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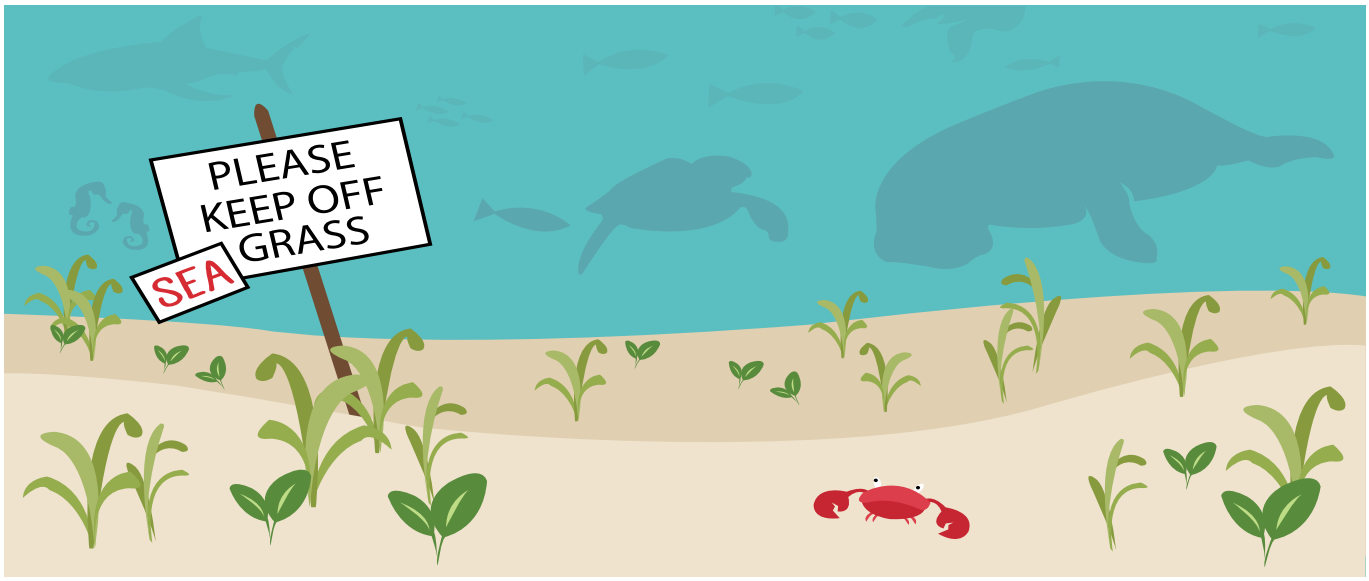

SECRET GARDENS UNDER THE SEA: WHAT ARE SEAGRASS MEADOWS AND WHY ARE THEY IMPORTANT?

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In nearly all the seas around the world, in the shallow waters next to the land, are secret underwater gardens. These gardens are home to a special marine (saltwater) plant called seagrass. When seagrass grows in large areas, the habitat it creates is called a seagrass meadow. Seagrass meadows play an important role in keeping our oceans healthy and providing a home for all kinds of marine life. This marine life includes fishes that people eat, such as cod and plaice but also endangered species such as seahorses, turtles, and sea cows. Seagrasses absorb large amounts of carbon dioxide from the surrounding seawater, and so help to reduce the speed of climate change. Seagrasses help protect our coastlines from storms and rising tides because their leaves take energy out of the waves hitting the coast, and their roots act as an anchor in the underwater sand. Seagrasses also soak up nutrients and bacteria, helping to keep our seawater clean. But seagrasses around the world are being lost at a rate of about two football fields every hour. Lots of things can damage seagrass, from polluted water

to boats dragging their anchors in seagrass meadows. Overfishing is a problem, since it causes an imbalance in the food chain. Unfortunately, seagrass does not get the attention it deserves because most people are unaware of its existence. We need to increase awareness of the importance of this beautiful and valuable habitat and get more people involved in monitoring and protecting seagrass, before it is too late.

WHAT ARE SEAGRASSES?

Seagrasses are flowering plants (also known as *angiosperms*) that have adapted, over millions of years, to life underwater in the sea (Figure 1). Seagrasses only flower for a short time each year and, like many land plants, flowering is linked to the seasons. Unlike land plants that have oxygen available from the soil around their roots, in the waterlogged sediments (the underwater sand or mud that seagrass grows in) on the seafloor there is very little oxygen available, so instead seagrass exchanges oxygen and **carbon dioxide** through its thin leaves. The roots of the seagrass act as an anchor in the sediment.

