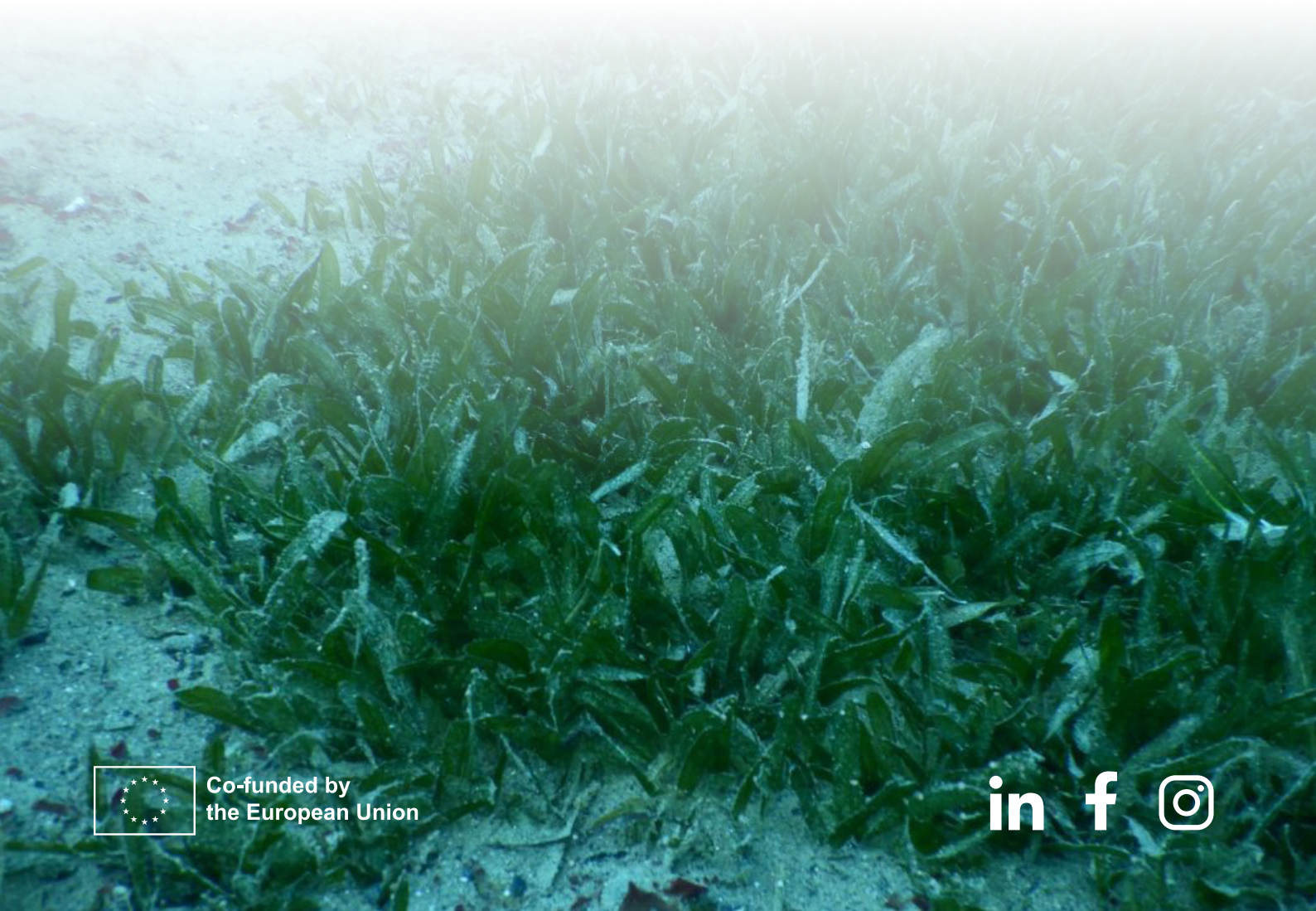
SEAQUEST

EDUCATIONAL ACTIVITIES GUIDE

FOR TEACHERS

EDITED BY
THEODOROS KEVREKIDIS
PARASKEVI MALEA



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THESSALONIKI, GREECE 2026

COVER PHOTO

Halophila stipulacea meadow in the Pagasetic Gulf, Northern Aegean Sea, Greece
(photo credit Christos Zoumbos/Theodoros Kevrekidis)

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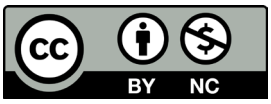

SEAQUEST EDUCATIONAL ACTIVITIES GUIDE FOR TEACHERS

ERASMUS+
EU PROGRAMME FOR EDUCATION, TRAINING, YOUTH AND SPORT

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SEAQUEST: SEAGRASS EDUCATION FOR CHILDREN TOWARDS AWARENESS QUOTIENT FOR ENVIRONMENTAL SUSTAINABILITY

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SEAQUEST

Erasmus+

CONSORTIUM OF THE PROJECT

The Project involves Universities, Research Institutes and Non – Governmental Organizations from five European Union countries – Greece, Portugal, Denmark, Belgium and Cyprus

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PREFACE

SEAQUEST is an Erasmus+ project that aims to raise awareness of the value, vulnerability, and necessity of preserving seagrasses. Seagrasses are flowering plants that grow submerged and rooted in marine and estuarine environments worldwide. Seagrasses form extensive underwater meadows, which provide multiple functions and ecosystem services that are valuable to the environment and to people. However, a full appreciation of the ecological and socio-economic importance of seagrasses has not been reached yet. In addition, a global trend of seagrass loss has been well documented, mainly because of human development and activity. Therefore, raising public awareness of seagrasses is crucial for the sustainability of these critical marine ecosystems. To this end, the key principles and concepts in relation to seagrasses that a seagrass-literate person should know have been developed (*Apostoloumi, C., Malea, P., Kevrekidis, T., 2021. Marine Pollution Bulletin, 173, 112936*).

SEAQUEST particularly aims to promote seagrass literacy in primary education across Europe, through research, educational tools, teacher training, tech-based learning through an interactive game, and community engagement. The *SEAQUEST Educational Toolkit* consists of the *SEAQUEST Curriculum for Teachers* and

the *SEAQUEST Educational Activities Guide for Teachers* to effectively introduce seagrass literacy in primary schools, combined with a digital interactive game.

To support teachers in enhancing seagrass literacy, the present guide, the SEAQUEST Educational Activities Guide for Teachers, includes the appropriate Pedagogical Framework and Teacher Guidance, and a series of Lesson Plans. The Lesson Plans are divided into seven Thematic Modules. The first Thematic Module corresponds to the fifth Essential Principle of Ocean Literacy (*The ocean supports a great diversity of life and ecosystems;* NOAA, 2013. Ocean literacy: the essential principles and fundamental concepts of Ocean Sciences for learners of all ages http://oceanliteracy.wp2.coexploration.org/?page_id=164), while each of the remaining Thematic Modules corresponds to one of the essential Principles about Seagrasses (1. *Seagrasses are unique plants, 2. Seagrasses form extensive underwater meadows, 3. Seagrasses support a great diversity of life, 4. Seagrasses stabilize the seabed, improve water quality and store carbon, 5. Seagrasses and humans are inextricably interconnected, and 6. Seagrasses are largely unexplored*; Apostoloumi, C., Malea, P., Kevrekidis, T., 2021. Marine Pollution Bulletin, 173, 112936). Following the structure and pedagogical approach of the presented lesson plans, teachers can also develop additional awareness-raising and action-oriented lesson plans inspired by the activities and themes presented in the SEAQUEST Curriculum for Teachers.

We wish to thank all SEAQUEST project partners for their contribution to the development of the present Educational Activities Guide. We would like to express our gratitude to all authors who have contributed to the writing of the Guide sections. We also thank Adria Fessa for the artwork and layout, and those who contributed photographs and drawings to this Guide.

Considering that, due to the wide variety of topics and the attempt to simplify concepts, some errors and omissions undoubtedly remain in this book, any comments and suggestions that could improve it are welcome.

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CONTENTS

INTRODUCTION 13
Theodora Boubonari

A. PEDAGOGICAL FRAMEWORK AND TEACHER GUIDANCE 15
Theodora Boubonari

A1. **Aim and Objectives** 16

A2. **Pedagogical Approaches** 19

A3. **Competencies** 22

A4. **Assessment Strategies and Tools** 25

A5. **Guide For Teachers: How To Use The Seagrass Lesson Plans** 27

A6. **Further Reading** 31

B. LESSON PLANS 32

B1. **THEMATIC MODULE 1:**
The ocean supports a great diversity of life and ecosystems
Dominika Wojcieszek

LESSON PLAN 1.
Diversity of Life in the Ocean - Plankton 34

LESSON PLAN 2.
Diversity of Life in the Ocean - Benthos 41

LESSON PLAN 3.
Diversity of Life in the Ocean - Nekton 48

LESSON PLAN 4.
Diversity of Life in the Ocean 55

LESSON PLAN 5.
Diversity of Ecosystems in the Ocean 62

B2. **THEMATIC MODULE 2:**
Seagrasses are unique plants
Theodora Boubonari, Paraskevi Malea & Theodoros Kevrekidis

LESSON PLAN 1.
Seagrass morphology 71

LESSON PLAN 2.
Seagrasses vs. Macroalgae 78

LESSON PLAN 3.
Seagrass taxonomy & species identification 91

LESSON PLAN 4.
World seagrass distribution 105

B3 **THEMATIC MODULE 3:**
Seagrasses form extensive underwater meadows
Theodora Boubonari, Paraskevi Malea & Theodoros Kevrekidis

LESSON PLAN 1.
Habitat requirements of seagrasses- Environmental factors 116

LESSON PLAN 2.
Seagrass meadows 128

LESSON PLAN 3.
Seagrass meadows in Europe's coastal waters 139

LESSON PLANS 4, 5 & 6.
Seagrass field sampling 152

LESSON PLANS 7, 8 & 9.
Seagrass laboratory processing & analysis 160

LESSON PLANS 10, 11 & 12.
Posidonia oceanica laboratory study 172

B4 **THEMATIC MODULE 4:**
Seagrasses support a great diversity of life
Ana Alexandre

LESSON PLAN 1.
Seagrasses are important primary producers 190

LESSON PLAN 2.
Seagrasses provide food for other organisms 195

LESSON PLAN 3.
Seagrasses provide habitat for other organisms 200

LESSON PLAN 4.
Trophic interactions with other marine ecosystems 205

B5 **THEMATIC MODULE 5:**
Seagrasses stabilize the seabed, improve water quality and store carbon
Ana Alexandre

LESSON PLAN 1.
Seagrass meadows stabilize sediments 211

LESSON PLAN 2.
Seagrasses are filters for nutrients 216

LESSON PLAN 3.
Seagrasses improve water quality 221

LESSON PLAN 4.
Seagrasses capture and store carbon 228

B6 **THEMATIC MODULE 6:**
Seagrasses and humans are inextricably interconnected
Damla Kiral, Anna Nicolaou, Merve Buba

LESSON PLAN 1.
Seagrasses as Coastal Bodyguards 235

LESSON PLAN 2.
From Land to Sea – How Nutrient Excess Affects Seagrasses 244

LESSON PLAN 3.
We Are Seagrass Guardians 255

B7 **THEMATIC MODULE 7:**
Seagrasses are largely unexplored
Damla Kiral, Anna Nicolaou, Merve Buba

LESSON PLAN 1.
Seagrass Science Teams & Ocean Technology 266

INTRODUCTION

Theodora Boubonari
Democritus University of Thrace, Greece

Seagrass meadows are highly productive and biodiverse ecosystems that provide important services such as carbon storage, coastal protection, and habitat for marine species. Despite their ecological value, they are rapidly declining due to human activities and climate change. Building seagrass literacy from an early age is essential, as primary school students are particularly receptive to developing environmental awareness and positive attitudes toward ocean conservation. Introducing seagrass education in primary schools helps students develop scientific understanding, critical thinking, and environmental responsibility.

The SEAQUEST (Seagrass Education and Awareness through Quality Educational Solutions and Tools) Erasmus+ project aims to increase seagrass awareness in primary education across Europe. The project brings together educators and marine experts to develop educational resources, teacher training, and digital learning tools that make seagrass ecosystems accessible and engaging for young learners. SEAQUEST supports broader sustainability and ocean literacy goals by encouraging understanding and conservation of marine ecosystems.

To support teachers, SEAQUEST has developed an Educational Toolkit consisting of three main components: the SEAQUEST Curriculum for Teachers, the SEAQUEST Educational Activities Guide for Teachers, and a digital interactive game. Together, these resources provide learning objectives, lesson plans, classroom and field activities, and interactive experiences that support effective and engaging seagrass education. The toolkit was designed based on research identifying the need for age-appropriate and scientifically accurate marine education materials.

The Educational Activities Guide for Teachers consists of the following:

a. an overview of the aims and objectives,

b. the pedagogical approaches underlying the lesson plans.

c. the key competences students will develop, including scientific, environmental, digital, and social competences,

d. assessment strategies and tools which capture student learning across all competency areas

e. a practical section, guide for Teachers: How to Use the Seagrass Lesson Plans, providing advice on preparation, adaptation, implementation, and assessment, enabling teachers with varying levels of experience to use the materials effectively.

f. The main section of the guide which contains detailed lesson plans that progressively build students' understanding, from seagrass identification and ecology to field and laboratory investigations. Each lesson includes learning objectives, materials, activities, assessment methods, and suggestions for differentiation, creating a coherent and accessible resource for promoting seagrass literacy and ocean stewardship.

A. PEDAGOGICAL FRAMEWORK AND TEACHER GUIDANCE

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A1.
AIM AND OBJECTIVES

OVERALL AIM

The SEAQUEST project aims to enhance seagrass literacy among primary school students across Europe, developing oceanic citizens who understand the crucial role of seagrass ecosystems in marine biodiversity conservation, climate regulation, and global environmental sustainability. The curriculum aims to foster environmental stewardship aligned with international conservation initiatives, building students' capacity to become informed advocates and active participants in seagrass protection and restoration efforts. Through comprehensive seagrass education, students will develop the knowledge, skills, and values necessary to contribute to marine ecosystem conservation, while recognizing seagrasses as foundational components of healthy ocean systems that support both marine life and human well-being.

SPECIFIC OBJECTIVES

Knowledge Objectives

Students should be able to:

- Ecological Understanding: demonstrate comprehensive knowledge of seagrass ecosystem structure, function, and biodiversity
- Environmental Interconnections: analyse the relationships between seagrass meadows and broader marine and terrestrial ecosystems
- Conservation Awareness: identify current threats to seagrass habitats and evaluate conservation strategies within a broader perspective of global environmental challenges and solutions

SKILLS OBJECTIVES

Students should be able to:

- Scientific Inquiry: design and conduct investigations using scientific methodology to study seagrass ecosystems
- Critical Analysis: evaluate environmental data and research findings to make evidence-based conclusions
- Communication: effectively communicate scientific concepts and conservation messages to their schools and the local community
- Digital Literacy: utilize digital resources for environmental research and presentation

ATTITUDES AND VALUES OBJECTIVES

Students should be able to:

- Environmental Stewardship: develop personal responsibility for marine ecosystem protection
- Global Citizenship: demonstrate understanding of their role in addressing global environmental challenges
- Collaborative Action: engage in collective environmental action and community-based conservation initiatives

A2. PEDAGOGICAL APPROACHES

The lesson plans employ constructivist principles where students actively build knowledge through hands-on experiences, connecting new seagrass concepts to their existing understanding of ecosystems and environmental science. The following approaches recognize that meaningful learning occurs when students construct their own understanding through interaction with their environment and social contexts.

INQUIRY-BASED LEARNING

Students engage in authentic scientific investigations, formulating hypotheses about seagrass ecosystems, collecting and analysing data, and drawing evidence-based conclusions. This approach mirrors real scientific research processes and develops critical thinking skills while promoting deep conceptual understanding.

PROBLEM-BASED LEARNING (PBL)

Real-world seagrass conservation challenges serve as the foundation for learning experiences. Students work collaboratively to solve authentic problems such as designing restoration plans or developing community awareness campaigns. Research demonstrates that PBL enhances student engagement and develops 21st-century skills.

EXPERIENTIAL LEARNING

Direct engagement with seagrass environments through fieldwork, laboratory investigations, and virtual reality experiences provides concrete learning opportunities that support abstract concept development. This hands-on approach is particularly effective for environmental education and science learning.

COOPERATIVE LEARNING

Structured group activities promote peer interaction, shared responsibility, and collaborative knowledge construction. Students work in diverse teams to investigate different aspects of seagrass ecosystems, which research shows enhances both academic achievement and social skills.

TECHNOLOGY-ENHANCED LEARNING

Integration of digital tools, interactive games, and virtual reality experiences provides engaging, multimedia learning opportunities that accommodate different learning styles and preferences. Contemporary research supports the effectiveness of immersive technologies in environmental education.

A3.
COMPETENCIES

The SEAQUEST Educational Guide for Teachers develops a comprehensive range of competencies that enable students to become effective environmental stewards and scientifically literate citizens. These competencies integrate knowledge, skills, and attitudes across multiple domains, ensuring students develop both the technical abilities to study seagrass ecosystems and the communication skills to advocate for their protection.

SCIENTIFIC LITERACY COMPETENCIES

- Systematically observe and record seagrass ecosystem characteristics
- Identify key species
- Document changes in seagrass habitats over time
- Use scientific tools and instruments for data collection
- Collect, organize, and analyse quantitative and qualitative environmental data
- Create graphs, charts, and visual representations of findings
- Identify patterns and trends in seagrass ecosystem data
- Draw evidence-based conclusions from research findings
- Present research findings using appropriate scientific vocabulary
- Create reports, presentations, and displays
- Communicate conservation messages effectively

ENVIRONMENTAL LITERACY COMPETENCIES

- Understand interconnections within seagrass ecosystems
- Analyse relationships between human activities and environmental impacts
- Identify environmental challenges affecting seagrass habitats
- Understand principles of sustainable management
- Evaluate human practices affecting seagrass ecosystems

SOCIAL AND CIVIC COMPETENCIES

- Work effectively in groups on environmental projects
- Share responsibilities and contribute to collective goals
- Resolve conflicts constructively during group activities
- Support and encourage peer learning
- Motivate others to engage in conservation activities
- Advocate for seagrass ecosystem protection

DIGITAL COMPETENCIES

- Use digital databases and research tools effectively
- Use digital tools for data collection, analysis, and presentation
- Collaborate using online platforms and communication tools

A4. ASSESSMENT STRATEGIES AND TOOLS

The lesson plans employ diverse, authentic strategies that capture student learning across all competency areas. These assessment approaches incorporate both traditional academic measures and innovative performance-based assessments that reflect real-world conservation practices.

- Species Identification Challenges: Practical assessments of students' ability to identify and describe seagrass species and associated organisms
- Environmental Data Collection: Evaluation of students' skills in using scientific instruments and collecting accurate environmental data
- Exit Tickets: Brief written responses at the end of lessons to assess immediate comprehension and identify misconceptions
- Digital Quizzes: Real-time assessment using educational technology platforms to gauge understanding and adjust instruction
- Knowledge Tests: Structured assessments covering factual information about seagrass biology, ecology, and conservation
- Peer Feedback Sessions: Structured opportunities for students to provide constructive feedback on each other's work and ideas
- Concept Mapping: Visual representations of student understanding showing relationships between seagrass concepts
- Storytelling: Students create presentations combining scientific content with personal narratives about seagrass conservation
- Role-Play Scenarios: Students assume roles of different stakeholders in seagrass conservation debates
- Community Presentation: Public presentations where students share their learning and conservation recommendations with community members
- Digital Portfolio Development: Comprehensive collection of student work demonstrating growth and achievement across multiple competency areas
- Assessment Rubrics and Criteria: Assessment rubrics address multiple dimensions of student achievement concerning scientific accuracy, critical thinking, communication and collaboration

A5.
GUIDE FOR TEACHERS: HOW TO USE THE SEAGRASS LESSON PLANS

Each lesson plan follows a consistent structure based on the 5E Instructional Model (Engagement, Exploration, Explanation, Elaboration, Evaluation), ensuring that students actively construct knowledge through guided discovery and scientific investigation. The following guide will help you understand the lesson plan structure and make the most effective use of these materials in your classroom.

