BIODIVERSITY
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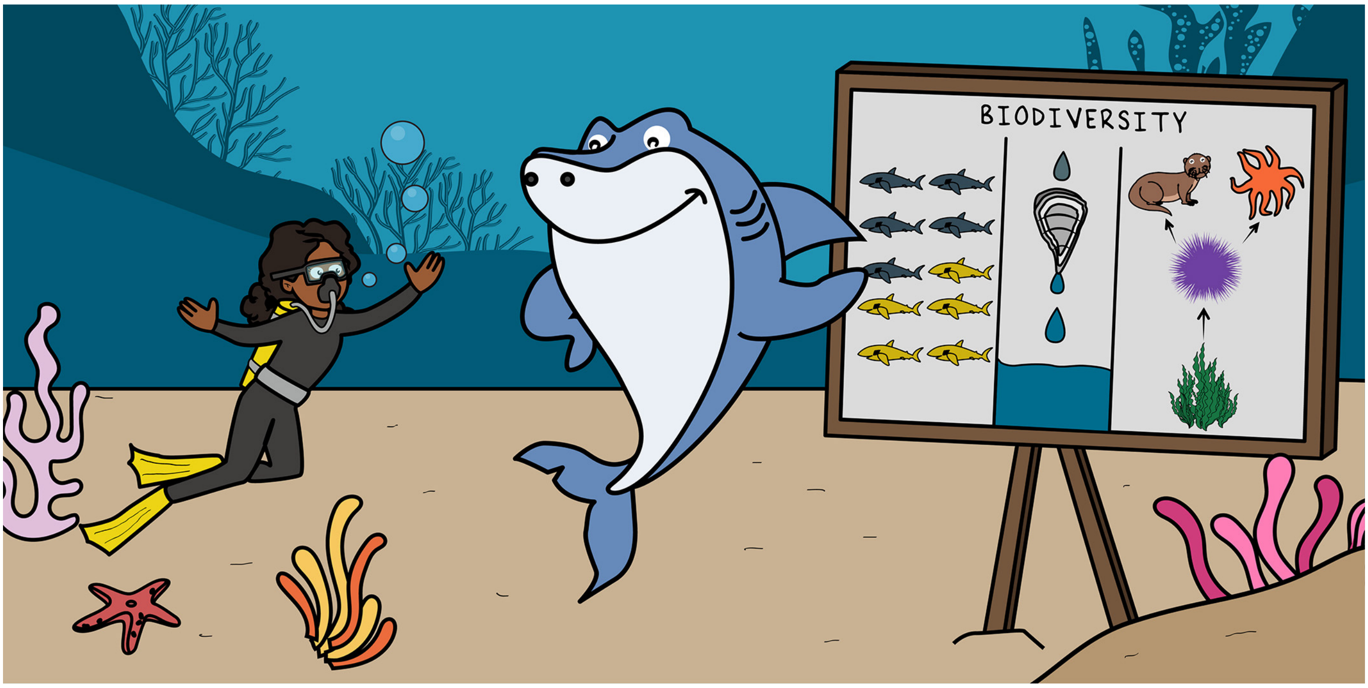

PROTECTING OUR OCEANS: WHY THE DEFINITION OF BIODIVERSITY MATTERS

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Biodiversity is one of the most-used terms in biology, but there are many ways of measuring and interpreting it. Understanding the meaning of the different measures of biodiversity is vitally important for managing and conserving endangered ecosystems. Marine ecosystems are degrading quickly due to human impacts like overfishing, habitat destruction, or climate change. In this article, we introduce and explain three aspects of biodiversity: taxonomic, functional, and food web biodiversity. All three focus on individual species and their roles in ecosystems and food chains. Each aspect of biodiversity is useful in measuring or achieving conservation goals, depending on the type of habitat or environment that is considered. The examples we provide show that finding the best way to protect an ecosystem requires careful consideration of biodiversity from different perspectives, which will remain a challenge for current and future conservationists.

DEFINITIONS ARE IMPORTANT

BIODIVERSITY

The rich variety of life on earth, including animals, plants, fungi, and bacteria.

MARINE MANAGERS

People who are responsible for governing ocean or coastal areas for conservation.

ECOSYSTEM

All the various organisms, such as animals and plants, and the environment they live in.