CARBON DIOXIDE (CO_2)

Carbon dioxide (CO_2) is one of the gasses contributing to climate change through a warming of our atmosphere. We need to reduce the amount of CO_2 in our atmosphere to help slow the rate at which our climate is changing (to slow global warming).

While they may look similar, seagrasses are very different from seaweeds, which are a type of organism known as algae, not a flowering plant. Seagrasses are part of a group of plants called monocotyledons. This group of plants also includes the grasses that grow on land, lilies (seagrasses' closest relative), and palms. Seagrasses have roots, veins, and leaves. Seagrasses, like other plants, have special food producers inside their cells, called chloroplasts. Chloroplasts use energy from the sun to convert carbon dioxide and water into sugar and oxygen for growth, through the process called photosynthesis. Veins inside the seagrass tissue then transport the sugar and oxygen around the plant. The veins also contain air pockets, called lacunae, that

FIGURE 1

A seagrass called *Zostera marina* (also commonly known as eelgrass) is present all along the coast of many areas of the northern hemisphere of the earth, for example, from North America to Europe (Picture: Pen-Y-Chain, North Wales, United Kingdom; source: Benjamin Jones).

help keep the seagrass leaves floating in the water (Figure 2). Seagrasses have roots and rhizomes (thicker stems), which extend into the sediment below the leaves. The roots and rhizomes absorb and store nutrients, and help to anchor the seagrass plants (and sediment) in place. Seaweeds, however, are much less complex than seagrasses, with no flowers or veins. While seaweeds have root-like tissues called holdfasts, which anchor the seaweed to rocks, holdfasts are not specialized to absorb nutrients the way that the roots of seagrasses are.

Because the environmental conditions (such as the temperature and the amount of sunlight) in a habitat change with the seasons and with the location of the habitat on the earth's surface, there are many different varieties of living organisms (species) that are adapted to living in different habitats. This is true for seagrasses, too. Different **species**' of seagrass have different shapes and sizes, with some species looking like paddles or tree leaves (*Halophila* species), and others looking more like traditional grass (*Zostera* species). Some even look like spaghetti (*Syringodium* species). All of the seagrass species have adapted to live in a range of different conditions. There are around 72 species of seagrass grouped into four families—Posidoniaceae, Zosteraceae, Hydrocharitaceae, and Cymodoceaceae. The species within each family are more closely related to each other than they are to seagrass species from a different family.

SPECIES

Group of individuals that actually or potentially interbreed (produce offspring) in nature.

In many places, seagrass plants cover large areas of the seafloor. These areas are called seagrass beds or seagrass meadows. Seagrass meadows are typically found in shallow, sheltered locations. These meadows look much like