LESSON OVERVIEW

This opening section provides a concise summary of the lesson's purpose, scope, and approach.

How to use it: Read this first to quickly grasp the lesson's intent and determine how it fits into your teaching sequence.

LEARNING OBJECTIVES

Learning objectives are organized into three categories:

Knowledge Objectives

Factual and conceptual knowledge students should acquire (using verbs such as: Define, Identify, Explain, Describe, Recognize).

Skills Objectives

Scientific and analytical skills students will develop (using verbs such as: Compare, Analyse, Create, Evaluate, Measure).

Attitudes and Values Objectives

Dispositions and values students should demonstrate (using verbs such as: Appreciate, Value, Demonstrate, Show).

How to use them: Share these objectives with students at the beginning of the lesson in student-friendly language ("By the end of today, you will be able to..."). Refer back to them during the lesson to maintain focus and guide assessment.

COMPETENCES ADDRESSED

This section identifies key competences developed through the lesson in four domains: **Scientific Literacy, Environmental Literacy, Digital Competences**, and **Social and Civic Competences.** While you don't need to explicitly teach "competences," being aware of them helps you facilitate activities that develop these skills holistically.

MATERIALS AND RESOURCES

Required Materials

Lists all essential items needed to conduct the lesson successfully.

Optional/Enhanced Materials

Suggests additional resources that can enrich the lesson experience.

How to use them: Review this section well in advance to ensure you have all necessary materials. Optional materials can enhance engagement but are not essential for achieving learning objectives.

LESSON STRUCTURE AND ACTIVITIES

PHASE 1: ENGAGEMENT

Capture student interest, activate prior knowledge, and introduce the lesson's central question. Start with energy and curiosity using the suggested questions.

PHASE 2: EXPLORATION

Allow students to explore concepts through hands-on activities before formal instruction. Step back and let students lead their own discovery. Resist explaining too much too soon.

PHASE 3: EXPLANATION

Introduce scientific terminology and concepts. Build on what students observed in Phase 2. Provide clear explanations using visuals and frequent comprehension checks.

PHASE 4: ELABORATION

Extend and apply new knowledge to new situations or problems. Challenge students to use what they've learned in new contexts, revealing how well they can transfer understanding.

PHASE 5: EVALUATION

Assess student learning through brief individual assessment. Use this as both formative assessment (to inform your next lesson) and closure.

ASSESSMENT

Formative Assessment

Ongoing monitoring throughout the lesson using observation, questioning, and group work monitoring. Adjust instruction in real-time based on student understanding.

Summative Assessment

End-of-lesson assessment (usually Exit Ticket) with evaluation criteria.

SUCCESS CRITERIA (FOR STUDENTS)

"I can..." statements in student-friendly language. You could share these at the beginning so students know what they're working toward. Revisit at the end for self-assessment. Self-Assessment through Success Criteria empowers students to monitor their own learning.

ADAPTING LESSONS FOR YOUR CONTEXT

While these lessons have been carefully designed, you know your students best. Feel free to adapt lessons to suit your local context by substituting local species examples, adjusting timing, modifying activities based on available resources, differentiating instruction, extending lessons into multiple sessions, connecting to local issues, or inviting guest speakers such as marine biologists or conservationists.

The lesson plans build upon each other logically. However, you may choose a different order based on available resources, student interest, curriculum integration, or seasonal considerations (e.g., for field sampling).

We hope these lessons inspire curiosity about seagrasses, foster scientific thinking, and cultivate environmental stewardship in your students.

A6.
FURTHER READING

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B. LESSON PLANS

B1.

THEMATIC MODULE 1: THE OCEAN SUPPORTS A GREAT DIVERSITY OF LIFE AND ECOSYSTEMS

Dominika Wojcieszek
European Marine Science Educators Association, Belgium

LESSON PLAN 1. DIVERSITY OF LIFE IN THE OCEAN - PLANKTON

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson introduces students to plankton as one of the three major groups of marine organisms, based on how they move and where they live in the ocean. Building on students' general understanding of ocean life, this lesson zooms in on the small, often microscopic organisms that float in the water column and cannot swim actively against ocean currents– the plankton. Through discussion, visual exploration, and a surprising connection to everyday classroom objects, students will discover that plankton, despite being mostly invisible to the naked eye, plays an enormous role in the ocean and on our planet. The lesson emphasizes observation skills, scientific vocabulary development, and an appreciation for the out-sized importance of microscopic life.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Define plankton as free-floating organisms that cannot swim against water currents
- Distinguish between the three main groups of plankton: phytoplankton, zooplankton, and bacterioplankton
- Explain that phytoplankton are photosynthetic organisms that form the base of marine food webs
- Explain that chalk and major geological structures, such as the White Cliffs of Dover, are sedimentary rocks formed from the accumulated skeletal remains of coccolithophores over millions of years

Teacher note:

Coccolithophores are unicellular, autotrophic organisms belonging to the marine phytoplankton that during certain phases of their cycle of life are able to produce calcium carbonate plates called coccoliths that cover the cell in a structure called coccosphere

Skills Objectives

By the end of this lesson, students will be able to:

- Observe and describe the characteristics of planktonic organisms using images and microscopy photographs
- Use scientific vocabulary accurately when describing plankton and its groups
- Place plankton correctly within the water column
- Compare phytoplankton and zooplankton based on their defining characteristics

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Demonstrate curiosity about microscopic marine life and its role in the ocean
- Show appreciation for the significance of organisms that are invisible to the naked eye

KEY COMPETENCIES

Scientific Literacy Competencies:

- Systematic observation and description of planktonic organisms from images and microscopy photographs
- Using appropriate scientific vocabulary (plankton, phytoplankton, zooplankton, bacterioplankton, coccolithophore, coccolith, calcium carbonate, photosynthesis)
- Creating visual representations of the water column with correctly placed organisms

Environmental Literacy Competencies:

- Understanding that microscopic organisms play a fundamental role in ocean ecosystems and on Earth as a whole
- Recognising the connection between ancient marine life and present-day geological structures and everyday objects

Social and Civic Competencies:

- Collaborative work during pair and group activities
- Sharing observations and contributing to collective understanding

MATERIALS NEEDED

- Images of the ocean surface and open water
- Microscopy images of phytoplankton and zooplankton, including coccolithophores and their coccoliths
- Images of the White Cliffs of Dover
- A piece of chalk (real or pictured)
- Clean A4 sheets (one per pair of students)
- Coloured pencils/markers
- Exit ticket templates (one per student)
- Word cards/posters displaying key vocabulary (plankton, phytoplankton, zooplankton, bacterioplankton, coccolithophore, coccolith)
- Optional: Short video of plankton under a microscope; images of coccolithophore blooms visible from satellite

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "What Hides in the Ocean?"

- Display images of the open ocean surface – calm, blue, seemingly empty water.
- Ask students: what do you think lives in this water? Can you see anything? Does that mean nothing is there?
- Reveal that the ocean is full of living organisms so small they are invisible to the naked eye. Ask: can you think of other tiny things we cannot see that are still very important? Guide students toward examples such as bacteria or dust mites, then bring the focus back to the ocean.
- Close with a bridging question: if these organisms are so small we cannot see them, how do you think scientists study them? Let's find out what they discovered!

PHASE 2: EXPLORATION

Activity: "Tiny but Mighty"

- Display microscopy images of a range of phytoplankton and zooplankton side by side. Ask students: what do you notice? Do these look like plants or animals – or neither? Can you spot any differences between them? **(Use Figure 1.2, SEAQUEST Curriculum for Teachers, page 46).**
- Working in pairs, students receive a clean A4 sheet and coloured pencils. They draw a simple cross-section of the ocean, marking the surface, the water column, and the sea-floor. Ask them: where do you think phytoplankton and zooplankton live – near the surface, in the deep water, or on the bottom? They mark their prediction on their drawing.
- Bring the class together to share their predictions and reasoning before moving on to the explanation.

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

Using visual aids (digital presentation or poster), explain the following while students follow along and update their water column drawings from Phase 2.

1. **What is plankton?**
    - Free-floating organisms that live in the water column
    - Cannot swim against water currents – they drift with them
    - Found mostly near the surface in the photic zone, where light is available
    - Despite being tiny, plankton makes up the majority of biomass in the ocean

2. **The three groups of plankton:**
    - **Phytoplankton**: photosynthetic organisms, like plants of the ocean; they produce oxygen and form the base of the marine food web
    - **Zooplankton**: small animals that feed on phytoplankton, other zooplankton or decaying organic material
    - **Bacterioplankton**: bacteria and archaea; they play a key role in breaking down organic matter and nutrient cycling

3. **Why plankton matters:**
    - Phytoplankton produce more than half of the oxygen we breathe
    - Plankton is the foundation of nearly all marine food webs – without it, larger animals including fish and whales could not survive

Activity: "Where Does Plankton Live?"

- Using the word bank (plankton, phytoplankton, zooplankton, bacterioplankton, water column, surface), students label and annotate their water column drawing from Phase 2, correcting any earlier predictions if needed.
- Teacher circulates, asking probing questions:
    - "Why do you think phytoplankton lives near the surface?"
    - "What would happen to zooplankton if all the phytoplankton disappeared?"
    - "Can plankton choose where it goes?"

Check for Understanding: Quick verbal quiz

- "Can plankton swim against the current?"
- "What is the difference between phytoplankton and zooplankton?"
- "Where in the water column, close to the surface or in deep water, do we find most plankton – and why?"

PHASE 4: ELABORATION

Activity: "From the Ocean to the Cliffs"

- Hold up a piece of chalk (real or picture) and ask students: do you know what this is? Do you know what it is made of? Where do you think it comes from?
- Display an image of the White Cliffs of Dover. Ask: has anyone seen these? What do you think they are made of? How could something this enormous have formed?
- Explain that chalk is formed almost entirely from the remains of coccolithophores – a type of phytoplankton that produces tiny plates of calcium carbonate called coccoliths. When coccolithophores die, their coccoliths sink slowly to the sea-floor and accumulate over millions of years, eventually forming thick layers of rock.
- Display microscopy images of coccolithophores and their coccoliths alongside the image of the White Cliffs of Dover. Ask: what does this tell us about how much phytoplankton must have lived and died in the ocean over millions of years to build structures this large?

- Share with students: the chalk that teachers once used on blackboards was formed by phytoplankton in ancient oceans. Today most classrooms use synthetic chalk or dry erase markers, but the connection between plankton and our everyday world remains. The ocean floor still accumulates coccoliths every single day.
- Close with a reflection question: if something as small and invisible as phytoplankton can build cliffs and fill classrooms with chalk, what does that tell us about its importance?

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket

Students complete a quick exit ticket with three components:

- **Draw and label:** A simple cross-section of the ocean showing where plankton can be found, with at least one example of phytoplankton and one example of zooplankton
- **Explain:** Write one sentence explaining why phytoplankton is important for life in the ocean
- **Reflect:** One thing I found most interesting today was...

Teacher collects exit tickets to assess:

- Accuracy of placement and labels
- Understanding of the role of phytoplankton in the marine ecosystem
- Engagement and curiosity levels

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
   - Students correctly place plankton in the water column
   - Students distinguish between phytoplankton and zooplankton
   - Students use scientific vocabulary appropriately
   - Students actively participate in discussions and collaborate effectively in pairs
2. **Questioning:**
   - Targeted questions during exploration to check understanding
   - Probing questions to encourage deeper thinking about the role and significance of plankton
3. **Peer Assessment:**
   - Partner checking during the water column drawing activity in Phase 2

Summative Assessment (End of Lesson):

4. **Exit Ticket Evaluation Criteria:**
   - **Scientific Accuracy**: Correctly labelled water column drawing with appropriate vocabulary
   - **Comprehension**: Explanation demonstrates understanding of the role of phytoplankton in the ocean
   - **Engagement**: Thoughtful reflection showing curiosity about microscopic marine life

Success Criteria for Students:

- I can explain what plankton is and why it cannot swim against the current
- I can name and describe the three groups of plankton
- I can explain why phytoplankton is important for life in the ocean and on land
- I can describe how the White Cliffs of Dover and classroom chalk are connected to ancient plankton

LESSON PLAN 2. DIVERSITY OF LIFE IN THE OCEAN - BENTHOS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson introduces students to benthos as the second of the three major groups of marine organisms, based on how they move and where they live in the ocean. Building on students' knowledge of plankton from the previous lesson, this lesson turns attention to the sea-floor – a vast and varied environment home to an extraordinary range of organisms. Through observation, discussion, and hands-on activities, students will explore what lives on, in, and near the sea-floor, how benthic organisms are classified by size, and how some animals' life cycles can span more than one lifestyle group. The lesson emphasizes observation skills, scientific vocabulary development, and an appreciation for the complexity of life at the bottom of the ocean.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Define benthos as organisms that live on, in, or near the sea-floor
- Distinguish between sessile and mobile benthic organisms and give examples of each
- Identify the three size-based subdivisions of benthos: megabenthos, macrobenthos, and meiobenthos
- Explain that benthos includes animals, plants, and microorganisms
- Describe how the life cycles of some animals, such as crabs and jellyfish, can span more than one lifestyle group.

Skills Objectives

By the end of this lesson, students will be able to:

- Systematically observe and describe the characteristics of benthic organisms using images
- Use scientific vocabulary accurately when describing benthos and its subdivisions
- Classify benthic organisms as sessile or mobile based on their characteristics
- Connect knowledge of plankton from the previous lesson to the life cycles of benthic organisms

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Demonstrate curiosity about life on the sea-floor and the variety of organisms found there
- Show appreciation for the interconnectedness of lifestyle groups across an organism's life cycle

KEY COMPETENCIES

Scientific Literacy Competencies:

- Systematic observation and classification of benthic organisms from images
- Using appropriate scientific vocabulary (benthos, sessile, mobile, megabenthos, macrobenthos, meiobenthos, substrate, larva)
- Creating visual representations of the sea-floor with correctly classified organisms

Environmental Literacy Competencies:

- Understanding that the sea-floor is a diverse and productive environment supporting a wide variety of life
- Recognising that lifestyle groups are not always fixed – some organisms move between different lifestyle groups during their lives

Social and Civic Competencies:

- Collaborative work during group activities
- Sharing observations and reasoning and contributing to collective understanding

MATERIALS NEEDED

- Images of various benthic environments – sandy sea-floor, rocky shore, coral reef, sea-grass meadow
- Images of a range of benthic organisms – corals, barnacles, crabs, seagrass, worms, starfish, shells, sponges
- Images and simple life cycle diagrams of a crab and a jellyfish
- Clean A4 or A3 sheets (one per pair of students)
- Coloured pencils/markers
- Glue
- Classification cards with images or names of benthic organisms (sessile vs. mobile sorting activity)
- Exit ticket templates (one per student)
- Word cards/posters displaying key vocabulary (benthos, sessile, mobile, megabenthos, macrobenthos, meiobenthos, substrate, larva)
- Optional: Videos of sea-floor environments; microscopy images of meiobenthic organisms

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "What Lives on the Bottom?"

- Remind students briefly of what they learned in the previous lesson: plankton floats in the water column and cannot swim against currents. Ask: if plankton lives in the water column, what do you think lives at the very bottom of the ocean?
- Display dramatic images of sea-floor environments – a sandy bottom, a rocky shore covered in barnacles and mussels, a coral reef, a seagrass meadow. Ask: what do you notice? Does anything surprise you? Does the bottom look the same everywhere? **(Use Figures 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14, SEAQUEST Curriculum for Teachers, pages 51-54).**
- Encourage students to share what organisms they can spot in the images. Ask: do these organisms seem to be moving or staying still? Do they seem attached to something or free to move around?
- Close with a bridging question: what would it mean for an organism to spend its whole life attached to one spot on the sea-floor – how would it eat, how would it survive?

PHASE 2: EXPLORATION

Activity: "Stuck or Free?"

- Provide students with a set of images of various benthic organisms – corals, barnacles, crabs, seagrass, starfish, tube worms, mussels, sponges, and sea cucumbers. **(Use Figures 1.1, 1.4, 1.5, 1.6,SEAQUEST Curriculum for Teachers, pages 45-49)**.
- Working in pairs, students sort the organisms into two groups on their A4/A3 sheet: those that appear attached to a surface and cannot move freely, and those that appear able to move around.
- Class discussion: which organisms did you place in each group? Were any difficult to classify? Why? Guide students toward the terms sessile (permanently attached) and mobile (able to move), without formally introducing them yet.
- Ask: do you think both groups still count as part of the same lifestyle group – or are they too different?

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:
Using visual aids (digital presentation or poster), explain the following while students follow along and glue the images to the sheet to create a simple diagram of various benthic organisms.

1. **What is benthos?**

- Organisms that live on, in, or near the sea-floor
- Found across all ocean depths, from shallow coastal waters to the deep sea
- Includes animals, plants, and microorganisms
- Two main types based on movement:
    - **Sessile**: permanently attached to a surface, such as corals, barnacles, and sponges
    - **Mobile**: able to move across or through the sea-floor, such as crabs, starfish, and snails

2. **Size-based subdivisions of benthos:**

- **Megabenthos**: large organisms visible to the naked eye, such as crabs, lobsters, sea urchins, and corals
- **Macrobenthos**: smaller organisms still visible without magnification, such as worms, small molluscs, and small crustaceans
- **Meiobenthos**: very small organisms that live between grains of sand and sediment, requiring magnification to observe, such as tiny worms and crustaceans

3. **Why benthos matters:**

- Benthic organisms play a key role in breaking down organic matter and recycling nutrients on the sea-floor
- They form the base of many coastal food chains
- Ecosystems such as coral reefs and seagrass meadows are themselves built and sustained by benthic organisms

Activity: "Label the Sea-floor"

- Using the diagrams the students created in Activity: "Stuck or Free?" showing various benthic organisms and word bank (benthos, sessile, mobile, megabenthos, macrobenthos, meiobenthos), students label the organisms and classify them.
- Teacher circulates, asking probing questions:
    - "How does a barnacle eat if it cannot move to find food?"
    - "Why might it be useful to be able to burrow into the sand?"
    - "Could a plant be part of the benthos?"

Check for Understanding: Quick verbal quiz

- "What do we call an organism that is permanently attached to a surface?"
- "Can benthos include plants – why or why not?"
- "What is the difference between megabenthos and meiobenthos?"

PHASE 4: ELABORATION

Activity: "One Animal, Two Worlds"

- Ask students: we know that plankton drifts in the water column and benthos lives on the sea-floor. Can an animal belong to both formations during its life?
- Display simple life cycle diagrams of a crab and a jellyfish. Working in small groups of 3–4, students study each life cycle and label which lifestyle group the animal belongs to at each stage of its life.
- For the crab: crab eggs hatch into larvae, which drift in the water column as zooplankton; they eventually transform into a final larval stage, which leave the water column, settle onto the sea-floor and molt into a juvenile crab. Juvenile and adult crabs live on the seabed as benthos.
- For the jellyfish: the larva stage is planktonic; the polyp stage is sessile benthos, attached to the sea-floor; the medusa stage is a free-swimming or floating, planktonic form.
- Provide discussion prompts:
  - Can the same animal belong to more than one lifestyle group during its life?
  - What changes – the animal, or the environment?
  - Why might it be useful for an animal to start its life as plankton before settling on the sea-floor?
- Bring the class together to share findings. Reinforce the idea that lifestyle groups describe where and how an organism lives at a given moment – and that this can change as the organism grows.

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket

Students complete a quick exit ticket with three components:

- **Draw and label:** A simple sea-floor scene showing at least three benthic organisms, labelling each as sessile or mobile and identifying its size group (megabenthos, macrobenthos, or meiobenthos)
- **Explain**: Write one sentence describing how a crab or jellyfish belongs to more than one lifestyle groups during its life
- **Reflect**: One thing I found most interesting today was...