Biodiversity is one of biology's most used keywords, but its definition can be challenging because it can mean different things in different contexts and to different scientists. There are many ways to think about biodiversity, but traditionally it describes the rich variety of life, including plants and animals. Defining the term biodiversity becomes important when **marine managers** consider how human impacts, such as climate change, pollution, or even deforestation, change ocean species and **ecosystems**, or how to conserve species and ecosystems in the face of human-made challenges. If marine managers want to set achievable conservation targets—for example protecting a coral reef—they need to consider *all* definitions of biodiversity [1]. In this article, we will explain several definitions of biodiversity and discuss how they influence conservation efforts.

PROTECTING MARINE ECOSYSTEMS

Marine ecosystems face serious impacts including overfishing, habitat destruction, pollution, and climate change. These impacts have resulted in the declines or extinctions of many marine species, as well as serious changes to the environments they inhabit. Of the 30,000 marine species the International Union for Conservation of Nature has assessed, one quarter (22%) are listed as critically endangered, endangered, or vulnerable. In marine ecosystems, species interact with each other in many ways, forming complex relationships that are dependent on one another. Changes in biodiversity can affect marine food chains, nutrient cycles, climate regulation, and even storm protection [2].

To deal with these challenges, marine managers have been creating and monitoring marine protected areas. These Marine Protected Areas (MPAs) can help to reverse biodiversity declines and help to boost ecosystem health. Properly managing a protected area depends on finding the most useful definition of biodiversity, given the conservation or monitoring goals. There are three broad ways of thinking about biodiversity: a species-focussed approach, which looks at the number of animals, a functional approach, which accounts for the roles species play in ecosystems, and a food-web approach, which considers predator-prey relationships. Each way of thinking about biodiversity has strengths and weaknesses.

TAXONOMIC BIODIVERSITY

Focusses on individual species of animals or plants, or the total number of species in an ecosystem. This is a classic way of considering biodiversity.

A SPECIES APPROACH: TAXONOMIC BIODIVERSITY

Defining biodiversity by the individual species present in an ecosystem—all life forms, from the smallest viruses to the largest mammals—is called **taxonomic biodiversity**. If we measure taxonomic biodiversity, we describe individual species of animals or plants, the total number of species present in an environment, or how a single species changes between areas or over time. For example, a desert has low taxonomic biodiversity, because it contains very few species. In contrast, a coral reef can contain thousands of different animal and plant species, and thus has high taxonomic biodiversity. Taxonomic biodiversity is the most traditional way of thinking about biodiversity.

For example, marine managers have recently created areas in the open ocean that are closed to fishing. Some of these protected areas are larger than France! However, there are still questions about how species living in these areas benefit, especially the species that migrate large distances, such as turtles, marine mammals, or sharks. Gray reef sharks are a small species of shark that has been declining in numbers. Scientists can study these sharks by tagging them and then following their movements over time. This allows researchers to figure out whether the sharks stay within a protected area or if they must redraw the protected area's boundaries to better protect the species [3]. The shark example is a biodiversity approach that considers just a single species. Alternatively, scientists can consider whether protecting an area has results in changes to a wide variety of species. Increases in the numbers or abundance of species can provide researchers with evidence that a marine protected area is successful at protecting the biodiversity that it harbors.

ROLES IN AN ECOSYSTEM: FUNCTIONAL BIODIVERSITY

Functional biodiversity focuses on the roles or functions organisms have in an ecosystem and how these roles affect the way the ecosystem works. For example, imagine two rocky shore communities. In the first one, you might find three different species of barnacles. In the second community, you find one species of barnacle, a starfish, and an anemone. While both communities have the same number of species, the second community has species that are functionally quite different. The second community has higher functional biodiversity.

FUNCTIONAL BIODIVERSITY

Investigates the various roles or functions species can have in an ecosystem.

In general, a greater number of species allows an ecosystem to recover from disturbances, like coral bleaching or pollution, faster. This is often because of the roles or functions species have within the ecosystem. Functional diversity helps marine managers understand how the species in an ecosystem affect that ecosystem's ability to resist and recover from disturbances.

We can measure functional diversity by looking at the characteristics, or **functional traits**, of a species. These might be differences in body shape, body size, diet, or behavior. Studying functional biodiversity helps scientists understand the role a species plays in the environment and helps them to measure whether multiple species do the same

FUNCTIONAL TRAIT

A specific characteristic of an animal or plant, like its size or its shape. A functional trait impacts the role the animal or plant plays in its ecosystem.

thing in a community or whether a species is unique in its function. From a conservation perspective, marine managers want to ensure that an ecosystem has many species with different functions, as well as species that are performing similar functions. This way, if one species is lost, another will still perform the function, and this helps to ensure that the ecosystem can continue to function properly.