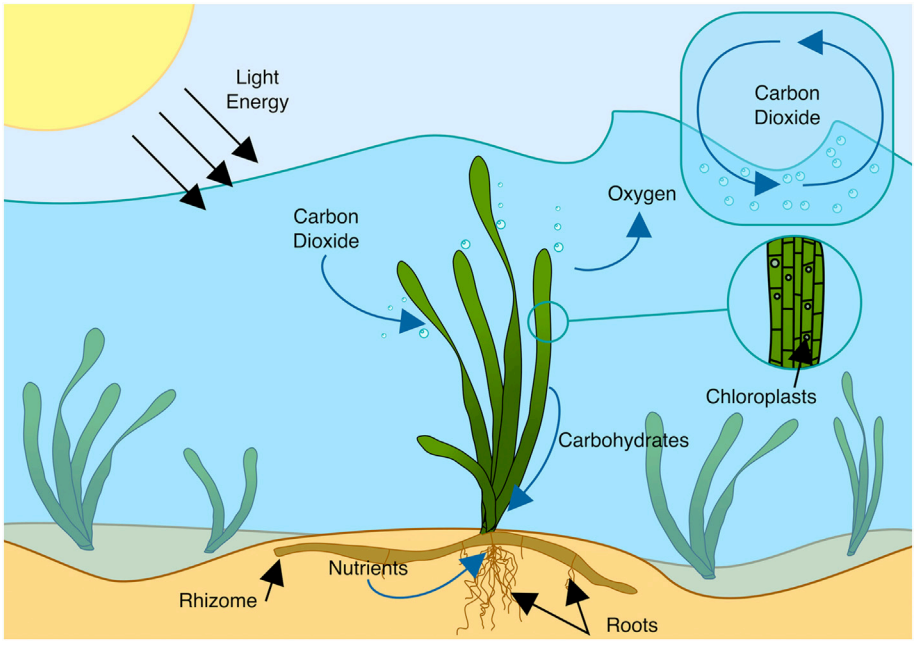

FIGURE 2

FIGURE 2

Carbon uptake and photosynthesis in a seagrass meadow. Special cells within the seagrass, called chloroplasts, use energy from the sun to convert carbon dioxide and water into carbohydrates (or sugar) and oxygen through photosynthesis. Seagrass roots and rhizomes absorb and store nutrients and help to anchor the seagrass plants in place.

the grasslands and meadows that you see on the land. Much like African savannas, these seagrass meadows are great places for animals to hunt and hide. For this reason, seagrass meadows are often referred to as the "prairies of the sea." Fish visit seagrass meadows to hunt or to hide in between the seagrass leaves. Where seagrass meadows are exposed to the air at low tide (called intertidal seagrass), you can find lots of invertebrate animals (animals without backbones) such as shellfish, crabs, and urchins, grazing or hiding between the leaves or in the sediment underneath (Figure 3). Seagrass meadows range in size and density from small patches of 1 m^2 to large, continuous meadows covering tens of thousands of hectares (1 ha is 10,000 m^2 or about the same size as an international rugby field). The largest recorded seagrass meadow covers 4,500 km^2—enough to fill nearly 414,000 rugby fields. Meadows can be monospecific, which means they contain just one seagrass species, or they may contain multispecies communities, with up to 12 seagrass species present.

Just like flowering plants on land, seagrasses have flowers, fruits, and seeds. Without insects and the wind, pollination and movement of seeds is helped by marine animals and water movements (currents). Small animals called crustaceans (known as amphipods, which are similar to very small shrimps) have been described as the "bees of the sea," because they pollinate seagrass flowers just like bees do for land plants.

WHERE DO SEAGRASSES LIVE?

Seagrasses are found all over the world, in both hot and cold locations. Seagrasses live in shallow seas on the continental shelf of all continents except Antarctica (Figure 4). The continental shelf is the underwater area of land surrounding each continent, creating an area of relatively shallow water known as a shelf sea. It is believed that seagrasses cover 125,000 km^2 around the world, but other estimates suggest that this number might be a lot bigger—seagrasses may cover up to 600,000 km^2 of the shallow ocean.

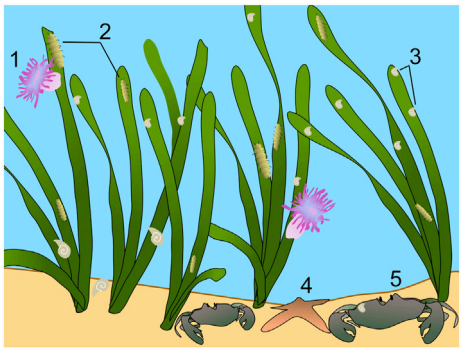

FIGURE 3

FIGURE 3

Some of the invertebrate life supported by seagrass meadows: (1) anemone anchored to the seagrass to feed; (2) isopod (small crustacean); (3) gastropod (sea snail) grazing along the seagrass leaves; (4) starfish sheltering between the leaves of the seagrass; and (5) crab (large crustacean) hunting for food in between the seagrass leaves.

FIGURE 4

Global distribution of seagrass meadows (seagrass locations shown by green dots).

FIGURE 4

Seagrass meadows are found in areas with soft sediment that are either intertidal (uncovered daily by seawater, as the tide goes in and out) or subtidal (always under the water). Seagrasses prefer sheltered places, such as shallow bays, lagoons, and estuaries (sheltered areas where rivers flow in to the sea), where waves are limited and light and nutrient levels are high. Seagrasses can be found up to around 60 m deep, but this depends on the availability of light because, like plants on the land, seagrass meadows need sunlight for photosynthesis to occur. Tides, wave action, water clarity, and low salinity (low amounts of salt in the water) control where seagrasses can live at their shallow edge nearest the shore [1], all of these things must be just right for seagrass to survive and grow.