Teacher collects exit tickets to assess:

- Accuracy of labels and classifications
- Understanding of the sessile/mobile distinction and size-based subdivisions
- Understanding of how life cycles can cross lifestyle groups
- Engagement and curiosity levels

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
    - Students correctly classify benthic organisms as sessile or mobile
    - Students correctly assign organisms to size-based subdivisions
    - Students use scientific vocabulary appropriately
    - Students actively participate in discussions and collaborate effectively in pairs and groups
2. **Questioning:**
    - Targeted questions during exploration to check understanding
    - Probing questions to encourage deeper thinking about life on the sea-floor and the connections between lifestyle groups
3. **Peer Assessment:**
    - Partner checking during the water column drawing activity in Phase 2

Summative Assessment (End of Lesson):

4. **Exit Ticket Evaluation Criteria:**
    - **Scientific Accuracy:** Correctly labelled sea-floor scene with appropriate vocabulary and accurate classifications
    - **Comprehension**: Explanation demonstrates understanding of how life cycles can span more than one lifestyle group
    - **Engagement**: Thoughtful reflection showing curiosity about benthic life

Success Criteria for Students:

- I can define benthos and give at least three examples of benthic organisms
- I can explain the difference between sessile and mobile benthos
- I can name and briefly describe the three size-based subdivisions of benthos
- I can explain how a crab or jellyfish belongs to different lifestyle groups at different stages of its life

LESSON PLAN 3. DIVERSITY OF LIFE IN THE OCEAN - NEKTON

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson introduces students to nekton as the third and final major lifestyle group of marine organisms. Building on students' knowledge of plankton and benthos from the previous two lessons, this lesson focuses on the powerful, active swimmers of the ocean – organisms that can move freely against water currents and travel vast distances through the water column. Through discussion, sorting activities, and a whole-class capstone activity bringing all three lifestyle groups together, students will consolidate their understanding of how ocean life is organized and appreciate the remarkable diversity of animals that make up the nekton. The lesson emphasizes observation and classification skills, scientific vocabulary development, and a sense of wonder at the scale and variety of life in the open ocean.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Define nekton as organisms capable of swimming actively against water currents
- Identify the main animal groups found among nekton: fish, mammals, reptiles, birds.
- Explain that nekton live primarily in the water column but may use the seabed for resting, hiding, foraging and breeding
- Explain that plants cannot be nekton as they are incapable of self-locomotion
- Distinguish nekton from plankton and benthos and place all three lifestyle groups correctly within the water column

Skills Objectives

By the end of this lesson, students will be able to:

- Classify marine organisms as plankton, nekton, or benthos based on their defining characteristics
- Use scientific vocabulary accurately when describing nekton and comparing it to the other two lifestyle groups
- Place representatives of all three lifestyle groups correctly within the water column
- Justify classification decisions based on observable characteristics and prior knowledge

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Demonstrate curiosity about the diversity of animals that make up the nekton
- Show appreciation for the ocean as a complex, layered environment shared by three distinct lifestyle groups

KEY COMPETENCIES

Scientific Literacy Competencies:

- Systematic observation and classification of marine organisms across all three lifestyle groups
- Using appropriate scientific vocabulary (nekton, plankton, benthos, water column, lifestyle group, locomotion)
- Creating visual representations of the full water column with correctly placed organisms from all three lifestyle groups

Environmental Literacy Competencies:

- Understanding that the ocean is organized into distinct lifestyle groups based on where and how organisms live
- Recognising the diversity and complexity of life in the open ocean

Social and Civic Competencies:

- Collaborative work during sorting and classification activities
- Sharing observations and reasoning and contributing to collective understanding during the whole-class capstone activity

MATERIALS NEEDED

- Images of nekton representatives – sharks, other fish, whales, and sea turtles – in open water
- Classification cards with images or names of marine organisms from all three lifestyle groups (for sorting activity in Phase 2)
- Cut-outs of various marine organisms from all three lifestyle groups with magnets for the blackboard capstone activity
- Clean A4 sheets (one per pair of students)
- Coloured pencils/markers
- Exit ticket templates (one per student)
- Word cards/posters displaying key vocabulary (nekton, plankton, benthos, water column, locomotion, sessile)
- Optional: Videos of large nekton animals in the open ocean; satellite tracking maps of whale or sea turtle movements

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "Built to Swim"

- Remind students briefly of what they have learned across the previous two lessons: plankton drifts in the water column and cannot swim against currents; benthos lives on, in, or near the sea-floor. Ask: what about the animals in between – the powerful swimmers of the open ocean?
- Display dramatic images of a whale, a shark, a sea turtle, and a school of fish moving through open water. Ask: what do all of these animals have in common? How do they move? Could they swim against a strong current? **(Use Figure 1.3, SEAQUEST Curriculum for Teachers, page 47).**
- Encourage students to notice that these animals are built for active movement – streamlined bodies, powerful fins or tails, strong muscles. Ask: do you think these animals stay in one place, or do they travel long distances?
- Optionally display a satellite tracking map of whale or sea turtle movements across ocean basins. Ask: why these organisms move across ocean basins?
- Close with a bridging question: if plankton drifts and benthos stays on the bottom, what would you call animals that can swim wherever they want?

PHASE 2: EXPLORATION

Activity: "Plankton, Benthos, or Nekton?"

- Provide each pair of students with a set of classification cards showing a range of marine organisms from all three lifestyle groups – including phytoplankton, zooplankton,- seagrass, corals, crabs, barnacles, starfish, sharks, other fish, whales, and sea turtles. **(Use Figures 1.2, 1.3, 1.5, 1.6, SEAQUEST Curriculum for Teachers, pages 46-49).**
- Working in pairs, students sort the cards into three groups on their A4 sheet: plankton, benthos, and nekton. They should draw on everything they have learned in the previous two lessons.
- Encourage students to discuss each card before placing it: why does this organism belong here? What characteristic makes you sure – or unsure?
- Bring the class together to compare groupings. Discuss any organisms students found difficult to classify and why. Ask: were there any surprises? Did any organisms end up in a different group than you expected?

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

Using visual aids (digital presentation or poster), explain the following while students follow along and update their water column drawings from Phase 2.

1. **What is nekton?**
    - Organisms capable of swimming actively against water currents
    - Live primarily in the water column but may use the seabed for resting, hiding, foraging and breeding
    - Found at a range of depths, from the surface to deeper waters
    - Unlike plankton, nekton controls where it goes; unlike benthos, it is not tied to the sea-floor
2. **Who belongs to nekton?**
    - **Fish**: the most diverse and abundant group of nekton, found at all depths and in all ocean regions
    - **Sharks** (cartilaginous fish): powerful predators and among the most efficient swimmers in the ocean
    - **Whales**: the largest animals on Earth (specifically blue whales), capable of crossing entire ocean basins
    - **Sea turtles**: reptiles that spend almost their entire lives swimming in the open ocean, returning to land to lay eggs in the sand
    - **Fun fact**: plants can never be nekton – no matter how much water moves around them, plants cannot swim!

3. **Putting it all together:**
    - The ocean is home to three major lifestyle groups: plankton, nekton, and benthos
    - Each lifestyle group is defined by where organisms live and how they move
    - Together, the lifestyle groups account for all life in the ocean – from the tiniest drifting micro-organism to the largest swimming animal on Earth

Check for Understanding: Quick verbal quiz

- "Can nekton swim against the current – what makes it different from plankton?"
- "Name one animal from each of the four nekton groups we discussed."
- "Could a seagrass plant ever be nekton – why not?"

PHASE 4: ELABORATION

Activity: "The Ocean Belongs to Everyone" This activity brings together knowledge from all three lessons to build a shared picture of ocean life.

- Use the classroom blackboard as the ocean. Draw a simple sea-floor at the bottom, mark the water column in the middle, and indicate the surface at the top.
- Prepare cut-outs of a wide range of marine organisms from all three lifestyle groups – including examples of phytoplankton, zooplankton, seagrass, corals, barnacles, crabs, starfish, sharks, other fish, whales, and sea turtles. **(Use Figures 1.2, 1.3, 1.5, 1.6, SEAQUEST Curriculum for Teachers, pages 46-49)**.
- Provide magnets to students so each cut-out can be fixed to the board.
- Show the cut-outs one by one and invite students to identify the organism. The student who answers correctly receives the cut-out.
- Once all cut-outs have been distributed, invite students one by one to the board to place their organism in the correct position – plankton in the water column (mainly near the surface for light), nekton in the water column, benthos on the sea-floor – and briefly explain their reasoning to the class.
- Once all organisms are placed, step back and look at the complete picture together. Ask:
- Does the ocean look full or empty now?
- Which lifestyle group has the most numerous organisms? Which has the largest?
- Can you find an organism that started its life in a different lifestyle group?
- What would happen to the whole system if one lifestyle group disappeared?
- Close by reinforcing that the ocean is a complex, layered environment where every lifestyle group depends on the others – plankton feeds nekton, benthos recycles nutrients that support plankton, and nekton connects the surface to the deep.

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket

Students complete a quick exit ticket with three components:

- **Draw and label:** The two components of the marine environment (water column, sea-floor) showing all three lifestyle groups – plankton, nekton, and benthos – with at least two example organisms per group
- **Explain:** Write one sentence explaining what makes nekton different from both plankton and benthos
- **Reflect:** One thing I found most interesting across these three lessons was...

Teacher collects exit tickets to assess:

- Accuracy of placement and labels across all three lifestyle groups
- Understanding of the defining characteristics of nekton and how it differs from the other two lifestyle groups
- Engagement and curiosity levels

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
    - Students correctly classify organisms across all three lifestyle groups
    - Students use scientific vocabulary accurately when describing nekton and comparing it to plankton and benthos
    - Students actively participate in discussions and the capstone blackboard activity
    - Students collaborate effectively in pairs and as a whole class
2. **Questioning:**
    - Targeted questions during the sorting activity to check understanding and address misconceptions
    - Probing questions during the capstone activity to encourage deeper thinking about the relationships between lifestyle groups
3. **Peer Assessment:**
    - Partner checking during the sorting activity in Phase 2

Summative Assessment (End of Lesson):

4. **Exit Ticket Evaluation Criteria:**
    - **Scientific Accuracy**: Correctly labelled full water column diagram with appropriate vocabulary and accurate placement of all three lifestyle groups
    - **Comprehension**: Explanation demonstrates clear understanding of what defines nekton and how it differs from plankton and benthos
    - **Engagement**: Thoughtful reflection showing curiosity and a sense of the bigger picture across all three lessons

Success Criteria for Students:

- I can define nekton and explain what makes it different from plankton and benthos
- I can name at least one example of nekton from each of the four animal groups we discussed
- I can place all three lifestyle groups correctly in marine environment (water column, seafloor)
- I can explain why plants cannot be nekton
- I can describe how the three lifestyle groups are connected and depend on each other

LESSON PLAN 4. DIVERSITY OF LIFE IN THE OCEAN

DURATION: 45 MINUTES

LESSON OVERVIEW

This introductory lesson focuses on the major lifestyle groups of marine organisms – plankton, nekton, and benthos – providing students with foundational knowledge about how ocean life is organized according to where organisms live and how they move. Through discussion, hands-on exploration, and collaborative activities, students will discover that different organisms are adapted to life in different parts of the water column. The lesson emphasizes observation skills, scientific vocabulary development, and understanding that the ocean is a complex, layered environment shared by an extraordinary variety of life forms.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Explain that the ocean hosts a great variety of life forms occupying different parts of the marine environment (water column, sea-floor)
- Distinguish between the three major lifestyle groups of marine organisms: plankton, nekton, and benthos
- List examples of each lifestyle group, including phytoplankton and zooplankton, animal categories found among nekton (mammals, birds, reptiles, fish), and examples of benthic organisms and their groups
- Explain that some animals belong to different lifestyle groups at different stages of their life cycle

Skills Objectives

By the end of this lesson, students will be able to:

- Systematically observe and record the characteristics of lifestyle groups
- Use scientific vocabulary accurately when describing marine organisms' lifestyle groups
- Place representatives of each lifestyle group in the correct position within the marine environment (water column, sea-floor)
- Compare and contrast the three lifestyle groups based on their defining characteristics

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Demonstrate curiosity about ocean biodiversity
- Show appreciation for the complexity and variety of life in marine environment

KEY COMPETENCIES

Scientific Literacy Competencies:

- Systematic observation and recording of the characteristics of the lifestyle groups of marine organisms
- Using appropriate scientific vocabulary (plankton, nekton, benthos, phytoplankton, zooplankton, bacterioplankton, sessile)
- Creating visual representations of the marine environment (water column, sea-floor) with correctly placed organisms

Environmental Literacy Competencies:

- Understanding of ocean biodiversity and the variety of life forms it supports
- Recognising that different organisms are adapted to life in different parts of the marine environment

Social and Civic Competencies:

- Collaborative work during pair and group activities
- Sharing observations and contributing to

collective understanding

MATERIALS NEEDED

- Images of various marine organisms representing all three lifestyle groups (plankton, nekton, benthos)
- Cut-outs of various marine organisms (fish, sea turtles, seaweed, crabs, molluscs, planktonic organisms) with magnets for blackboard activity
- Clean A4 sheets (one per pair of students)
- Coloured pencils/markers
- Simple life cycle diagrams of selected animals (fish, crab, jellyfish) – one set per group or displayed for the whole class
- Exit ticket templates (one per student)
- Word cards/posters displaying key vocabulary (plankton, nekton, benthos, phytoplankton, zooplankton, bacterioplankton, sessile)
- Optional: Videos of marine ecosystems showing organisms in their natural habitats; microscopy images of planktonic organisms

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "Life in the Ocean."

- Display images of various marine organisms – fish, whales, seaweeds, plankton, molluscs, crabs, etc. **(Use Figures 1.2, 1.3, 1.5, 1.6, SEAQUEST Curriculum for Teachers, pages 46-49).**
- Encourage discussion with questions: Do you recognise any of these organisms? How do they move? Where do they live? What do they need to survive? Do all of them need the same things? What does a seaweed need – does it always need to be attached to something? How is a whale different from seaweed in how it lives and moves?
- Guide students toward noticing that different organisms occupy different parts of the ocean and have very different ways of living.

PHASE 2: EXPLORATION

Activity: "Ocean – there is room for everyone."

- Display the word **PLANKTON** alongside images of phytoplankton and zooplankton. Ask students: Have you heard this word before? What does it make you think of? If students mention Sponge Bob, ask: Based on that, do you think plankton is big or small? Do you associate the word plankton with whales (often they know it's food for the whales) – and if so, what does that tell us?
- Display the word **NEKTON** alongside images of fish, sea turtles, whales, and penguins. Repeat a similar discussion: Have you heard this word? What do these organisms have in common?
- Display the word **BENTHOS** alongside images of crabs, seagrass, barnacles, and molluscs. Again, invite initial observations and associations.
- Working in pairs, students receive a clean A4 sheet and coloured pencils. They draw a simple cross-section of the ocean, marking the surface, the water column, and the sea-floor. They then draw or write where plankton, nekton, and benthos can be found.

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

Using visual aids (digital presentation or a poster) explain the following.

1. **Plankton**
    - Free-floating organisms living in the water column
    - Usually microscopic or very small
    - Cannot swim against water currents – they drift with them
    - Comprises three main groups: phytoplankton (photosynthetic organisms), zooplankton (animals), and bacterioplankton
    - Makes up the majority of biomass in the ocean
2. **Nekton**
    - Organisms capable of swimming actively and moving against water currents
    - Live primarily in the water column but may use the seabed for resting, hiding, foraging and breeding
    - Includes representatives of multiple animal categories: fish, mammals, reptiles, and even some birds
    - Plants cannot be nekton as they are not capable of self-locomotion
3. **Benthos**
    - Organisms that live on, in, or near the sea-floor

- Subdivided into groups based on size (e.g. macrobenthos, meiobenthos, microbenthos)
- Includes animals, plants, and microorganisms
- Some move across the sea-floor; others are sessile (permanently attached to a surface), such as barnacles or corals

Activity: "Let's find them homes."

- Prepare cut-outs of various marine organisms – a few examples of fish, sea turtles, seaweed, crabs, molluscs, and planktonic organisms introduced earlier. Species do not need to be specific. **(Use Figures 1.2, 1.3, 1.5, 1.6, SEAQUEST Curriculum for Teachers, pages 46-49).**
- Show cut-outs one by one and invite students to identify the organism. The student who answers correctly receives the cut-out.
- Once all cut-outs have been distributed, use the classroom blackboard as the ocean – draw a simple sea-floor at the bottom and mark the surface at the top.
- Provide magnets to students so each cut-out can be fixed to the board.
- Invite students one by one to place their cut-out in the correct position – plankton in the water column (mainly near the surface), nekton in the water column, benthos on the floor – and briefly explain their reasoning.

Check for Understanding: Quick verbal quiz

- "What is the name of the group of organisms that live on or near the ocean floor?"
- "Which group do fish, whales, and sea turtles belong to?"
- "Can plankton swim against the current?"

PHASE 4: ELABORATION

Activity: "One animal two worlds"

Students work in small groups (3–4 students) with simple life cycle diagrams of selected animals, such as a fish, a crab, and a jellyfish. The goal is to discover that not all animals spend their entire lives belonging to the same lifestyle group.

Life cycle diagrams can be displayed for the whole class or printed for each group. Students label which lifestyle group the animal belongs to at each stage of its life, for example:

- **Fish**: eggs and larvae → plankton; adults → nekton
- **Crab**: larvae → plankton; adults → benthos
- **Jellyfish**: larvae → plankton; polyp stage → benthos; medusa stage → plankton

Provide discussion prompts:

- Can the same animal belong to more than one lifestyle group during its life?
- What changes – the animal or the environment?

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket

Students complete a quick exit ticket with three components:

- **Draw and label:** A simple cross-section of the ocean showing where plankton, nekton, and benthos can be found, with at least one example organism for each lifestyle group
- **Explain:** Write one sentence describing one key characteristic of any one lifestyle group
- **Reflect:** One thing I found most interesting today was..

Teacher collects exit tickets to assess:

- Accuracy of placement and labels
- Understanding of the defining characteristics of each lifestyle group
- Engagement and curiosity levels

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
    - Students correctly place organisms within the appropriate lifestyle group
    - Students use scientific vocabulary appropriately
    - Students actively participate in discussions
    - Students collaborate effectively in pairs and groups
2. **Questioning:**
    - Targeted questions during exploration to check understanding
    - Probing questions to encourage deeper thinking about the defining characteristics of each lifestyle group
3. **Peer Assessment:**
    - Partner checking during the water column/sea-floor drawing activity in Phase 2

Summative Assessment (End of Lesson):

4. **Exit Ticket Evaluation Criteria:**
    - **Scientific Accuracy**: Correctly labelled ocean diagram with appropriate vocabulary and at least one example organism per lifestyle group
    - **Comprehension**: Explanation demonstrates understanding of the defining characteristics of at least one lifestyle group
    - **Engagement**: Thoughtful reflection showing curiosity about ocean biodiversity

Success Criteria for Students:

- I can identify and describe the three major ecological formations: plankton, nekton, and benthos
- I can place different marine organisms in the correct position within the marine environment (water column, sea-floor)
- I can explain at least one defining characteristic of each lifestyle group
- I can give an example of an animal that belongs to different lifestyle groups at different stages of its life are connected and depend on each other

LESSON PLAN 5. DIVERSITY OF ECOSYSTEMS IN THE OCEAN

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson introduces students to the diversity of marine ecosystems, providing foundational knowledge about the physical and chemical factors that shape life in the ocean. Through discussion, collaborative mapping, and creative group activities, students will explore how light, temperature, salinity, and oxygen determine which organisms can survive in different parts of the ocean. The lesson guides students from a broad understanding of ocean conditions and light zones to a closer look at three main marine ecosystem groups – the open ocean, the coastal and near-shore zone, and the deep sea – and the unique communities of organisms each one supports. The lesson emphasizes observation and comparison skills, scientific vocabulary development, and an appreciation for the extraordinary diversity and complexity of marine environments.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Explain that marine environments are structured by physical (abiotic) factors including light, temperature, salinity, and oxygen
- Describe the three ocean light zones: photic, dysphotic, and aphotic
- Identify the three main marine ecosystem groups: the open ocean, the coastal and near-shore zone, and the deep sea
- Describe the key characteristics of each ecosystem group and give examples of organisms found there
- Explain that different physical conditions (abiotic factors) support different ecosystems and communities of organisms

Skills Objectives

By the end of this lesson, students will be able to:

- Observe and compare the characteristics of different marine ecosystems
- Use scientific vocabulary accurately when describing marine ecosystems and their conditions
- Place marine ecosystems and organisms in their correct geographical and environmental context on a world map
- Justify the assignment of organisms to ecosystems based on their adaptations and environmental requirements

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Demonstrate curiosity about the diversity of marine ecosystems and the life they support
- Show appreciation for the complexity of ocean ecosystems and their dependence on a delicate balance of environmental conditions.

