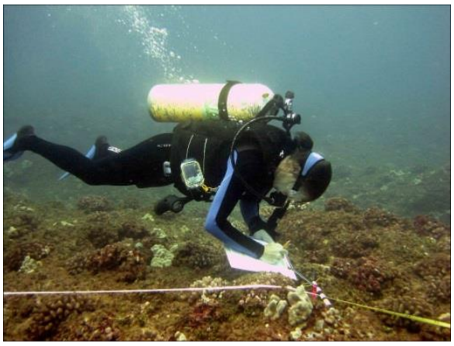

Fig.3. Belt transect survey (photo credit: NOAA)

To demarcate transects, materials such as waterproof fiberglass tape on a spool with a winding handle, marked rope with coloured indicators or knots denoting distance, or plastic chains with links of known length are commonly utilized.

Quadrat Sampling: Quadrat sampling is a widely used technique in ecology for studying and assessing plant communities or other organisms within a defined area. In this method, the study area is divided into smaller, equally sized square or rectangular plots called quadrats. These quadrats serve as sampling units for collecting data on the presence, abundance, and distribution of plants or other organisms within them. Researchers randomly or systematically place quadrats throughout the study area to ensure representative sampling. Within each quadrat, they record various parameters such as the species present, their abundance (e.g., number of individuals), and sometimes additional characteristics like plant height or biomass. Quadrat sampling provides a standardized and efficient way to gather ecological data, allowing researchers to estimate species richness, diversity, and other community-level metrics. It is commonly used in a wide range of ecological studies, including biodiversity assessments, vegetation surveys, and monitoring ecosystem changes over time. Commonly, quadrats of 0.5-1m^2 or larger are employed for assessing species diversity, while smaller 25 cm by 25 cm quadrats are suitable for fine-scale investigations of sessile benthic juvenile recruits and other diminutive organisms. Permanent quadrats serve the purpose of longitudinally observing specific coral colonies.

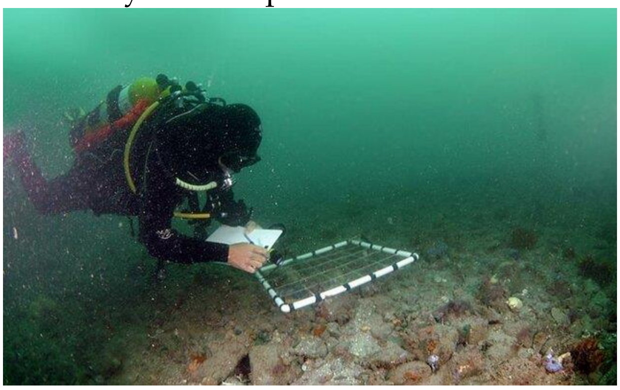

Fig. 4. Quadrat sampling of urchin (Photo credit: James et al., 2016)

Limitations: The major limitations of dive-based methods by humans, are that these surveys are limited to shallow depths. Deeper areas or remote locations may be inaccessible, leading to gaps in data. Poor visibility can hinder the ability of divers to do the survey accurately.

Underwater Videography

Dive-based surveys are limited by the endurance and physical limitations of divers, hence presently many researchers prefer underwater videography as they can maintain consistent sampling effort over time. Utilizing video footage to capture the general reef area offers qualitative insights. For quantitative studies, videos are particularly advantageous for large-scale ecological monitoring using techniques such as belt transects. The width of the belt in video transects is determined by the distance the camera is held from the coral reef benthos. Replicating the exact path, speed, and distance from the substrate for repeated video sampling poses challenges but is essential for maintaining consistency in data collection.

ROV and AUV based surveys

Advances in underwater robotics, including remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs), have opened up new frontiers in marine exploration. ROVs and AUVs can access habitats that may be inaccessible or too dangerous for human divers to reach, making them valuable tools for marine research and conservation. These robotic platforms enable researchers to collect high-resolution data from previously inaccessible depths, allowing for unprecedented insights into deep-sea ecosystems and the organisms that inhabit them.

a. *ROVs (Remotely Operated Vehicle)*: An ROV (Remotely Operated Vehicle) based biodiversity assessment of marine ecosystems involves using unmanned underwater vehicles equipped with cameras and sensors to explore and document the diversity of life in the ocean. The ROV is launched from a research vessel and maneuverer to the designated survey locations. It is controlled remotely by operators on the surface using a tether, which provides power and communication between the ROV and the surface. As the ROV explores the underwater environment, it captures high-resolution video footage and still images using onboard cameras. Additionally, it may collect environmental data such as temperature, salinity, and depth using sensors. The ROV systematically surveys the seafloor, reefs, or other habitats within the study area, recording observations of marine life and habitat characteristics.

Fig.5. ROV Doc Ricketts to study animal communities (photo credit: MBARI)

b. *Autonomous Underwater Vehicles (AUVs)*: AUVs are unmanned underwater vehicles designed to operate autonomously without direct human control. These vehicles are equipped with various sensors, navigation systems, and propulsion mechanisms to navigate underwater environments and perform specific tasks or missions. AUVs use a combination of sensors and navigation systems to determine their position, orientation, and trajectory underwater. This typically includes inertial navigation systems (such as gyroscopes and accelerometers), GPS (Global Positioning System) when near the surface, acoustic positioning systems, and depth sensors. AUVs are outfitted with various sensors to collect data about the underwater environment. These sensors can include cameras, sonars (such as side-scan sonar or multibeam sonar), acoustic sensors for navigation and communication, environmental sensors (for measuring temperature, salinity, pressure, etc.), and instruments for measuring water quality parameters. AUVs are used for a wide range of applications in marine science, oceanography, defence, industry, and environmental monitoring. They can be deployed to study marine biodiversity, map the seafloor, conduct oceanographic surveys, monitor environmental conditions (such as pollution or climate change impacts), search for underwater objects or archaeological sites, and support offshore operations such as oil and gas exploration or pipeline inspection. AUVs are typically deployed from surface vessels or shore-based facilities using launch and recovery systems. Once deployed, they navigate autonomously to their designated survey area, execute their mission, and return to the surface for recovery or data transfer.