SEAGRASSES ARE ECOLOGICAL ENGINEERS

Seagrasses are known as *ecological engineers*, which means they can change the conditions around them to suit their own needs. They do this by using their strong roots and long leaves to calm the water, reducing nutrient levels to prevent algal overgrowth and removing sediment floating in the water to provide clear water allowing the sun to reach the seagrass. All these things improve conditions for seagrass growth. The bigger and denser the seagrass meadow, the greater the ability of the meadow to create what are known as positive feedbacks, which lead to conditions that help seagrasses grow.

WHY IS SEAGRASS IMPORTANT?

Seagrass supports thousands of marine animals. For example, it provides a home or feeding area for more than 1,000 species of fish, including fishes that humans eat, such as cod and herring, as well as larger endangered

species such as turtles, seahorses, dugongs, and manatees (sea cows). Seagrass meadows also support coral reefs and other habitats for fish, by providing food or a place for baby fish to live. Seagrasses are known as primary producers because they make their own food though photosynthesis, they can then be eaten by animals and so they have an important role in the food web. Seagrass holds underwater soil (known as sediment) together, which helps to protect the coasts from the impacts of storms and large waves, by preventing coastal erosion.

Seagrass meadows also play an important role in the fight against rapid climate change, because seagrasses take up carbon dioxide that is dissolved in seawater, like other plants take it up from the air. The carbon dioxide is used to build the plant's tissues or is stored in the sediment. Estimates suggest that seagrass meadows can bury carbon in underwater sediments 40 times faster than tropical forests bury it in soil, and seagrasses provide one of the greatest contributions to the total carbon buried in ocean sediments [2]. The removal of carbon dioxide from the water helps to keep the **pH** of the water stable. A stable pH might protect animals that have shells or external skeletons, such as corals and mollusks (clams, oysters, and their relatives) from the effects of low pH in seawater, which is known as ocean acidification.

pH

We use the measure of pH to investigate how acidic or basic a liquid is on a scale of 0–14. The lower the pH, the more acidic the liquid is. Seawater usually has a pH of around 8.

All of the ways in which seagrass helps humans are called ecosystem services, and these ecosystem services make seagrass one of the most important marine ecosystems for human well-being.

SEAGRASS, BIODIVERSITY, AND FOOD SECURITY

Worldwide, fish from the ocean provide a source of protein for millions of people. A large percentage (in some countries more than 60%) of the animal protein eaten by humans comes from the sea. Coastal fishing areas provide food and income for more than one billion people. But the majority of the world's fishing areas are overfished and at risk of collapse. Seagrasses provide fish with shelter from predators and a plentiful food supply, and seagrass meadows have high biodiversity, meaning that a large collection of different types of plants and animals live there. As a result, we now know that seagrass meadows are great places for people to catch fish and collect other types of seafood. Research from across the Indo-Pacific region, including Indonesia and the Philippines, has demonstrated the important role of seagrass meadows in producing fish and edible invertebrates for food [3]. For example, at low tide, exposed seagrass meadows in the tropics provide people with an easy-to-reach hunting ground for small fish and edible invertebrates. At other times, traps and nets can be used to catch fish that migrate in and out of seagrass. In cooler regions, seagrass is also an important habitat for food fish. The Atlantic cod (*Gadus morhua*), which is

the world's third most caught fish species, uses seagrass as a nursery ground. Young cod grow faster and have higher chances of reaching adulthood when they live in seagrass meadows [4].

The supply of seafood from seagrass is fairly reliable and so it provides a sense of *food security* for people. Food security is the ability of the earth to provide healthy and sustainable diets for its people. Food security is important because, as the human population continues to increase, there will be increased demand for food and competition for resources. This could threaten food security as well as biodiversity.

In tropical regions such as the Indo-Pacific, habitats such as coral reefs are expected to decline due to rising sea temperatures, ocean acidification, and pollution. But tropical seagrass meadows have some characteristics that might make them less vulnerable to global climate change than other marine habitats. This means that seagrass may have a better chance of providing a reliable source of seafood for people in the future, but only if other threats to seagrasses can be minimized. The protection of seagrass meadows could provide a long-term strategy to maintain biodiversity and food security.