KEY COMPETENCIES

Scientific Literacy Competencies:

- Systematic observation and comparison of the characteristics of different marine ecosystems
- Using appropriate scientific vocabulary (photic, dysphotic, aphotic, pelagic, benthic, salinity, hydrothermal vent, coral reef, seagrass meadow, mangrove)
- Creating visual representations of marine ecosystems and their distribution

Environmental Literacy Competencies:

- Understanding that ocean biodiversity is driven by physical and chemical environmental conditions
- Recognising that different ecosystems support different communities of organisms and that each ecosystem is unique and irreplaceable

Social and Civic Competencies:

- Collaborative work during group mapping and ecosystem design activities
- Sharing observations and reasoning and contributing to collective understanding

MATERIALS NEEDED

- Images of various marine organisms and ecosystems (open ocean, coral reef, seagrass meadow, mangrove, sandy shore, rocky shore)
- World map displaying continents and oceans for whole-class discussion
- Contour world maps (one per group)
- Ecosystem and organism pictures or labelled cards (coral reef, seagrass meadow, mangrove, open ocean, whales, great white sharks, sea turtles) for the mapping activity
- Environmental conditions cards for the “Design Your Ecosystem” activity (one per group)
- Blank habitat templates for the “Design Your Ecosystem” activity (one per group)
- Organism picture or name cards for the “Design Your Ecosystem” activity
- Coloured pencils/markers
- Exit ticket templates (one per student)
- Word cards/posters displaying key vocabulary (photic, dysphotic, aphotic, pelagic, salinity, hydrothermal vent, coral reef, seagrass meadow, mangrove)
- Optional: Videos of different marine ecosystems; map of tracked whale or sea turtle movements showing open ocean distribution

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: " Same Needs, Different Ways"

- Display images of various marine organisms – seaweeds, seagrass, fish, dolphins, corals, crabs, etc. **(Use Figures 1.2, 1.3, 1.5, 1.6, SEAQUEST Curriculum for Teachers, pages 46-49).**
- Encourage discussion with questions: What do all of these organisms have in common? What do they all need to survive – food, oxygen, water, warmth? Do they all get these things in the same way?
- Guide students toward noticing that while all living things share the same basic needs, they meet them in very different ways. Plants use photosynthesis to produce food and need light to do so. Animals cannot produce their own food and must consume other organisms. Not all organisms need light, but most need oxygen.
- Close the activity with a bridging question: If organisms have such different needs and ways of living, do you think they all live in the same kinds of places – or do different places suit different organisms?

PHASE 2: EXPLORATION

Activity: "Every Place is Different"

- Display a cross-section of the ocean showing the photic, dysphotic, and aphotic zones. Encourage discussion: What do you think can live where there is no light? Can plants survive in the deep ocean? Can some organisms move between zones, or do they stay in one place? **(Use Figure 1.7, SEAQUEST Curriculum for Teachers, page 50).**
- Display an image of a large whale, such as a blue whale. Discuss: Where does an animal this size live? Can we find it close to the shore? Does it rest on the sea-floor? Guide students toward the idea that some animals live in the open ocean, far from the coast, in what is called the oceanic zone. Optionally, display a map of tracked whale movements to illustrate how they travel across vast stretches of open ocean.
- Display images of a sandy shore, a coral reef, and a seagrass meadow side by side. For each, prompt discussion: What kinds of organisms live here? Can animals dig into or hide in the sand? Are organisms attached to a surface or moving freely – or both? Is it easy to find food or shelter here? Does this ecosystem need light to function? **(Use Figures 1.13, 1.14, page 54, Figure 3.2, 3.3, 3.4, pages 84-85 SEAQUEST Curriculum for Teachers,).**

- After discussing all three, ask: What do these ecosystems have in common? How are they different? Guide students toward the conclusion that each ecosystem has its own distinct characteristics – physical conditions, available resources, and communities of organisms – and that these differences make each one a unique place to live.

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

Using visual aids (digital presentation or a poster) explain the following

1. **Factors Shaping Life in the Ocean**
    - Marine environments are shaped by a variety of physical and chemical factors
    - Among the most important are light, oxygen, salinity, and temperature – and these vary greatly across different marine environments.
    - Based on light availability, the ocean is divided into three zones: the photic zone (sufficient light for photosynthesis), the dysphotic zone (dim light, insufficient for photosynthesis), and the aphotic zone (complete darkness)
    - These varying conditions give rise to three main marine ecosystem groups: the open ocean, the coastal and near-shore zone, and the deep sea

2. **Open Ocean**
    - Covers approximately 70% of the Earth's surface
    - Characterised by vast stretches of open water with few places to hide or rest
    - Animals are adapted for long-distance swimming and life in open water, such as whales, tuna, and sharks

3. **Coastal and Near-Shore Zone**
    - Among the most productive and biologically rich environments on Earth
    - Includes sandy and rocky shores, each with distinct communities of organisms
    - Coral reefs form in warm, clear, shallow waters where light can reach; they are highly sensitive to changes in temperature and water quality
    - Seagrass meadows can form across a range of temperatures (most seagrasses thrive in temperatures 15°C - 30°C) but require abundant light, as seagrass is a flowering plant that depends on photosynthesis

4. **Deep Ocean**
    - Characterised by complete darkness, extreme hydrostatic pressure, and very low temperatures
    - No plants can survive here due to the absence of light
    - All organisms are highly specialised to endure these extreme conditions
    - Hydrothermal vents on the ocean floor support unique communities of organisms that depend on chemical energy rather than sunlight

Activity: "Where in the World?"

- Display a world map showing continents and oceans. First discuss together: where do we find warm waters and where do we find cold waters? What makes some regions warmer than others? Then establish the distinction between coastal zones and the open ocean – where does the coast end and the open ocean begin?
- Hand out contour world maps (one per group).
- Students work in groups of 4–5. Each group receives a set of pictures or labelled cards representing different marine ecosystems and organisms – coral reefs, seagrass meadows, mangroves, open ocean environments, and animals such as whales, great white sharks, and sea turtles.
- Groups discuss together and place each ecosystem or organism in the location on the map where they think it most likely occurs. For example: coral reefs in shallow tropical and subtropical waters coastal zones, seagrass meadows from cold to tropical coastal environments, open ocean animals distributed across the Pacific, Atlantic, and Indian Oceans.
- Bring the class back together to compare group maps and discuss any differences. Correct any misconceptions and reinforce the idea that physical factors – especially temperature, light, and proximity to the coast – determine where each ecosystem can exist.

Check for Understanding: Quick verbal quiz

- "In what water temperatures do we find coral reefs – warm, cold, or both?"
- "Where do whales live – close to the shore, in the open ocean, or both?"
- "Can seagrass survive without light – why or why not?"

PHASE 4: ELABORATION

Activity: "Crossing Borders"

- Each group of 4–5 students receives a card describing a set of environmental conditions, for example:
  - "Shallow coastal water, tropical region, warm temperature, abundant light, clear water"
  - "Open water, temperate region, moderate temperature, no sea-floor in reach"
  - "Coastal zone, temperate region, moderate light, sandy and muddy substrate"
  - "Complete darkness, extreme pressure, very low temperature, no light"
- Based on their conditions card, the group must decide: which ecosystem would form here? They then build their ecosystem by selecting from a set of organism pictures or name cards and placing them onto a simple blank habitat template (a drawn outline of their environment).
- Groups must justify their choices by answering three questions together:
  - What ecosystem is this and why?
  - Which organisms can survive here and why?
  - Which organisms definitely could not survive here and why not?
- Each group briefly presents its ecosystem to the class, explaining its reasoning. The class can ask questions or challenge choices.
- Close with a whole-class discussion: Did different conditions always lead to different ecosystems? What factor seemed most important in determining what could live somewhere – temperature, light, or something else?

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket

- **Draw and label:** A simple cross-section of the ocean showing the three main marine ecosystem groups (open ocean, coastal and near-shore, deep sea) with at least one example organism or feature for each
- **Explain:** Write one sentence describing how one physical factor (light, temperature, salinity, or oxygen) shapes life in a specific ecosystem
- **Reflect:** One thing I found most interesting today was...

Teacher collects exit tickets to assess:

- Accuracy of ecosystem placement and labels
- Understanding of the relationship between physical conditions and the ecosystems they support
- Engagement and curiosity levels

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
    - Students correctly identify the three main marine ecosystem groups and their key characteristics
    - Students accurately place marine ecosystems in their correct geographical context on the world map
    - Students use scientific vocabulary appropriately
    - Students actively participate in discussions and collaborate effectively in pairs and groups
2. **Questioning:**
    - Targeted questions during exploration to check understanding of how physical factors shape ecosystems
    - Probing questions during the mapping and ecosystem design activities to encourage deeper thinking about the relationships between environmental conditions and the organisms they support
3. **Peer Assessment:**
    - Group checking during the “Where in the World?” mapping activity in Phase 3

Summative Assessment (End of Lesson):

4. **Exit Ticket Evaluation Criteria:**
    - **Scientific Accuracy**: Correctly labelled ocean cross-section showing all three ecosystem groups with appropriate vocabulary and at least one example organism or feature per ecosystem
    - **Comprehension**: Explanation demonstrates understanding of how at least one physical factor shapes life in a specific ecosystem
    - **Engagement**: Thoughtful reflection showing curiosity about the diversity and complexity of marine environments

Success Criteria for Students:

- I can name and describe the three main marine ecosystem groups: the open ocean, the coastal and near-shore zone, and the deep sea
- I can explain how physical factors such as light, temperature, and salinity determine which organisms can survive in a given ecosystem
- I can place marine ecosystems in their correct geographical locations on a world map
- I can describe at least one key characteristic of each ecosystem and give an example of an organism found there

B2.

THEMATIC MODULE 2: SEAGRASSES ARE UNIQUE PLANTS

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LESSON PLAN 1. SEAGRASS MORPHOLOGY

DURATION: 45 MINUTES

LESSON OVERVIEW

This introductory lesson focuses on the general morphology of seagrasses, providing students with foundational knowledge about the structural characteristics that either are common or distinguish seagrasses from terrestrial plants. Through hands-on exploration, visual analysis, and comparative activities, students will discover how seagrasses are adapted to marine environments. The lesson emphasizes observation skills, scientific vocabulary development, and understanding structure-function relationships in marine flowering plants.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Define seagrasses as marine flowering plants with specialized adaptations
- Identify and label the main morphological characteristics of seagrasses (orthotropic rhizome, plagiotropic rhizome, nodes, internodes, roots, shoots, leaves, sheath, blade)
- Distinguish between above-substrate and below-substrate structures
- Explain that seagrasses are angiosperms (flowering plants) adapted to marine environments

Skills Objectives

By the end of this lesson, students will be able to:

- Systematically observe and record morphological characteristics of seagrasses
- Use scientific vocabulary accurately when describing plant morphology
- Create labelled diagrams showing seagrass structure
- Compare and contrast seagrass and terrestrial plant structures

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Demonstrate curiosity about marine plant adaptations
- Show respect for scientific observation and accuracy

KEY COMPETENCIES

Scientific Literacy Competencies:

- Systematic observation and recording of seagrass morphological characteristics
- Using appropriate scientific vocabulary (rhizome, node, internode, roots, shoots, leaves, sheath, blade)
- Creating visual representations (labelled diagrams)

Environmental Literacy Competencies:

- Understanding of seagrass
- Recognizing adaptations to marine environments

Social and Civic Competencies:

- Collaborative work during group activities
- Sharing observations and contributing to collective understanding

MATERIALS NEEDED

- Photos of seagrass plants and seagrass beds (see SEAQUEST Curriculum for Teachers p. 71-72)
- Large seagrass image (printed or digital)
- Unlabelled seagrass diagram worksheets (one per student)
- Coloured pencils/markers
- Venn diagram handouts (one per group)
- Exit ticket templates (one per student)
- Word cards/posters
- Optional: Preserved seagrass plants, videos of seagrass beds

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "What Lives Underwater?"

- Display images of various underwater plants (macroalgae, seagrasses)
- Pose question: Which of those look like plants we already know? Why?
- Show stunning images of seagrass beds to spark interest
- Let's explore these kinds of plants!

PHASE 2: EXPLORATION

Activity: "Above and Below"

- Provide students with large diagrams/photographs showing complete seagrass plants (both below and above substrate parts visible)
- Working in pairs, students use coloured pencils to:
  - Circle above-substrate parts in GREEN
  - Circle below-substrate parts in BROWN
- Class discussion: What did you find above? What did you find below? Why might plants need both?

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

Using visual aids (poster, digital presentation, or physical model) explain the following, while students at the same time do the activity (Fig. 1).

1. **What are seagrasses?**
    - Marine flowering plants (angiosperms)
    - Have roots, vascular system, flowers, and fruits
    - Live submerged in salt-water
2. **Below-Substrate Structures:**
    - **Rhizomes**: horizontal (or plagiotropic) stems that grow in segments along or beneath the substrate; provide anchoring and help the plant spread. Many seagrasses also have vertical (orthotropic) rhizomes
    - **Nodes**: junction points on rhizomes where roots and shoots emerge
    - **Internodes**: sections between nodes
    - **Roots**: absorb nutrients from sediment pore water (interstitial water)
3. **Above-Substrate Structures:**
    - **Shoots**: leaves with rhizome, horizontal or vertical
    - **Leaves**: consist of two parts
        - **Sheath**: basal portion protecting developing leaves
        - **Blade**: distal portion for photosynthesis and absorption of nutrients from seawater
4. **Special Adaptations:**
    - Flexible leaves to withstand water currents
    - Horizontal rhizomes to colonize sea-floor. The rhizome helps the plant to anchor on the seabed
    - Specialized leaves with a very reduced cuticle and an epidermis which lacks stomata, allowing seagrasses to absorb nutrients and gases, such as CO_2, directly from the surrounding seawater through their leaf surfaces

Activity: "Label the Seagrass"

- Distribute worksheets with unlabelled seagrass diagram (Fig. 1)
- Using a word bank (rhizome, roots, shoot, leaves, node, internode, sheath, blade), students label the morphological characteristics
- Teacher circulates, providing guidance and asking probing questions:
- "Where do you think the plant gets nutrients?"
- "Which part helps it spread across the seafloor?"
- "Where does photosynthesis happen?"
- "How do seagrass leaves absorb nutrients differently from land plant leaves?"

Check for Understanding: Quick verbal quiz

- "Point to the rhizome!"
- "What's the difference between a node and internode?"
- "Which part does photosynthesis?"

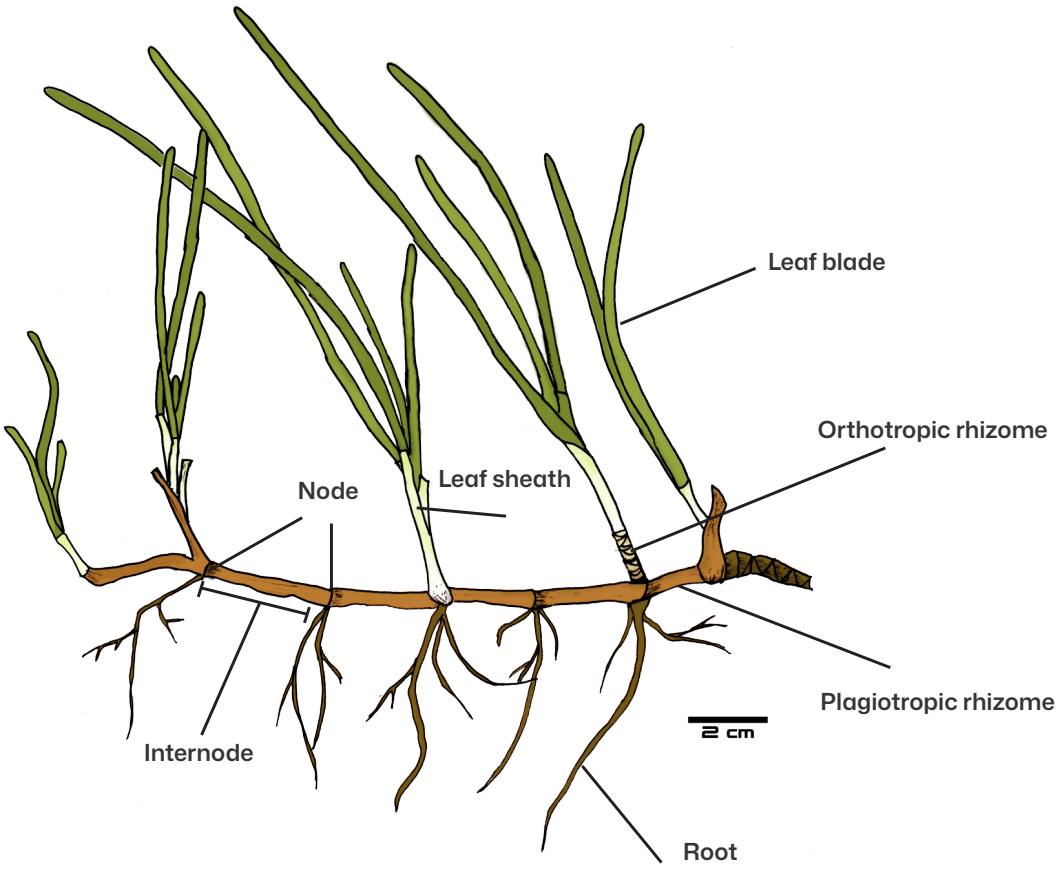


Figure 1. A schematic depiction of the basic components of a seagrass species

PHASE 4: ELABORATION

Activity: "Seagrass vs. Land Plant" Comparison

Students work in small groups (3-4 students) with a Venn diagram or with real plants (Fig 2):

- Left circle: Terrestrial flowering plants
- Right circle: Seagrasses
- Overlap: What they share (to be written by students while discussing)

Provide discussion prompts:

- What do they have in common?
- Both have leaves, but how are they different in function?
- What structures help each survive in their environment?
- "Land plants have a thick cuticle and stomata on their leaves. Why might seagrasses have different leaf structures?"





Figure 2. "Seagrass vs. Land Plant" activity

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket

Students complete a quick exit ticket with three components:

- **Draw and label:** A simple seagrass showing at least 5 morphological characteristics (rhizome, root, node, shoot, leaf with sheath and blade)
- **Explain:** Write one sentence explaining why the rhizome is important for seagrasses
- **Reflect:** One thing I found most interesting today was...