For example, the functionally important species in the Baltic Sea are algae, blue mussels, and seagrass (Figure 1). These species carry out a range of roles and are found on shallow, rocky, underwater islands or near sandy shores (Figure 1). These functionally important species provide important habitats for other species, form the basis of the food chain, and are often nursery grounds for fish. Conservation planning should therefore focus on these three critical species, since they support other species. Depending on where those species occur, marine managers can expand or redraw conservation maps to protect them. Therefore, functional diversity links species within ecosystems and helps us understand their roles and how we can best protect them [4].

Figure 1

Figure 1

Seagrasses are functionally important species because they provide habitats, food, and nursery grounds for many marine species. Because of its important function within the ecosystem, seagrass considered a key species that needs to be included when protected areas are planned. This figure shows a fan mussel found in a Mediterranean seagrass meadow. Fan mussels filter seawater to feed on small particles in the water [image credit: Arnaud Abadie (CC BY 2.0)].

WHO EATS WHOM: FOOD WEB BIODIVERSITY

Food web biodiversity focuses on how animals and plants interact with each other through feeding relationships. For example, if food web biodiversity is high, then a predator, such as a gray seal, can feed on many different species of fish (its prey). If one fish species decreases in number, gray seals can feed on a range of other fish species and continue to thrive. To understand food web biodiversity, we need to understand how many species exist in each part of a food chain, and who eats whom. This information can help us understand how extinctions of one species might affect the whole ecosystem.

FOOD WEB BIODIVERSITY

Focusses on how animals and plants interact through predator-prey relationships. Food web diversity considers food chains and food webs.

In marine kelp forests, for example, large kelp needs nutrients and light to grow. Kelp are the main food source for purple sea urchins, which in turn are important in the diets of larger predators, such as sunflower starfish or sea otters. Sea otters were hunted in the nineteenth century, which caused purple sea urchin numbers to explode, as predators did not feed on them. In turn, the urchins decimated kelp forests and transformed the ecosystem to bare rock (Figure 2). More recently, researchers found that when numbers of sunflower starfish, another urchin predator, decreased, sea urchin numbers increased and decimated kelp forests again. When protected areas allow predators such as sea otters or starfish to become more numerous, these predators suppress the number of urchins, preventing the destruction of kelp forests [5].

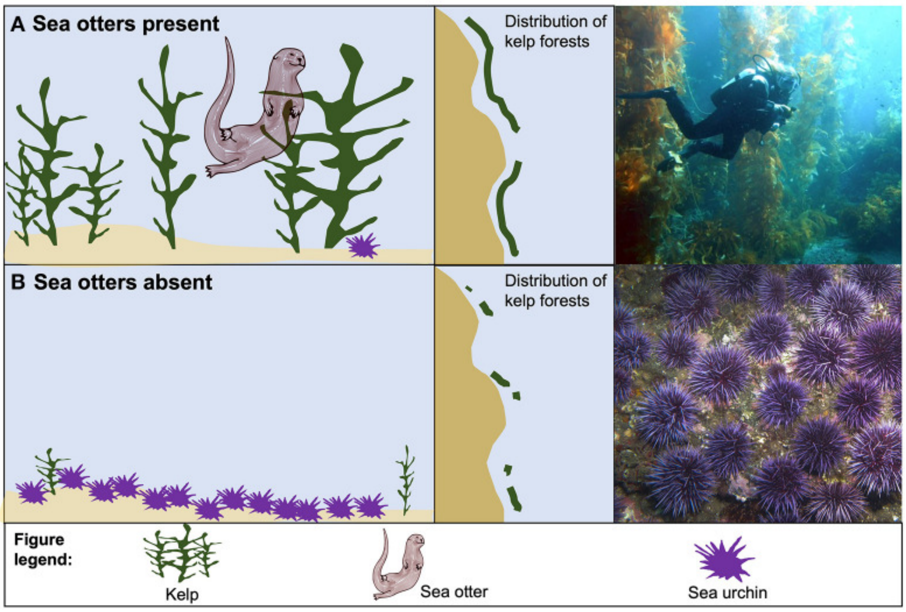

Figure 2

Figure 2

(A) When top predators (such as sea otters or starfish) are present, they keep purple urchin numbers under control by eating them, allowing kelp forests to grow. The picture of the diver shows how large these kelp forests can grow. Kelp forests can provide many other animals with shelter and food. **(B)** If sea urchins are not eaten, they can increase in numbers and destroy kelp forests by grazing. This makes kelp forests much smaller or even completely destroys them, impacting the whole ecosystem [figure credits: Eric T. Gunther (CC BY-SA 3.0) and Ed Bierman (CC BY 2.0)].