Overall, AUVs offer significant advantages for underwater exploration and research by providing a cost-effective, efficient, and versatile platform for collecting data in challenging marine environments. Their autonomy and capability to operate in remote or hazardous areas make them valuable tools for advancing our understanding of the oceans and addressing various marine-related challenges.

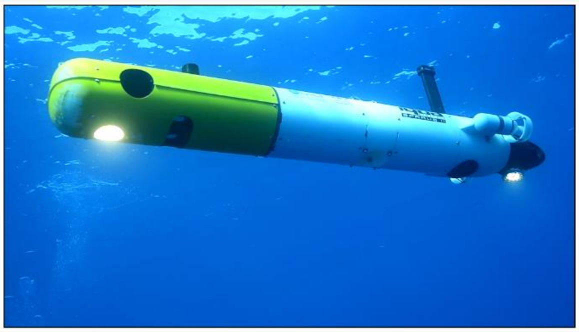

Fig.6. Autonomous Underwater Vehicles (AUVs) (Photo credit: Gutnik et al., 2022)

Limitations: Both ROVs and AUVs are limited in the area they can cover during a single mission. Their usage is restricted by factors such as battery life, operational constraints during sampling. ROVs and AUVs have limited payload capacity for carrying scientific instruments, sensors, and sampling equipment. This can constrain the types and amount of data that can be collected during a single mission. ROVs and AUVs are sophisticated and expensive platforms that require significant investment in equipment, maintenance, and personnel. Cost considerations may limit the frequency and duration of ROV and AUV surveys, constraining their utility for long-term biodiversity monitoring.

Aerial Survey

An aerial survey is a method of data collection in which observations or measurements are made from an aircraft or other aerial platform. These surveys are often used in various fields such as environmental monitoring, wildlife management, land-use planning, and geographic mapping. Aerial surveys can involve visual observations, photography, remote sensing, or other sensing technologies to gather information about the Earth's surface or atmosphere. They are particularly useful for covering large areas quickly and efficiently, providing a broad perspective that may not be possible with ground-based methods. Aerial surveys are commonly employed to assess land cover, monitor wildlife populations, map terrain features, monitor environmental changes, and conduct various research and monitoring activities.

Limitations: Aerial surveys are highly dependent on weather conditions. Adverse weather such as fog, clouds, rain, or high winds can limit visibility and disrupt data collection. Conducting aerial surveys can be expensive and hence limit the frequency and extent of surveys, especially in large or remote areas. Aerial surveys can provide an overview of large areas, they may lack the capability for detailed ground-level observations. Fine-scale features or subtle changes may be difficult to detect from an aerial perspective.

Citizen Science Initiatives

In addition to technological advancements, citizen science initiatives play a crucial role in marine biodiversity assessment and conservation by harnessing the collective efforts of volunteers, enthusiasts, and local communities to contribute valuable data and observations. Citizen scientists can contribute to marine biodiversity assessment by collecting data on marine species, habitats, and environmental conditions. This can include recording observations of marine life during beach walks, snorkeling or diving trips, or from shoreline vantage points. By engaging a large number of volunteers, citizen science initiatives can collect data over large spatial scales and time periods, providing valuable insights into marine biodiversity patterns and trends. Citizen scientists can help monitor the abundance, distribution, and behaviour of marine species, including both common and rare species. This information can contribute to understanding population dynamics, detecting changes in species distributions, and identifying areas of ecological importance or concern. Citizen science initiatives can assist in mapping and monitoring marine habitats such as coral reefs, seagrass beds, and mangrove forests. Citizen scientists can help monitor environmental parameters such as water quality, temperature, salinity, and pollution levels in marine ecosystems. By collecting and analyzing water samples or using simple monitoring tools, volunteers can contribute to ongoing efforts to track environmental changes, identify sources of pollution, and assess the impacts of human activities on marine ecosystems.

Limitations: One of the primary concerns with citizen science data is its quality and reliability. Since volunteers may have varying levels of expertise and training, there is a risk of inconsistencies or inaccuracies in the data collected. Citizen science projects may not always achieve comprehensive spatial or temporal coverage of the study area. Data collection efforts may be concentrated in easily accessible or popular locations, leading to biases in the data and gaps in our understanding of biodiversity patterns.

Identifying species accurately can be challenging, especially for non-experts participating in citizen science projects. Misidentifications or errors in species identification can introduce noise into the data and undermine the reliability of biodiversity assessments.

This chapter has explored the major sampling methods in greater detail, and examined their strengths, limitations, and applications in marine biodiversity monitoring. From the bustling coral reefs of tropical seas to the frigid waters of the polar regions, each ecosystem presents its own unique challenges and opportunities for exploration.

Reference and Suggested Readings

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