Teacher collects exit tickets to assess:

- Accuracy of labels
- Understanding of structure-function relationships
- Engagement and curiosity levels

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
    - Students correctly identify above/below substrate parts
    - Students use scientific vocabulary appropriately
    - Students actively participate in discussions
    - Students collaborate effectively in pairs/groups
2. **Questioning:**
    - Targeted questions during exploration to check understanding
    - Probing questions to encourage deeper thinking
3. **Peer Assessment:**
    - Partner checking during labelling activity

Summative Assessment (End of Lesson):

4. **Exit Ticket Evaluation Criteria:**
    - **Scientific Accuracy**: Correctly labelled diagram with appropriate vocabulary
    - **Comprehension**: Explanation demonstrates understanding of rhizome function
    - **Engagement**: Thoughtful reflection showing curiosity

Success Criteria for Students:

- I can label at least 5 morphological characteristics of a seagrass plant
- I can explain the difference between above and below substrate structures
- I can describe at least one way seagrasses are adapted to marine environment

LESSON PLAN 2. SEAGRASSES VS. MACROALGAE

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson builds upon students' foundational knowledge of seagrass morphology by helping them distinguish seagrasses from macroalgae, organisms commonly confused with seagrasses in marine environments. Through comparative analysis, hands-on investigation, and critical thinking activities, students will explore the fundamental biological differences between these two groups of marine autotroph organisms. The lesson emphasizes observation skills, comparative reasoning, and understanding the diversity of marine life while reinforcing previously learned seagrass terminology.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Define macroalgae as multicellular, autotrophic organisms distinct from seagrasses
- Identify at least five key structural and functional differences between seagrasses and macroalgae
- Explain that macroalgae lack true roots, vascular system, flowers, fruits, and seeds
- Describe how macroalgae anchor, obtain nutrients (direct absorption), photosynthesise (all cells), and reproduce (spores)
- Recognize the three main groups of macroalgae (green, red, brown)

Skills Objectives

By the end of this lesson, students will be able to:

- Systematically compare and contrast two different types of marine autotroph organisms
- Analyse structural features to classify organisms correctly
- Use comparative scientific vocabulary accurately
- Create comparison charts organizing multiple characteristics
- Evaluate visual evidence to make evidence-based identifications

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Demonstrate curiosity about organism classification and biological differences
- Value accuracy in scientific observation and identification
- Show respect for the complexity and uniqueness of different marine organisms

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Systematically observe and record characteristics of different marine autotroph organisms
- Identify key characteristics and distinguish between taxonomic groups
- Use scientific tools (comparison charts, classification keys) for analysis
- Present findings using appropriate scientific vocabulary
- Draw evidence-based conclusions from comparative observations

Environmental Literacy Competencies:

- Understand biodiversity within the marine environment
- Analyse structural adaptations to the marine environment

Digital Competencies:

- Use digital resources for species identification and comparison

Social and Civic Competencies:

- Work effectively in groups on comparative analysis
- Share observations and contribute to collective understanding
- Support peer learning through collaborative identification activities

MATERIALS NEEDED

Required

- 6-8 marine autotroph organism images for opening activity (digital or printed) (see Appendix)
- Large seagrass and macroalgae images for group investigation (one set per group)
- 10 organism images for identification challenge (digital or printed cards)
- Markers/coloured pencils
- Magnifying glasses
- Preserved specimens of seagrass and macroalgae (if available)
- Videos showing seagrasses and macroalgae in natural habitats

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "Marine Mystery - What Am I?"

Display 6-8 images of autotroph organisms or real samples (mix of seagrasses, green algae, red algae, brown algae).

Interactive Poll:

- "Raise your hand if you think this is a seagrass"
- Record class responses for each image or sample
- Reveal: "Some of you had different answers. Why might these organisms be confusing?"

Question: "If they both live underwater and look green, how can we tell if something is a seagrass or macroalgae? Are they the same thing?"

PHASE 2: EXPLORATION

Activity 1: "Investigation Cards"

Students work in groups of 3-4. Each group receives:

- 2 large images: one clearly labelled seagrass, one clearly labelled macroalgae
- Investigation worksheet with observation prompts
- Magnifying glasses (if available)

Investigation Prompts (students record observations):

1. **Anchoring Structure:**
   - How does each organism attach to the substrate?
   - Draw what you observe at the base
2. **Internal Structure:**
   - Can you see tubes inside? Where?
   - What does this tell us about how materials move through the organism?
3. **Photosynthesis Zones:**
   - Where do you think photosynthesis happens in each organism?
   - Is it only in certain parts or everywhere?
4. **Overall Body Structure:**
   - Does it have distinct parts (roots, stems, leaves)?
   - Or is it more uniform throughout?
5. **Colour Observation:**
   - What colours do you observe in the macroalgae samples?

Teacher circulates, asking guiding questions:

- "What structures from our last lesson do you recognize in the seagrass?"
- "Do you see similar structures in the macroalgae?"
- "What's different about how they attach?"

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

Build a large comparison chart on the board as you explain (students create their own version):

Feature	Seagrasses	Macroalgae
Organism category	Flowering plants (angiosperms)	Simpler organisms (macroalgae)
Structure	Distinct organs: roots, rhizomes, shoots, leaves	Simple body (thallus) - no true organs
Anchoring	Rhizomes	Holdfast (just anchors to rocks/shells)
Where Photosynthesis Occurs	Only in leaf cells	All cells throughout the body
Nutrient and Mineral Uptake	Through roots from sediment and through leaves from seawater	Directly from seawater across their entire surface area
Internal Transport	Vascular system (nutrients, sugars-products of photosynthesis)	No internal transport system
Reproduction	Flowers, Fruits, Seeds	Spores (no flowers)

Detailed Explanation with Visuals (Fig. 1):

1. **What are Macroalgae?**
   - Multicellular autotrophs (make their own food)
   - Also called seaweeds
   - Much simpler than seagrasses

2. **Key Difference 1 - Anchoring:**
   - **Seagrasses**: rhizomes that anchor the plant into the sea-floor
   - **Macroalgae**: Simple holdfasts that just grip hard surfaces like rocks or shells (like a suction cup)

3. **Key Difference 2 - Internal Transport:**
   - **Seagrasses**: Have internal tubes (vascular system) inside the plant carrying nutrients and sugars (products of photosynthesis)
   - **Macroalgae**: No internal tubes. Each cell absorbs what it needs directly from seawater

4. **Key Difference 3 - Photosynthesis Location:**
   - **Seagrasses**: Only special cells in leaves do photosynthesis
   - **Macroalgae**: All cells can photosynthesise

5. **Key Difference 4 - Reproduction:**
   - **Seagrasses**: Flowers → fruits → seeds (just like land plants)
   - **Macroalgae**: Release spores into water (like mushrooms)

6. **Macroalgae Diversity - Three Groups** (Fig. 2)**:**
   - **Chlorophyta**: Green macroalgae
   - **Rhodophyta**: Red macroalgae
   - **Phaeophyta**: Brown macroalgae
   - Show representative images of each
   - These colours come from different pigments for photosynthesis

Address questions and clarify misconceptions.

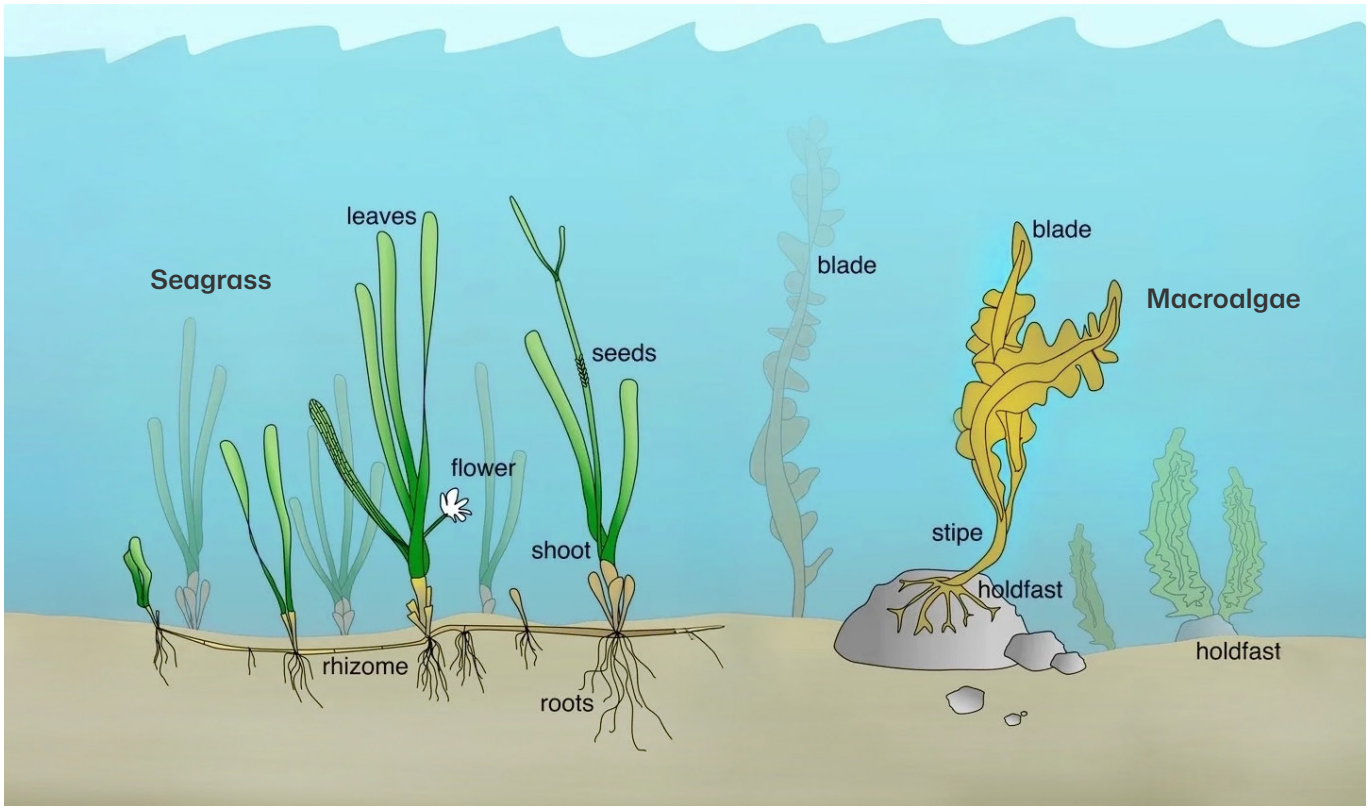


Figure 1. Schematic diagrams of a seagrass and macroalgae (modified from Seagrass-Watch https://www.seagrasswatch.org/).

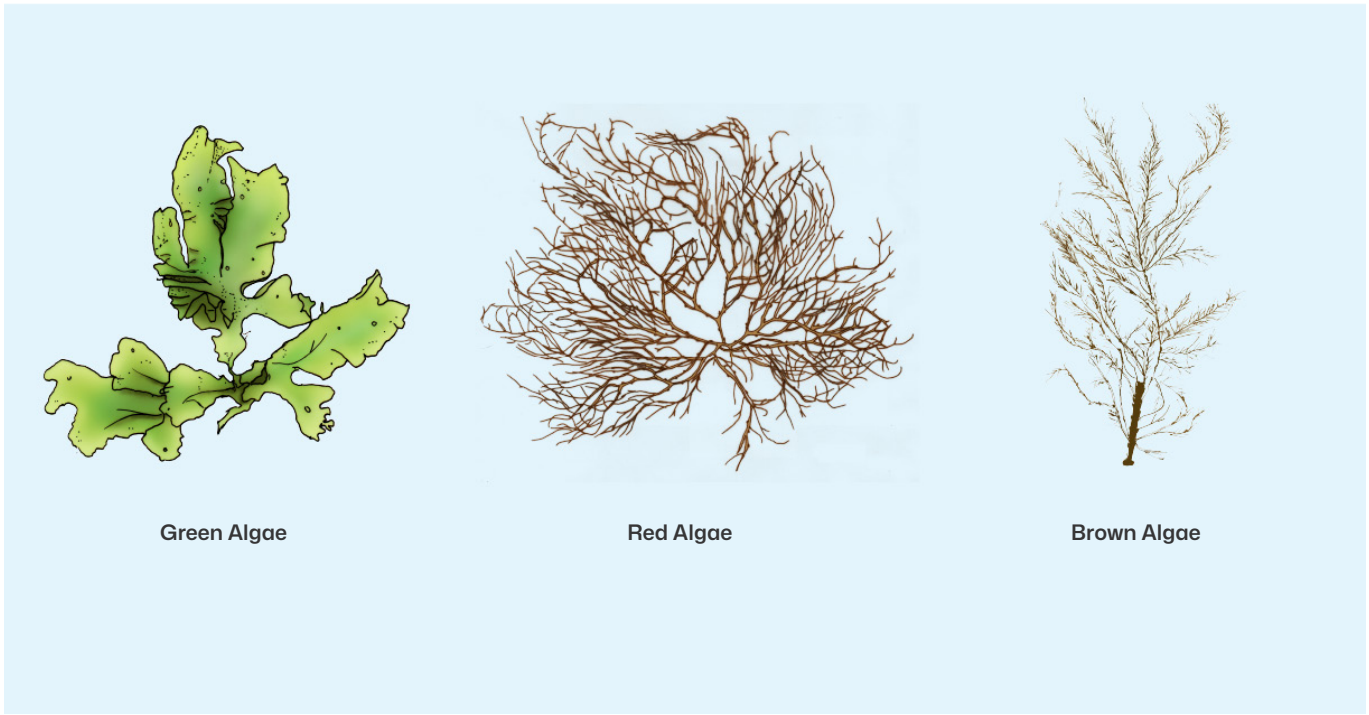


Figure 2. Schematic diagrams of green, red and brown macroalgae

PHASE 4: ELABORATION

Activity: "Identification Challenge"

Part A: Image Sort (5 minutes)

Display 10 images on screen or distribute printed cards to groups. Students must:

1. Classify each as "Seagrass" or "Macroalgae"
2. Write down two evidence clues they used for each identification

Example images might show:

- Seagrass with visible rhizome and roots
- Brown microalgae with holdfast
- Seagrass meadow from above
- Red macroalgae on rocks
- Green macroalgae close-up
- Seagrass with ribbon-like leaves

PHASE 5: EVALUATION

Assessment Activity: "Quick Quiz Exit Ticket"

Students complete individually:

1. **Matching:** Draw lines to connect features to the correct organism

Holdfasts for anchoring •	
Have vessels inside •	• Seagrasses
Reproduce with spores •	
True roots and rhizomes •	
All cells photosynthesise •	• Macroalgae
Flowers and fruits •	

2. **Real-World Scenario:** "You're snorkelling and find a green organism underwater attached to a rock. What things would you check to determine if it's a seagrass or macroalgae?"

1 _____

2 _____

3 _____

Success Criteria Shared with Students:

- I can list at least 4 differences between seagrasses and macroalgae
- I can use evidence (what I observe) to identify if an organism is a seagrass or macroalgae
- I can use scientific vocabulary accurately (holdfasts, vascular system, spores, etc.)

ASSESSMENT STRATEGIES

Formative Assessment (During the Lesson)

- Opening Poll Responses: Monitor initial student guesses to gauge prior misconceptions about seagrasses vs. macroalgae
- Investigation Worksheet Observations: Review group responses to the investigation prompts to check observation accuracy and vocabulary use
- Teacher Questioning: Use guiding questions to informally assess recall and comparative reasoning in real time
- Comparison Chart Co-Construction: Observe student contributions to check whether features are correctly matched to each organism
- Identification Challenge (Image Sort): Evaluate classifications and evidence clues to assess whether students apply criteria rather than surface appearance

Summative Assessment (End of Lesson)

- Quick Quiz Exit Ticket - Matching Task: Score individual accuracy in connecting features to the correct organism
- Real-World Scenario Response: Assess the identification criteria students propose, checking for evidence-based rather than colour-based reasoning