This is just one example highlighting why food web biodiversity can help scientists better understand how species change over time. Conserving or restoring food web structure and food web biodiversity can have very large and positive management impacts.

CONCLUSION

There is no one right way to measure biodiversity in the marine environment. Instead, the definition of biodiversity depends on the specific area or the conservation target. Are managers looking to conserve a specific species, or to increase the total number of species? If so, then perhaps the taxonomic concept of biodiversity is best. Alternatively, researchers might choose to conserve an area based on the functional traits of species that are found there. If there are species that provide food and shelter for many other species, the functional approach might be the best. Finally, if we understand how species interact, and which species are the most important in an area's food chains, managers might consider the food web approach to conserving biodiversity to be most useful. Finding the best management approach is not easy—it means scientists need to consider the best definition for biodiversity in any specific scenario. Such choices will continue challenging marine managers now and in the future, as they seek to protect ocean environments and the species that depend on them.

POSITION IN CURRENT LITERATURE

There is no one definition for the term biodiversity. However, if we want to achieve conservation goals or make sure we use the best possible species survey, we need to be clear how to define and interpret it. This paper introduces the classical definition of biodiversity as well as the advantage of considering other concepts. By focusing on marine conservation, we are giving examples of studies in which the different concepts have been applied recently. In the past, the success of a marine conservation project was measured by investigating changes in the number of species or the abundance of a specific species (the taxonomic approach). More recently, scientists and marine managers have considered a more comprehensive measurement of biodiversity: according to a communities' functional and food web biodiversity. Recent examples of these measures of biodiversity are given. In viewing biodiversity as more than just species, these ideas relating to the function and food chains serve as a starting point for understanding how ecosystems work, and how changes in them affect the services humans benefit from. This allows us to implement more successful conservation strategies that are designed for a specific habitat or ecosystem.

REFERENCES

1. Cochrane, S. K. J., Andersen, J. H., Berg, T., Blanchet, H., Borja, A., Carstensen, J., et al. 2016. What is marine biodiversity? towards common concepts and their implications for assessing biodiversity status. *Front. Mar. Sci.* 3:248. doi: 10.3389/fmars.2016.00248
2. Halpern, B. S., Selkoe, K. Y. A., Micheli, F., and Kappel, C. V. 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. *Conserv. Biol.* 21:1301–15. doi: 10.1111/j.1523-1739.2007.00752.x
3. White, T. D., Carlisle, A. B., Kroodsma, D. A., Block, B. A., Casagrandi, R., Leo, G. A. D., et al. 2017. Assessing the effectiveness of a large marine protected area for reef shark conservation. *Biol. Conserv.* 207:64–71. doi: 10.1016/j.biocon.2017.01.009
4. Virtanen, E. A., Viitasalo, M., Lappalainen, J., and Moilanen, A. 2018. Evaluation, gap analysis, and potential expansion of the Finnish marine protected area network. *Front. Mar. Sci.* 5:402. doi: 10.3389/fmars.2018.00402
5. Eisaguirre, J. H., Eisaguirre, J. M., Davis, K., Carlson, P. M., Gaines, S. D., and Caselle, J. E. 2020. Trophic redundancy and predator size class structure drive

differences in kelp forest ecosystem dynamics. *Ecology.* 101:e02993. doi: 10.1002/ecy.2993

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As the inaugural sixth grade class of Somerset Academy Prep we are excited to learn about all things science. Living in South Florida has really influenced our love for marine biology and the biodiversity in our ecosystems. Participating in different STEM activities is our JAM! We love to work as a team and inquire about the world around us. We feel lucky to collaborate together to review this article and hope to participate in more in the future.

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Lydia is an ecologist trying to understand the rules that make ecosystems work. In her work, she investigates how human disturbances, such as climate change, invasive species, or pollution, affect ecosystems and the species in them. To answer these questions, Lydia analyses observations and conducts experiments in different habitats, including coral reefs, mudflats, saltmarshes, and, more recently, microbial communities. *lydia.bach@gla.ac.uk

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