SEAGRASS IS AT RISK

Despite their importance, seagrass meadows around the world are being lost at a rate of around 7% each year, or an area equal to two football fields every hour [5]. Seagrass loss is often linked to coastal development (where new buildings are constructed along the coast), pollution of rivers and other water bodies that flow into the sea, and the removal of too many marine animals (overfishing). As human populations grow, our impact on the environment increases. Poor water quality (particularly high levels of nutrients) caused by pollution is the biggest threat to seagrasses around the world. Water quality problems are particularly serious in countries that are growing rapidly, but where there are not many laws to regulate pollution or for seagrass protection. Boating, trampling, ports, dredging, and any activity that physically damages seagrass or alters the conditions around seagrass meadows can put pressure on seagrass systems. Small-scale threats to seagrass, such as damage done by boat anchors, can make it harder for seagrass meadows to cope with climate change, ocean acidification, and sea-level rise. Since scientific evidence of the value of seagrass meadows is growing, it is obvious that we need to improve seagrass protection around the world. But we do not know as much about seagrass as we do about other marine and land-based habitats, so we need to keep learning about how seagrass responds to change and how we can best protect and restore it (bring it back to areas where it has been lost). We also need to teach more people about the importance of seagrass to get more support for its protection.

WHAT IS THE FUTURE OUTLOOK FOR SEAGRASS MEADOWS?

The role of seagrass meadows in maintaining the health of our oceans is clear, but these sensitive habitats are declining [5]. Action is required to stop the loss of the world's seagrass meadows and to provide protection to keep up all of the services that seagrass meadows provide to people and our oceans.

Reducing local stress on seagrass will support its ability to stand up to the impacts of larger-scale, longer-term stress, like climate change. This means we need to work to improve local water quality, prevent damage to seagrass meadows, create protected areas of seagrass, reduce overfishing, and reduce stress from coastal development [6]. Protecting seagrass will protect the biodiversity found within the meadows, will help fight climate change, and will provide food security for humans. Bold steps are required to protect as well as restore these habitats, but lots of people taking small steps to protect seagrasses can work toward a brighter future for these secret undersea gardens.

WHERE CAN I FIND OUT MORE?

Project Seagrass: International seagrass conservation charity: www.projectseagrass.org.
SeagrassWatch: International seagrass monitoring network: www.seagrasswatch.org.
World Seagrass Association: International association of scientists and conservationists interested in seagrass conservation and biology: wsa.seagrassonline.org.

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AINHOA, AGE: 11

Hello, my name is Ainhoa and I am 11 years old. I live in Madrid but I have also lived in Japan, USA, and Italy. I have a little brother named Aimar. I love all kinds of dance but I do rhythmic gymnastics. I also love drawing.

BLANCA, AGE: 10

Hello, my name is Blanca and I live in Madrid. I have a dog called Freddy and I love to play with him. I like chocolate and reading. Blue has been my favorite color for as long as I can remember.

AUTHORS

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Leanne Claire Cullen-Unsworth is a marine scientist who loves seagrass. Her research focuses on the benefits that people receive from the marine environment, including the supply of seafood. She currently leads an international project investigating reasons for the loss of seagrass meadows in Southeast Asia. In her role as codirector of Project Seagrass

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BENJAMIN LAWRENCE JONES

Benjamin Lawrence Jones is an ocean scientist and spends most of his time in, on or near the sea. He works at Cardiff University (UK) and is also a founding director of the marine conservation charity Project Seagrass. He studies how seagrass meadows are affected by the actions of humans and also how members of the public can help save these underwater gardens using technology like phone apps. He is also interested in the marine life that live in seagrass meadows.

RICHARD LILLEY

Richard Lilley loves the sea and spends as much time as he can playing and diving in the water. He lives in Edinburgh and is also a founding director of the marine conservation charity Project Seagrass. He spends his time researching what seafood different people like to eat, and then finds out where those fish people like to eat live. Often, it is in the seagrass! For this reason he wants to protect seagrass meadows so we can all enjoy seafood in the future too!

RICHARD K. F. UNSWORTH

Richard K. F. Unsworth is an ocean loving scientist who studies all things seagrass and fish related in our coastal seas. He is based at Swansea University (UK) and is also a founding director of the marine conservation charity Project Seagrass. His research focuses on trying to understand how coastal habitats such as seagrasses and other coastal habitats are important for people and how they can be protected into the future.