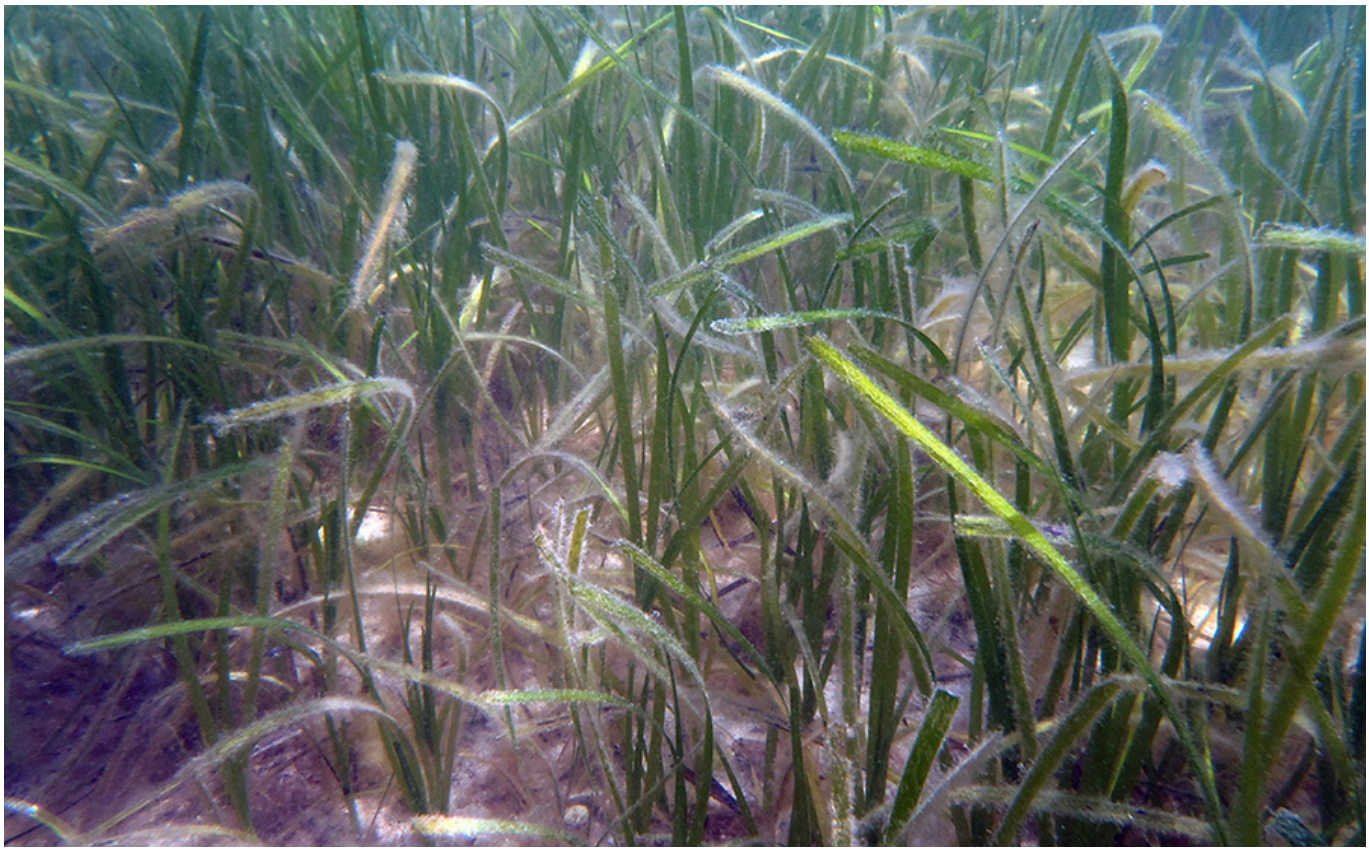
Appendix

Images of seagrasses and macroalgae

Seagrasses



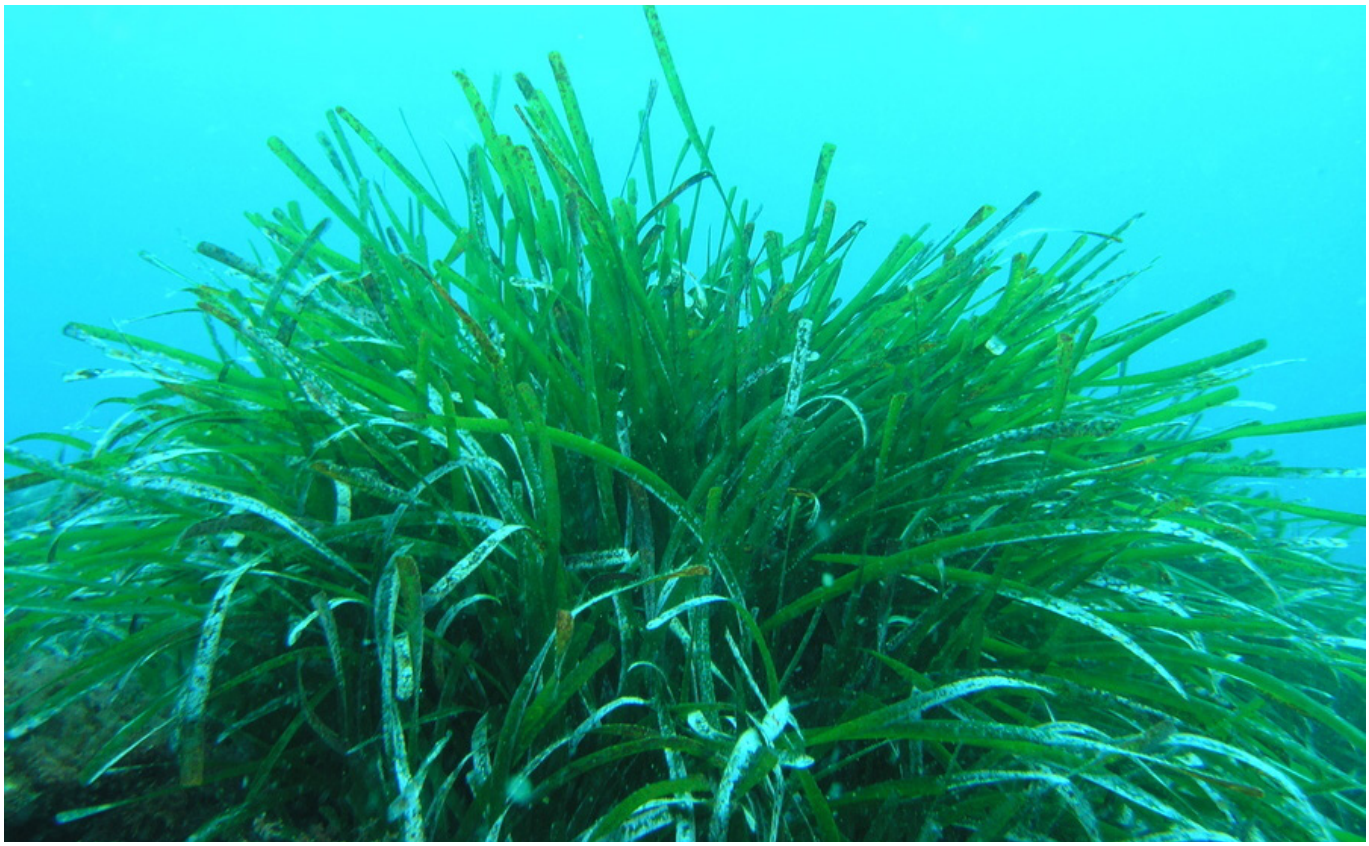
Cymodocea nodosa (Mar Menor, Murcia, Spain; photo credit Isabel Rubio Perez/AlgaeBase)
https://www.algaebase.org/search/images/detail/?img_id=25038



Zostera marina (Ria de Aldan, Galicia, Spain; photo credit Ignacio Bárbara/AlgaeBase)
https://www.algaebase.org/search/images/detail/?img_id=22743



Zostera noltei growing in the lower intertidal zone, Ría de Arousa, Galicia, Spain (photo credit Ignacio Barbara/AlgaeBase) https://www.algaebase.org/search/images/detail/?img_id=22783



Posidonia oceanica (Portals Vells, Mallorca, Balearic Islands, Spain; photo credit Eduardo Infantes Ordas/AlgaeBase) https://www.algaebase.org/search/images/detail/?img_id=11447

Green macroalgae

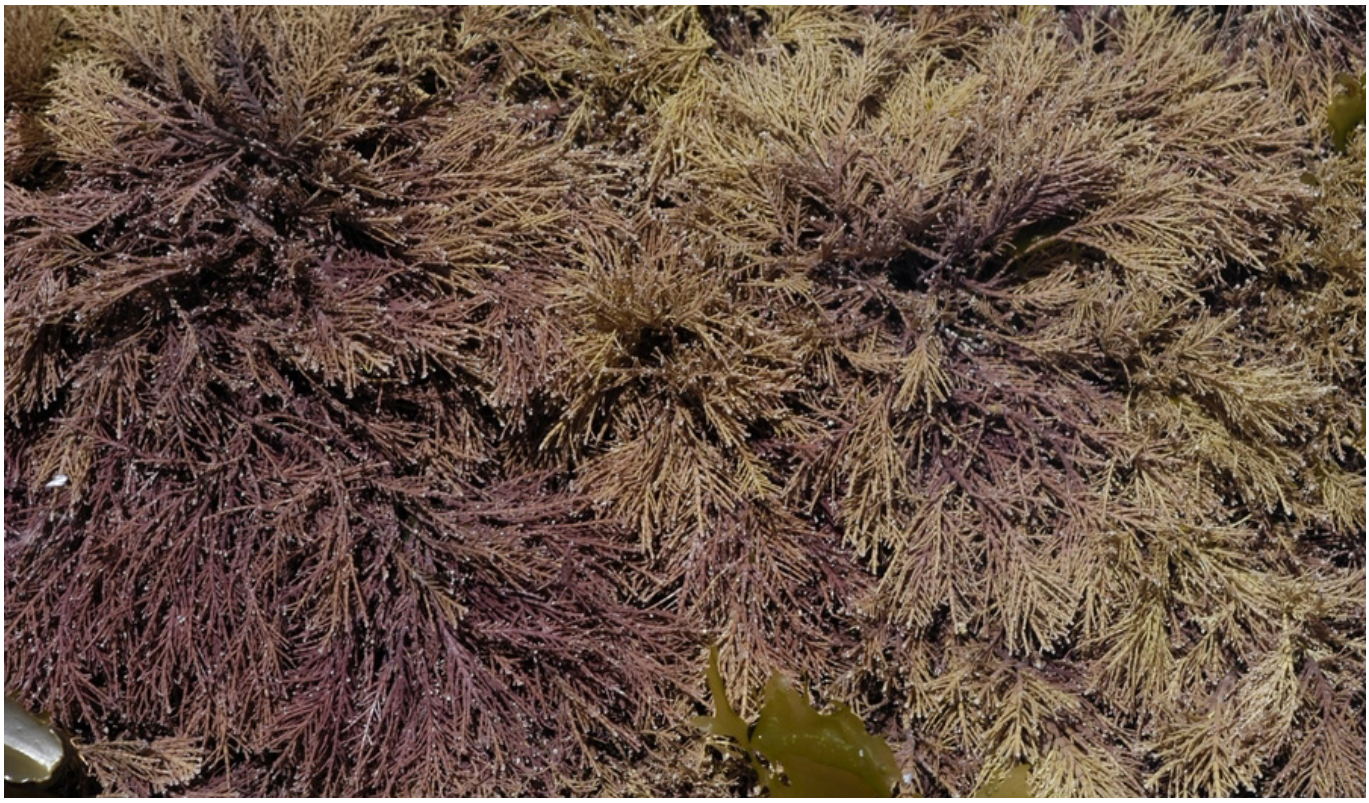


Ulva rigida (Black Hd., Co. Clare, Ireland; photo credit Michael Guiry)
https://www.algaebase.org/search/images/detail/?img_id=3904

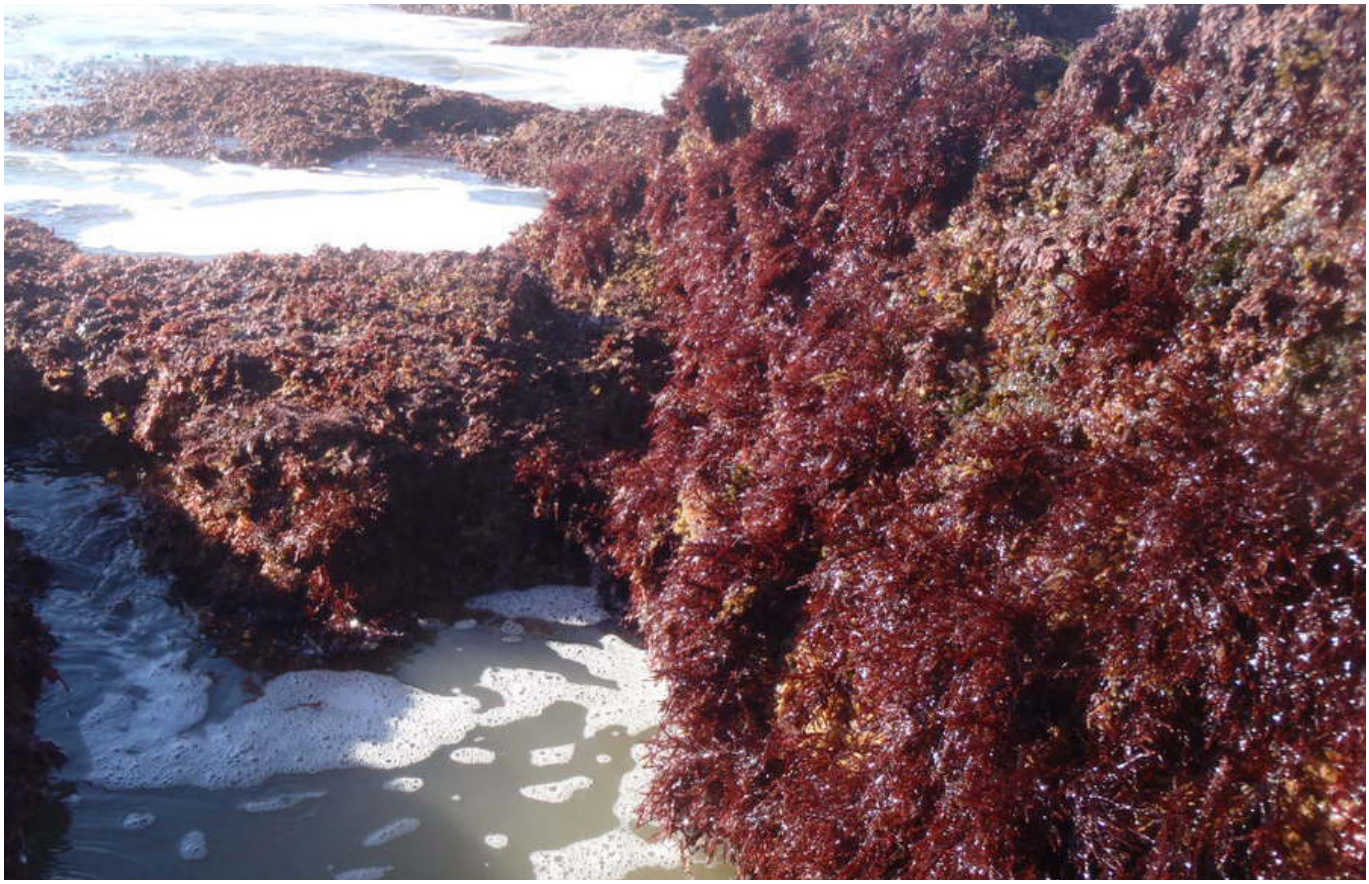


Codium fragile (Ria de A Coruna, Galicia, Spain; photo credit Ignacio Bárbara/AlgaeBase)
https://www.algaebase.org/search/images/detail/?img_id=12057

Red macroalgae

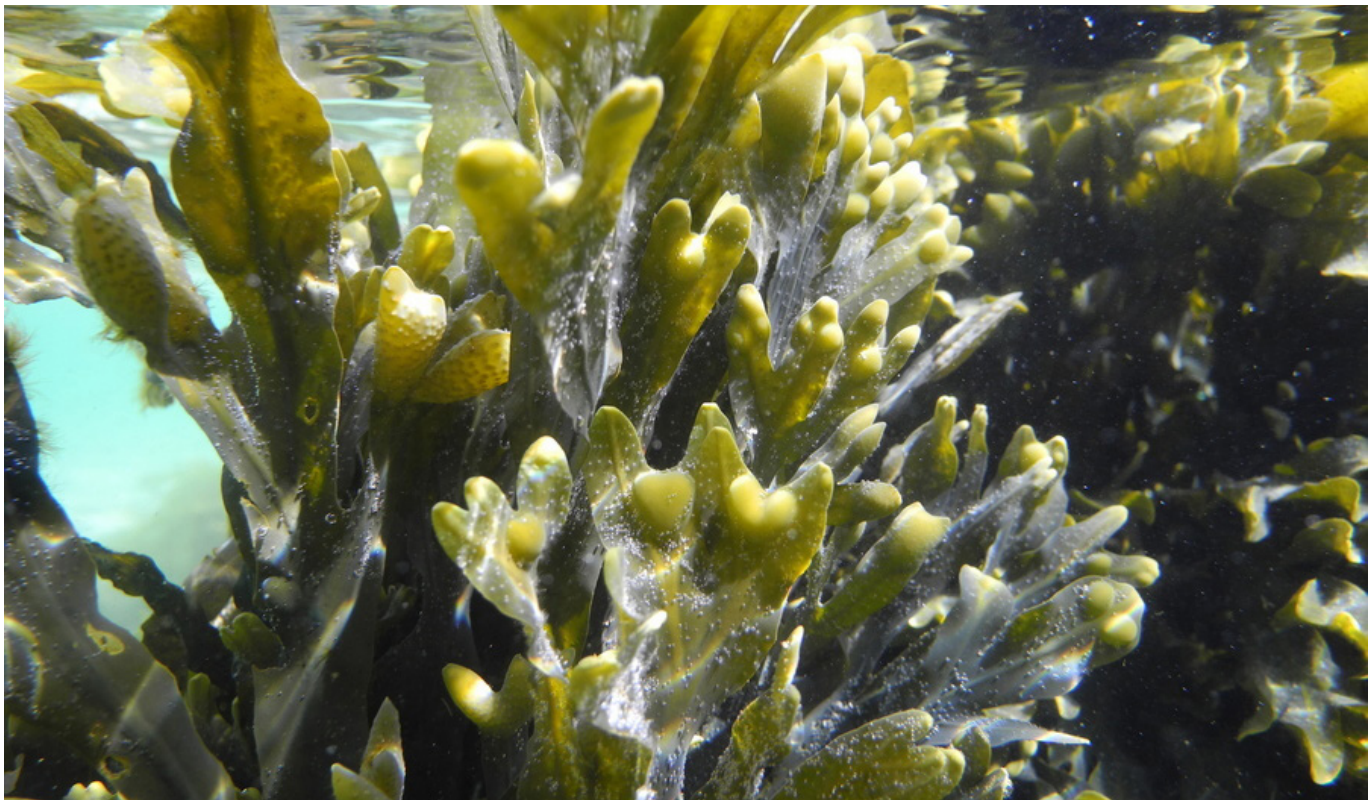


Corallina officinalis (Spanish Point, Co. Clare, Ireland; photo credit Michael Guiry/AlgaeBase)
https://www.algaebase.org/search/images/detail/?img_id=7285

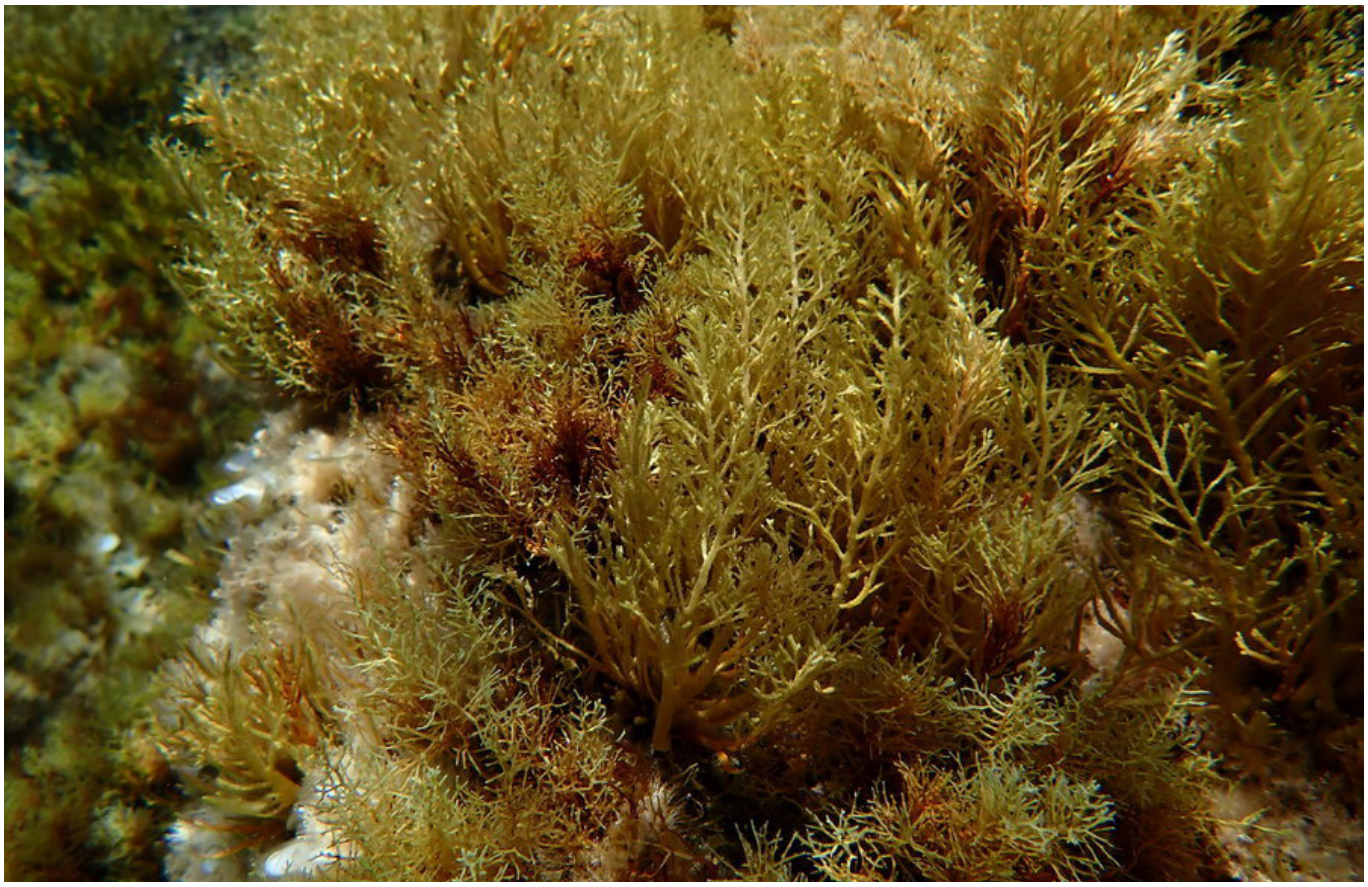


Gelidium corneum (South of Portugal; photo credit Ignacio Bárbara/AlgaeBase)
https://www.algaebase.org/search/images/detail/?img_id=18513

Brown macroalgae



Fucus vesiculosus (Silverstrand, Co. Galway, Ireland; photo credit M.D. Guiry/AlgaeBase)
https://www.algaebase.org/search/images/detail/?img_id=20906



Cystoseira compressa (Pantelleria, southern Italy; photo credit G. Marletta/AlgaeBase)
https://www.algaebase.org/search/images/detail/?img_id=35056

LESSON PLAN 3. SEAGRASS TAXONOMY & SPECIES IDENTIFICATION

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson introduces students to taxonomy—the science of describing, naming and classifying organisms—and guides them through identifying six key seagrass species. Through hands-on observation and comparison activities, students will focus on six representative species: *Halophila stipulacea, Cymodocea nodosa, Posidonia oceanica, Zostera marina, Zostera noltei* (a smaller relative of *Zostera marina*) and *Ruppia maritima* (a brackish water species). By examining sketches and photographs, students will identify distinctive features and learn to recognize each species.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Define taxonomy as the science of describing, naming and classifying organisms
- Explain why scientists use taxonomy to organize living organisms
- Identify that approximately 70 seagrass species exist worldwide
- Name six key seagrass species: *Halophila stipulacea, Cymodocea nodosa, Posidonia oceanica, Zostera marina, Zostera noltei*, and *Ruppia maritima*
- Describe distinctive features of each of the six species
- Use scientific naming conventions correctly (genus and species names)

Skills Objectives

By the end of this lesson, students will be able to:

- Observe and compare morphological features of different seagrass species
- Identify distinctive characteristics that differentiate species
- Organize observations systematically using comparison figures
- Work collaboratively to analyse visual evidence (sketches and photographs)
- Justify species identification using observable evidence

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Value scientific methods for organizing and communicating about biodiversity
- Show patience and attention to detail during observation activities

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Observe and record seagrass species characteristics
- Identify key species using morphological features
- Use scientific nomenclature and vocabulary accurately (taxonomy, genus, species)
- Document similarities and differences between species
- Draw evidence-based conclusions from visual observations

Environmental Literacy Competencies:

- Understand diversity within seagrass species

Digital Competencies:

- Use digital images for scientific observation and species identification
- Navigate databases of species (if available)

Social and Civic Competencies:

- Work effectively in teams on observation and identification activities
- Share observations and contribute to group understanding
- Support peer learning through collaborative species identification

MATERIALS NEEDED

Required:

- Species Investigation Packs (one per group):
  - 3-4 photographs per species of *Halophila stipulacea, Cymodocea nodosa, Posidonia oceanica, Zostera marina, Zostera noltei, and Ruppia maritima*
  - 1-2 detailed sketches per species
  - Magnified detail images (leaf tips, rhizomes, sheaths, etc.)

Enhanced:

- Actual preserved specimens (if available)
- Magnifying glasses for detail observation
- Video clips showing each species in its natural habitat (1-2 minutes total):

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "Mystery Species Gallery"

Display 6 unlabelled images of the six focal species on the board/screen (see Appendix):

- *Halophila stipulacea*
- *Cymodocea nodosa*
- *Posidonia oceanica*
- *Zostera marina*
- *Zostera noltei*
- *Ruppia maritima*

Interactive prompt:

- "These are all seagrasses, but they look quite different! What differences do you notice?"
- Students share observations (size, leaf shape, overall appearance)
- "How can scientists around the world talk about these different types and make sure they're discussing the same plant?"

Hook question: "Imagine you're a marine scientist in Greece and you want to share your seagrass findings with a scientist in Portugal. How do you make sure you're both talking about the exact same species?"

Learning Intention Shared: "By the end of this lesson, you'll be able to identify six key seagrass species".

PHASE 2: EXPLORATION

Activity 1: "Species Detective Teams"

Divide class into 6 groups. Each group receives a "Species Investigation Pack" for one of the six species:

Investigation Packs include:

- 3-4 photographs of the species from different angles
- a detailed sketch showing key features (see Appendix)
- Blank observation worksheet

Observation Worksheet prompts each group to record:

A. Leaf Characteristics:
- Shape (oval? ribbon-like? strap-shaped?)
- Size (small? medium? large?)
- Width (very narrow? medium? wide?)
- Tip shape (rounded? pointed? notched?)
- Arrangement (how are leaves attached?)

B. Rhizome & Root Features:
- Rhizome thickness (thin? robust?)
- Only horizontal rhizomes, or both horizontal and vertical rhizomes
- Any distinctive features on rhizomes?
- Root characteristics

C. Overall Appearance:
- Does it look delicate or robust?
- Any unique structures (sheaths, fibers, etc.)?

D. Most Distinctive Feature:
- What is the one thing that makes this species stand out?

Group Work:
- Groups examine their images and sketches carefully
- They discuss and record observations on worksheet
- Teacher circulates asking guiding questions:
  - "What's the first thing you notice about the leaves?"
  - "How would you describe the leaf shape to someone who can't see the photo?"
  - "What makes this species different from the others you've seen?"

Quick Gallery Rotation:
- Each group displays their investigation pack and worksheet at their table
- Groups rotate quickly to see the other three species
- Students observe the differences

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

Part A: What is Taxonomy and Why Do We Need It?
- Scientists organize organisms in a hierarchy to make sense of diversity.
- **Taxonomy** = the science of identifying, naming and classifying living organisms, i.e., organizing living organisms from very big groups to very small groups. At the top, organisms only share a few general things. As we go down, they share more and more similarities.
- For all living species: **Domain → Kingdom → Phylum→ Class → Order →Family → Genus → Species**

Why taxonomy matters:

- About **70 seagrass species** exist worldwide—we need organization
- Scientists in different countries speak different languages, but scientific names are universal
- Conservation efforts need accurate identification
- Research requires knowing exactly which species is being studied

Scientific Naming Convention:

- Two-part names: **Genus** (the first letter capitalized) + **species** (lower-case)
- Written in italics: *Posidonia oceanica*
- *Posidonia* = genus (like a family surname)
- *oceanica* = species (like a first name)

Part B: The six Seagrass Genera & Our Focus Species

Build a comparison table on the board as students present:

Genus	Focus Species	Distinctive Features
Halophila	*Halophila stipulacea*	Small leaves in pairs, blades oblong-elliptic, transparent sheaths, delicate appearance Rhizome creeping with a short erect lateral shoot and one unbranched root at each node. Each lateral shoot with 2 sheaths at the base and a pair of petiolate leaves at the top. Apical shoot with 3 leaf pairs. Sheaths transparent, covering the short petioles. Blades oblong, elliptic, up to 6 cm long, 10 mm wide; margin serrulate; mid-rib vein and intramarginal lateral veins connected by cross veins.
Cymodocea	*Cymodocea nodosa*	Narrow strap leaves, vertical rhizomes, long, white or pink internodes of the horizontal rhizomes Horizontal rhizome with a diameter of up to 4 mm, with lateral branches; at each node 1 strongly branched root and a short erect stem bearing 2-5 leaves. Leaf sheath linear, when shed leaving a closed circular scar on the erect stem. Leaf blades linear, up to 30-40 cm long and 2-4 mm wide, with 7-9 longitudinal veins*; apex rounded, sometimes slightly notched. *The veins are observed on the surface of the blade with a magnifying glass or a stereoscope, and on a cross-section under a microscope.
Posidonia	*Posidonia oceanica*	Robust, wide strap leaves, brown fibrous remains on rhizomes (like paintbrush!) Vertical rhizomes attached to horizontal rhizomes that branch. Rhizome diameter of 5-10 mm. Roots 3-4 mm thick, up to 40 cm long and richly branched. Leaf bundles consisting of 5 to 10 leaves attached to a vertical rhizome. Strap-shaped leaves 5-12 mm wide and 40-50 cm long, up to 1 m, with 13-17 longitudinal veins; apex obtuse to emarginate. The most robust seagrass in Mediterranean. Numerous brown fibrous remains of old sheaths covering the rhizomes like a paintbrush.

Genus	Focus Species	Distinctive Features
Zostera	*Zostera marina*	Long ribbon-like leaves, only horizontal rhizomes, closed leaf sheaths Only horizontal rhizomes with 1-3 cm long internodes. Leaf blades 30-60 cm long, 3-12 mm wide; longitudinal veins 5-11; blade apex rounded to slightly mucronate. Leaf sheath closed.
Zostera	*Zostera noltei*	Much smaller than *Zostera marina*, ribbon-like but very narrow leaves, only horizontal rhizomes Only horizontal rhizomes. Leaf blades up to 30 cm long and 0.5-1.5 mm wide, with 3 longitudinal veins; apex often asymmetrically notched. Leaf sheath open.
Ruppia	*Ruppia maritima*	Very slender appearance - extremely narrow leaves Very slender stems, up to 40 cm long, branched. Leaves 0.4-1.0 mm wide, 2-11.5 cm long, with pointed tips. Leaves are held in membranous sheaths. Slender horizontal rhizomes (width 0.8-1.0 mm) with fine roots.

Detailed presentation of each species from each group supported by the teacher (use images/ sketches):

1. ***Halophila stipulacea***
    - **Most distinctive feature:** Paired small leaves, blades oblong-elliptic (not strap-shaped)
    - Small, delicate appearance
    - Transparent sheaths at leaf base
    - Short petioles (leaf stalks)
    - Very different from the other five species
2. ***Cymodocea nodosa***
    - **Most distinctive feature:** Long, white or pink horizontal rhizome internodes + vertical rhizomes (erect stems)
    - Narrow strap-like leaves (30-40 cm long, 2-4 mm wide)
    - Leaves usually 2-5 per shoot
    - Rounded or slightly notched leaf tips
3. ***Posidonia oceanica***
    - **Most distinctive feature:** Brown fibrous remains of old sheaths covering rhizomes (looks like a paintbrush)
    - Wide strap-shaped leaves (5-12 mm wide)
    - Can grow very long (40-50 cm, sometimes up to 1m)
    - 5-10 leaves per bundle
    - Very robust seagrass
4. ***Zostera marina***
    - **Most distinctive feature:** long ribbon-like leaves with closed sheaths, only horizontal rhizomes
    - Moderate to robust size
    - Leaves 30-60 cm long, 3-12 mm wide
    - Rounded to slightly pointed leaf tips
    - 3-7 leaves per shoot

5. ***Zostera noltei***
    - **Most distinctive feature:** Much smaller than *Zostera marina*, ribbon-like but very narrow leaves (0.5-1.5 mm wide), only horizontal rhizomes
    - Only 3 longitudinal veins (compared to 5-11 in *Zostera marina*)
    - Leaf apex often asymmetrically notched
    - Open leaf sheath (vs. closed in *Zostera marina*)
    - Often found in intertidal areas
6. ***Ruppia maritima***
    - **Most distinctive feature:** Very slender appearance - extremely narrow leaves (0.4-1.0 mm wide)
    - Leaves 2.0-11.5 cm long with pointed, slightly toothed tips
    - Fine, slender rhizomes (0.8-1.0 mm width)
    - Found in brackish water environments
    - **Note**: Scientists debate whether *Ruppia* species should be classified as "true" seagrasses

Interactive check using images:

- Show image: "Which species has paired small leaves, oblong-elliptic blades?" (*Halophila stipulacea*)
- Show image: "Which one has the fibrous 'paintbrush' rhizomes?" (*Posidonia oceanica*)
- Show image: "Which has long, white/pink rhizome internodes?" (*Cymodocea nodosa*)

PHASE 4: ELABORATION

Activity: "Species Identification Challenge"

Part A: Team Comparison Chart

Students work in their original groups of 3-4. Each group receives a large blank comparison chart with all six species.

Chart Template

Feature	*Halophila stipulacea*	*Cymodocea nodosa*	*Posidonia oceanica*	*Zostera marina*	*Zostera noltei*	*Ruppia maritima*
Leaf Shape						
Leaf Width						
Rhizome Feature						
Most Distinctive Characteristic						

Task:

Groups work together to fill in the chart based on:

- Their own species investigation from Phase 2
- Information from groups' explanation
- Observations from gallery rotation

Teacher circulates, asking comparative questions:

- "Which species has the widest leaves?"
- "Which species is most delicate?"
- "What's similar between *Cymodocea* and *Zostera*? What's different?"
- "How can you tell *Halophila* apart from the other five immediately?"

Part B: Identification Quiz Game

Teacher displays 8-10 images from algaebase.org (mix of the six species, multiple images per species). Images should show different angles, growth stages, or habitat contexts.

Students work in pairs with mini-whiteboards or paper:

- Teacher shows each image for 30 seconds
- Pairs write down which species they think it is
- Quick reveal and scoring

Discussion after quiz:

- "Which species was easiest to identify? Why?"
- "What features did you look for first?"
- "Which species were most similar to each other?"

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket - "Species Identification & Taxonomy Check"

Students complete individually:

Part 1: Species Identification

[Provide 4 small images, one of each species]

Match each image to the correct species name:

Image A: _____

Image B: _____

Image C: _____

Image D: _____

Part 2: Scientific Naming

In the name *Cymodocea nodosa*, circle the name of the genus.

Part 3: Reflection

The easiest species for me to identify is _____ because:

ASSESSMENT STRATEGIES

Formative Assessment (During Lesson):

- Students systematically examine visual materials
- Students record accurate observations on worksheets
- Students identify distinctive morphological features
- Students engage in productive species comparison discussions
- Students use descriptive vocabulary appropriately
- During explanation: "Which species has paired leaves?"
- During elaboration: "How can you tell these two species apart?"
- Note questions students ask about unfamiliar species
- Assess understanding of similarities and differences
- Identify common errors or misconceptions
- Track which species students identify correctly/incorrectly
- Note which images cause most confusion

Summative Assessment (End of Lesson):

1. Exit Ticket Evaluation Activity (described above)

2. Success Criteria Shared with Students:

- I can recognize all six species from photographs
- I can name at least one distinctive feature for each species
- I can explain what makes each species different from the others
- I can identify the genus in a scientific name

Appendix

Apart from the photos provided below, teachers and/or students are encouraged to search AlgaeBase (https://www.algaebase.org/) for additional representative photos of each species by entering the scientific name (genus + species) in the search bar.



Figure 1. *Halophila stipulacea* (Tanzania; photo credit Katrin Oesterlund/Algaebase)
https://www.algaebase.org/search/images/detail/?img_id=12438



Figure 2. *Cymodocea nodosa* (Mar Menor, Murcia, Spain; photo credit Isabel Rubio Perez/AlgaeBase)
https://www.algaebase.org/search/images/detail/?img_id=25038

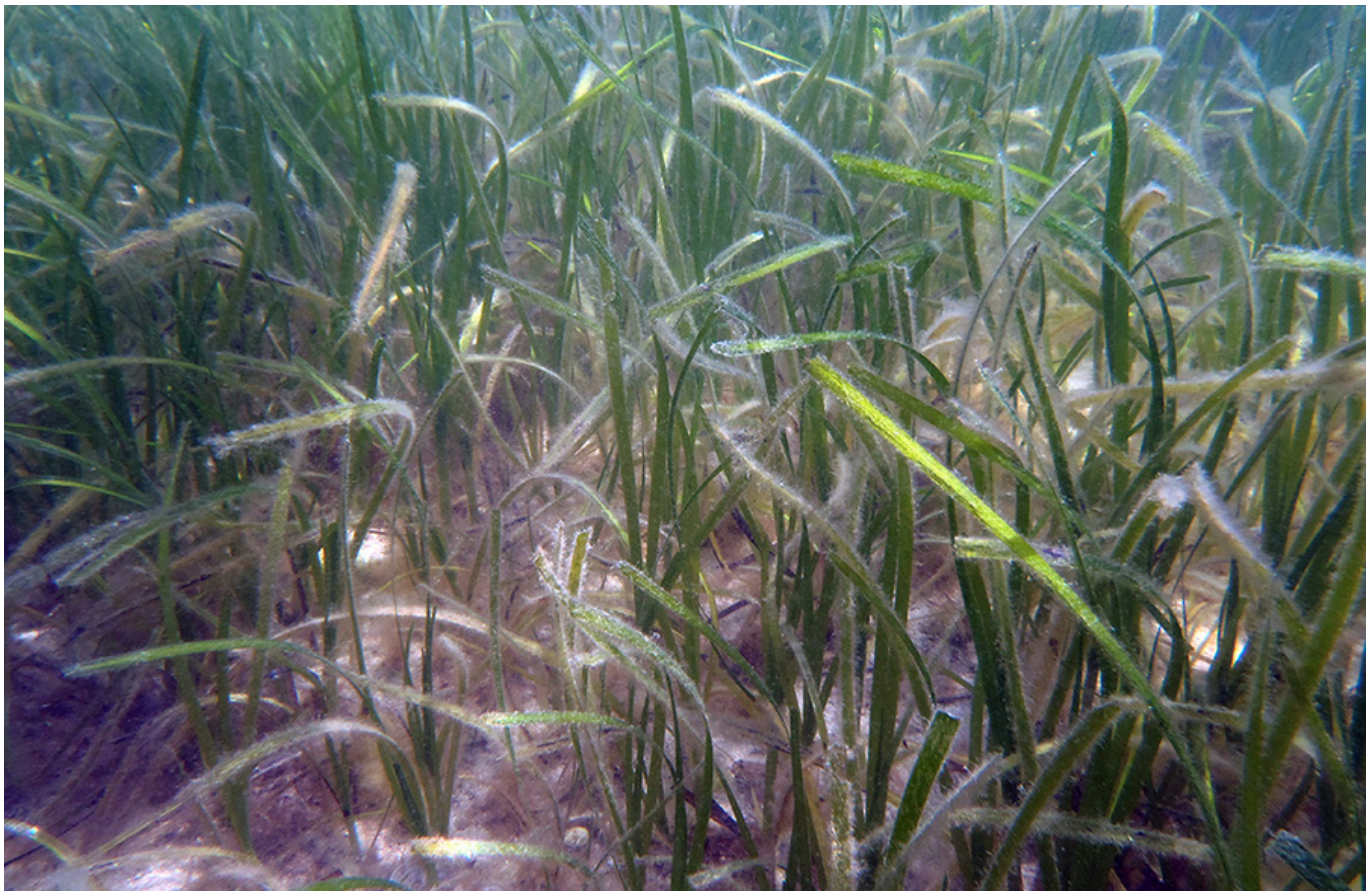


Figure 3. *Zostera marina* (Ria de Aldan, Galicia, Spain; photo credit Ignacio Bárbara/AlgaeBase) https://www.algaebase.org/search/images/detail/?img_id=22743



Figure 4. *Zostera noltei* growing in the lower intertidal zone, Ría de Arousa, Galicia, Spain (photo credit Ignacio Barbara/AlgaeBase) https://www.algaebase.org/search/images/detail/?img_id=22783

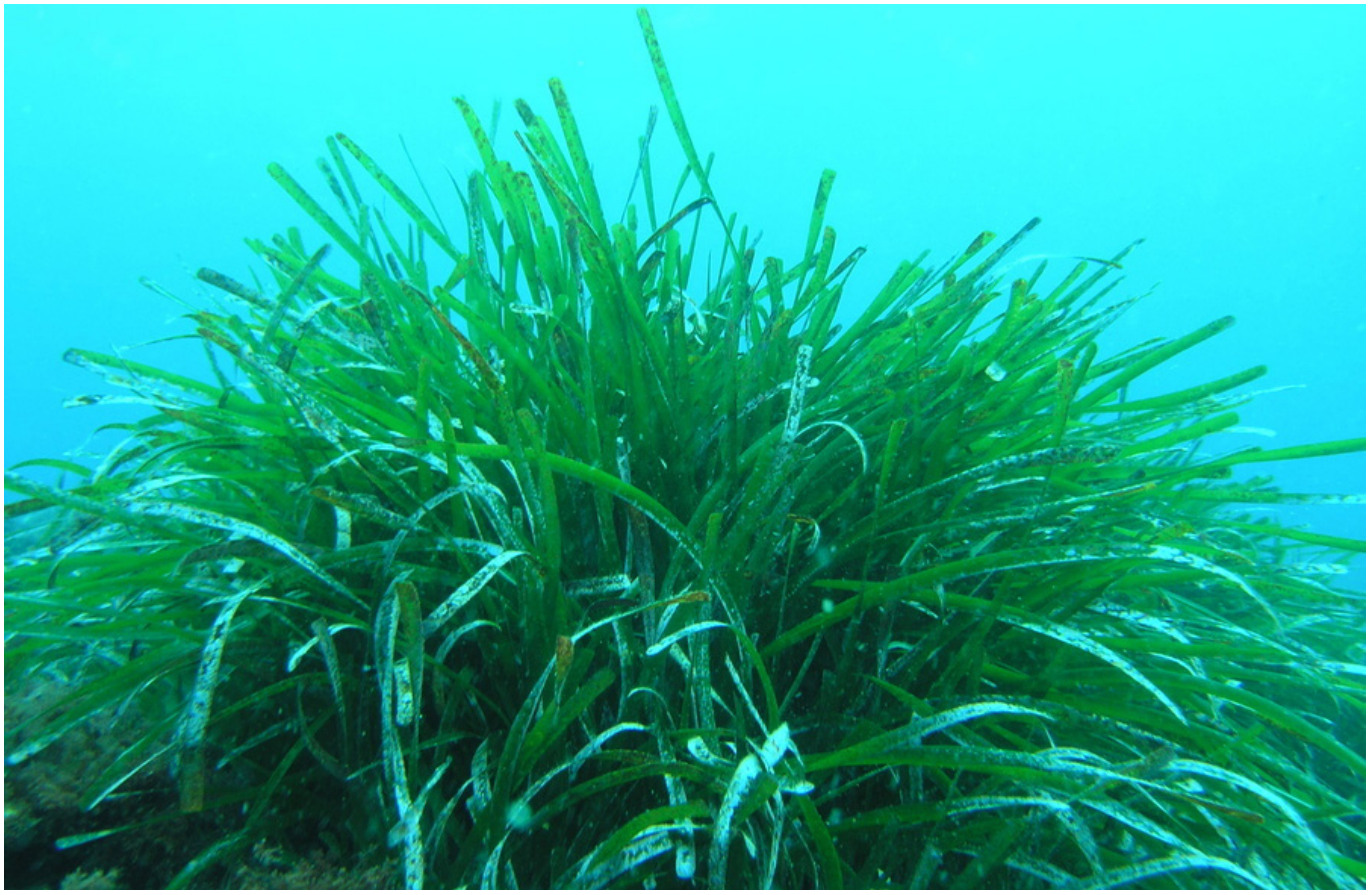


Figure 5. *Posidonia oceanica* (Portals Vells, Mallorca, Balearic Islands, Spain; photo credit Eduardo Infantes Ordas/AlgaeBase) https://www.algaebase.org/search/images/detail/?img_id=11447



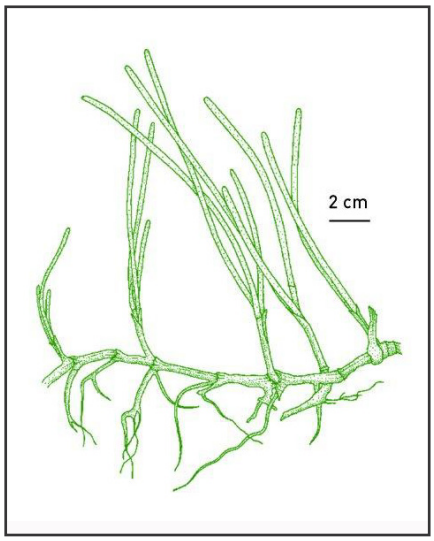
Figure 6. *Ruppia maritima* (Indian River Lagoon; photo credit Diane Litter/Algaebase) https://www.algaebase.org/search/images/detail/?img_id=13956

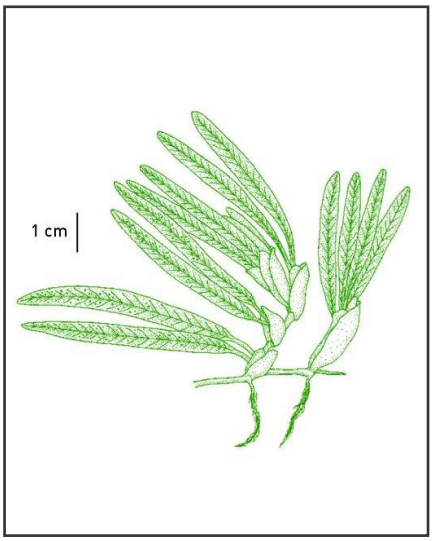
Representative photo and sketch of each species











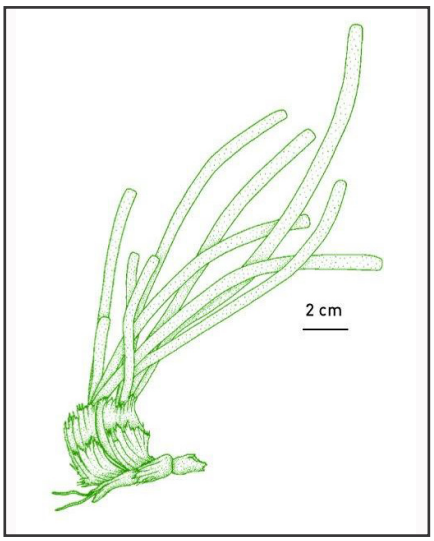


Figure 7

Cymodocea nodosa
(photo credit Paraskevi Malea; Schematic depiction from Green E.P. and Short F.T., 2003. World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA)

Figure 8

Halophila stipulacea
(photo credit Paraskevi Malea; schematic depiction from Green E.P. and Short F.T., 2003. World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA)

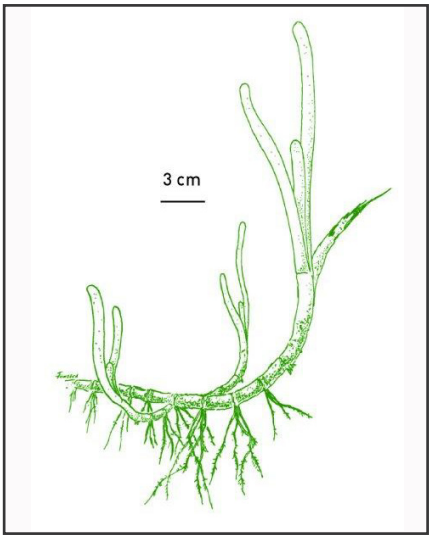
Figure 9

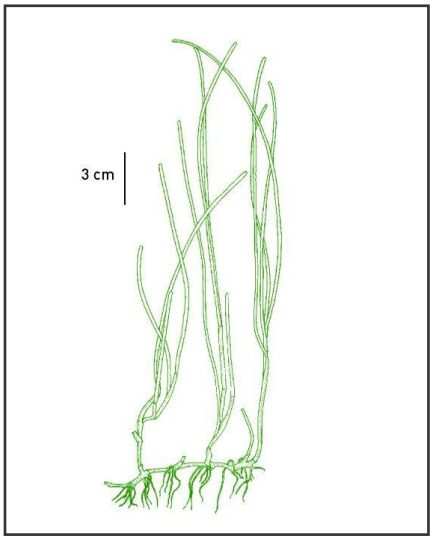
Posidonia oceanica
(photo credit Paraskevi Malea; schematic depiction from Green E.P. and Short F.T., 2003. World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA)











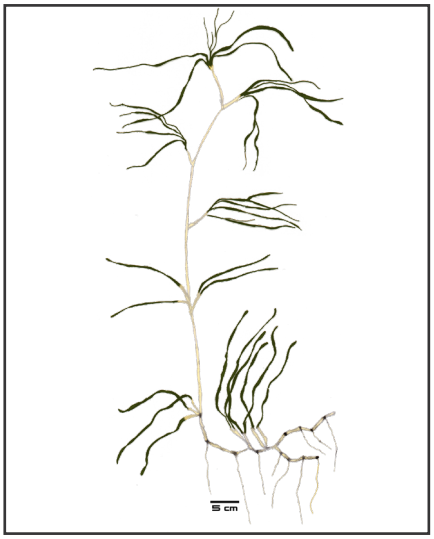


Figure 10

Zostera marina
(photo credit Michael Guiry/AlgaeBase; schematic depiction from Green E.P. and Short F.T., 2003. World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA)

Figure 11

Zostera noltei
(photo credit Ignacio Barbara/AlgaeBase; schematic depiction from Green E.P. and Short F.T., 2003. World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA)

Figure 12

Ruppia maritima
(photo credit Paraskevi Malea; schematic depiction from T. Kevrekidis et al., 2024. Exploring the coastal lagoons, Hellenic Foundation for Research and Innovation)

LESSON PLAN 4. WORLD SEAGRASS DISTRIBUTION

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson explores the global distribution of seagrasses and introduces students to the concept of seagrass bioregions—large geographical areas with characteristic seagrass species assemblages. Building on their taxonomic knowledge from Lesson 3, students will discover that seagrasses grow on every continent except Antarctica, with approximately 160 countries hosting seagrass meadows. Through map-based activities and comparative analysis, students will explore the six global seagrass bioregions (four temperate, two tropical) and understand how seagrass diversity varies across the planet. The lesson concludes with a focused look at seagrass species occurring in Europe coastal waters, connecting global patterns to local relevance.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Identify that seagrasses occur in coastal waters of more than 160 countries worldwide
- Recognize that seagrasses are absent only from Antarctic shores
- Define a bioregion as a geographical area with characteristic seagrass species assemblages
- Name the six global seagrass bioregions: Temperate North Atlantic, Tropical Atlantic, Mediterranean, Temperate North Pacific, Tropical Indo-Pacific, and Temperate Southern Oceans
- Distinguish between temperate and tropical bioregions
- Identify the three centres of high seagrass diversity (Southeast Asia, Japan/Korea, southwestern Australia)
- Name at least 3-5 seagrass species found in European coastal waters (*Posidonia oceanica, Zostera marina, Zostera noltei, Cymodocea nodosa, Halophila stipulacea*)
- Recognize that the Mediterranean is a moderate diversity bioregion dominated by *Posidonia oceanica*
- Recognize that the Temperate North Atlantic is a low diversity bioregion dominated by *Zostera marina*

Skills Objectives

By the end of this lesson, students will be able to:

- Read and interpret global distribution maps
- Locate bioregions on a world map

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Develop awareness of local seagrass species and their bioregional context
- Recognize international cooperation as very important in seagrass conservation across bioregions

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Identify key species within specific bioregions
- Use geographical terminology accurately (bioregion, distribution, temperate, tropical)
- Interpret scientific maps and biodiversity visualizations

Environmental Literacy Competencies:

- Understand biogeographical patterns

Digital Competencies:

- Use digital maps

Social and Civic Competencies:

- Work effectively in groups on geographical analysis activities
- Share findings about different seagrass bioregions
- Understand that seagrass conservation requires international cooperation

MATERIALS NEEDED

Required:

- Large world map (printed poster or digital projection) for whole-class use
- 6 bioregion information cards (one per group) (information in the SEAQUEST Curriculum for Teachers)
- Global seagrass biodiversity map (see Appendix, Fig. 1)
- Seagrass bioregions map (see Appendix, Fig. 2)
- Blank bioregion comparison chart (one per student pair)
- Mini world map outlines (one per group for shading activity) (see Appendix, Fig. 3)
- Images or illustrations of the 5 seagrass species occurring in Europe's coastal waters

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "Seagrass World Tour"

Display a blank world map on the board/screen with 6-8 coastal locations marked with question marks (e.g., Mediterranean Sea, Caribbean, Australia, North Atlantic, Japan, East Africa, Antarctica).

Interactive poll:

- "I'll show you a coastal location. Give me thumbs up if you think seagrasses grow there, thumbs down if you think they don't."
- Reveal each location one by one
- Students vote with thumbs
- Keep a tally: How many locations have seagrasses?

Surprise reveal: "Seagrasses grow in more than 160 countries around the world—on every continent except one! Can anyone guess which continent has no seagrasses?"

Answer: Antarctica

Hook question: "Some places have 5 species of seagrasses, while others have 24 species! Why might some regions have more seagrass diversity than others?"

Learning Intention Shared: "Today we're going on a global journey to discover where seagrasses live, why certain regions have more species, and which seagrasses grow right here in European waters."

PHASE 2: EXPLORATION

Activity 1: "Bioregion Explorer Cards"

Divide class into 6 groups. Each group receives an information card about one bioregion plus a mini world map outline (Fig. 3).

Each bioregion card includes:

- Bioregion name and location
- Number of species
- Photo/illustration

The Six Bioregions (Teacher distributes these):

1. **Temperate North Atlantic** (5 species)
   - Location: North Carolina, USA to Portugal
2. **Tropical Atlantic** (10 species)
   - Location: Caribbean, Gulf of Mexico, Bermuda, Bahamas, both tropical Atlantic coasts
3. **Mediterranean** (9 species)
   - Location: Mediterranean Sea, Black, Caspian, and Aral Seas, northwest Africa
4. **Temperate North Pacific** (15 species)
   - Location: Korea to Baja, Mexico
5. **Tropical Indo-Pacific** (24 species)
   - Location: East Africa, south Asia, tropical Australia to eastern Pacific
6. **Temperate Southern Oceans** (18 species)
   - Location: New Zealand, temperate Australia, South America, South Africa

Group Task:

1. Read your bioregion card together
2. Colour/shade your bioregion on the mini world map
3. Prepare to share three key facts with the class:
    - Where is it located?
    - How many species does it have?

Gallery Walk: Groups quickly rotate to see other bioregions' maps

Activity 2: "Diversity Hot Spots"

Teacher displays global seagrass biodiversity map showing colour gradients (darker = more species).

Guided observation:

- "Look at this map. Where do you see the darkest colours (most species)?"
- "What pattern do you notice? Are the high-diversity areas close together or spread out?"

Key points to highlight:

- Three centres of high diversity: Southeast Asia (largest), Japan/Korea, southwestern Australia
- All three are in the Eastern Hemisphere
- Other significant diversity: southern India, eastern Africa

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

Part A: Global Distribution Patterns

Using a large world map or digital projection:

Worldwide Presence:

- Seagrasses occur in more than 160 countries
- Found in all coastal waters except Antarctic shores
- Why no Antarctica? (extreme cold, low light availability)
- *Zostera marina* cross the Arctic Circle in Europe and exists in northern Pacific

Temperate vs. Tropical Genera:

- **7 tropical genera:** *Thalassia, Halophila, Syringodium, Halodule, Cymodocea, Thalassodendron, Enhalus*
- **5 temperate genera:** *Zostera, Phyllospadix, Heterozostera, Posidonia, Amphibolis*

Important exception: These categories aren't rigid.

- A *Cymodocea* species (tropical genus), specifically *Cymodocea nodosa* thrives in temperate Mediterranean
- *Zostera* species (temperate genus) also found in tropical coasts

Part B: The Six Global Seagrass Bioregions

What is a Bioregion?

- A bioregion is a large geographical area with characteristic seagrass species assemblages
- Assemblage : groups of different species that coexist in the same place at the same time

Four Temperate Bioregions:

Four Temperate Bioregions (the corresponding students' group support the teacher):

1. **Temperate North Atlantic** (lowest diversity, 5 species)
2. **Temperate North Pacific** (high diversity, 15 species)
3. **Mediterranean** (moderate diversity, 9 species, temperate/tropical mix)
4. **Temperate Southern Oceans** (low to high diversity, 18 species)

Two Tropical Bioregions (the corresponding students' group support the teacher):

1. **Tropical Atlantic** (high diversity, 10 species)
2. **Tropical Indo-Pacific** (highest diversity, 24 species—largest bioregion)

At the end of the task the teacher presents Fig. 2 where all bioregions are shown.

Part C: Focus on Europe's coastal waters

Seagrass Species in Europe: Five main species in Europe's coastal waters

- ***Posidonia oceanica*** – Mediterranean superstar
- ***Zostera marina*** – Widespread in northern coasts/latitudes
- ***Zostera noltei*** – Smaller
- ***Cymodocea nodosa*** – Mediterranean and Atlantic Portugal/Africa
- ***Halophila stipulacea*** – Originally Indian Ocean and Red Sea, introduced to Mediterranean via Suez Canal

Plus: *Ruppia maritima* (brackish water species, some debate if "true" seagrass)

Mediterranean Bioregion Characteristics:

Geographic Range: Mediterranean, Black, Caspian and Aral Seas, NW Africa

Species Diversity: Moderate diversity seagrasses, temperate/tropical mix of species (9 species)

Dominant Species: *Posidonia oceanica* (endemic of Mediterranean Sea—only found here)

Temperate North Atlantic Bioregion Characteristics:

Geographic Range: North Carolina, USA to Portugal

Species Diversity: Low diversity temperate seagrasses (5 species)

Dominant Species: *Zostera marina*

Interactive check:

- "Which bioregion has the most species? (Tropical Indo-Pacific: 24)"
- "Which has the least? (Temperate North Atlantic: 5)"
- "Name one seagrass species occurring in European waters" (Multiple answers accepted)

PHASE 4: ELABORATION

Activity: "Bioregion Comparison & European Species Match"

Part A: Bioregion Data Analysis

Students work in pairs. Provide a comparison chart:

Bioregion	Number of Species	Temperate or Tropical?
Temperate North Atlantic	5	Temperate
Tropical Atlantic	10	Tropical
Mediterranean	9	Mixed
Temperate North Pacific	15	Temperate
Tropical Indo-Pacific	24	Tropical
Temperate Southern Oceans	18	Temperate

Analysis Questions (students discuss and record answers):

1. Which bioregion has the highest diversity?
   - Tropical Indo-Pacific (24)
2. What pattern do you notice between temperate and tropical bioregions?
   - Both can have high diversity, but Tropical Indo-Pacific is highest

Part B: Seagrass Species Detective

Matching Activity:

Display 5 brief descriptions or images. Students match them to the correct seagrass species name.

Clues:

1. "I'm the Mediterranean champion, with fibrous remains on my rhizomes like a paintbrush.
   - Answer: *Posidonia oceanica*
2. "I'm found all along northern European coasts and can even survive in the Arctic Circle. My leaves are long ribbons.
   - Answer: *Zostera marina*
3. "I'm the smaller cousin of another *Zostera* species.
   - Answer: *Zostera noltei*
4. "I'm a tropical genus, but I've adapted to the Mediterranean. I have long white or pink horizontal rhizomes."
   - Answer: *Cymodocea nodosa*
5. "I'm a newcomer to the Mediterranean! I probably arrived through the Suez Canal and have small, oval leaves arranged in pairs."
   - Answer: *Halophila stipulacea*

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket - "Global Seagrass Distribution Check"

Students complete individually:

Part 1: Global Distribution

1. Seagrasses are found in about _____ countries worldwide. a) 50 b) 100 c) 160 d) 200
2. The only continent without seagrasses is _____.
3. True or False: All tropical bioregions have more species than all temperate bioregions. _____

Part 2: Bioregions

4. Which bioregion has the highest seagrass diversity? a) Mediterranean b) Tropical Atlantic c) Tropical Indo-Pacific d) Temperate North Atlantic
5. The Mediterranean bioregion is dominated by which species? a) *Zostera marina* b) *Posidonia oceanica* c) *Thalassia testudinum* d) *Halophila stipulacea*
6. Name one seagrass species: _____

Part 3: Map Skill

Provide small world map and ask children to label the 6 bioregions.

Part 4: Reflection

One thing that surprised me about global seagrass distribution:_____

ASSESSMENT STRATEGIES

Formative Assessment (During Lesson):

1. **Observation Checklist During Group Work:**
   - Students accurately locate their bioregion on maps
   - Students identify key characteristics from bioregion cards
   - Students engage in productive geographical discussions
   - Students participate in gallery walk observations
2. **Questioning Throughout:**
   - Opening activity: "Which continent has no seagrasses? Why?"
   - During explanation: pointing to bioregions on map for identification
3. **Group Presentations:**
   - Quality of three key facts shared about assigned bioregion
   - Accuracy of map shading/colouring
4. **Pair Work Monitoring:**
   - Listen to analysis discussions during comparison activity
   - Check reasoning for pattern recognition
   - Assess matching activity accuracy
   - Note misconceptions for whole-class addressing

Summative Assessment (End of Lesson):

1. Exit Ticket Evaluation Rubric:
2. Factual Knowledge
3. Geographical Skill

Success Criteria Shared with Students:

- I can name the six global seagrass bioregions
- I can identify which bioregion has the highest diversity
- I can name at least three seagrass species
- I can locate major bioregions on a world map

Appendix

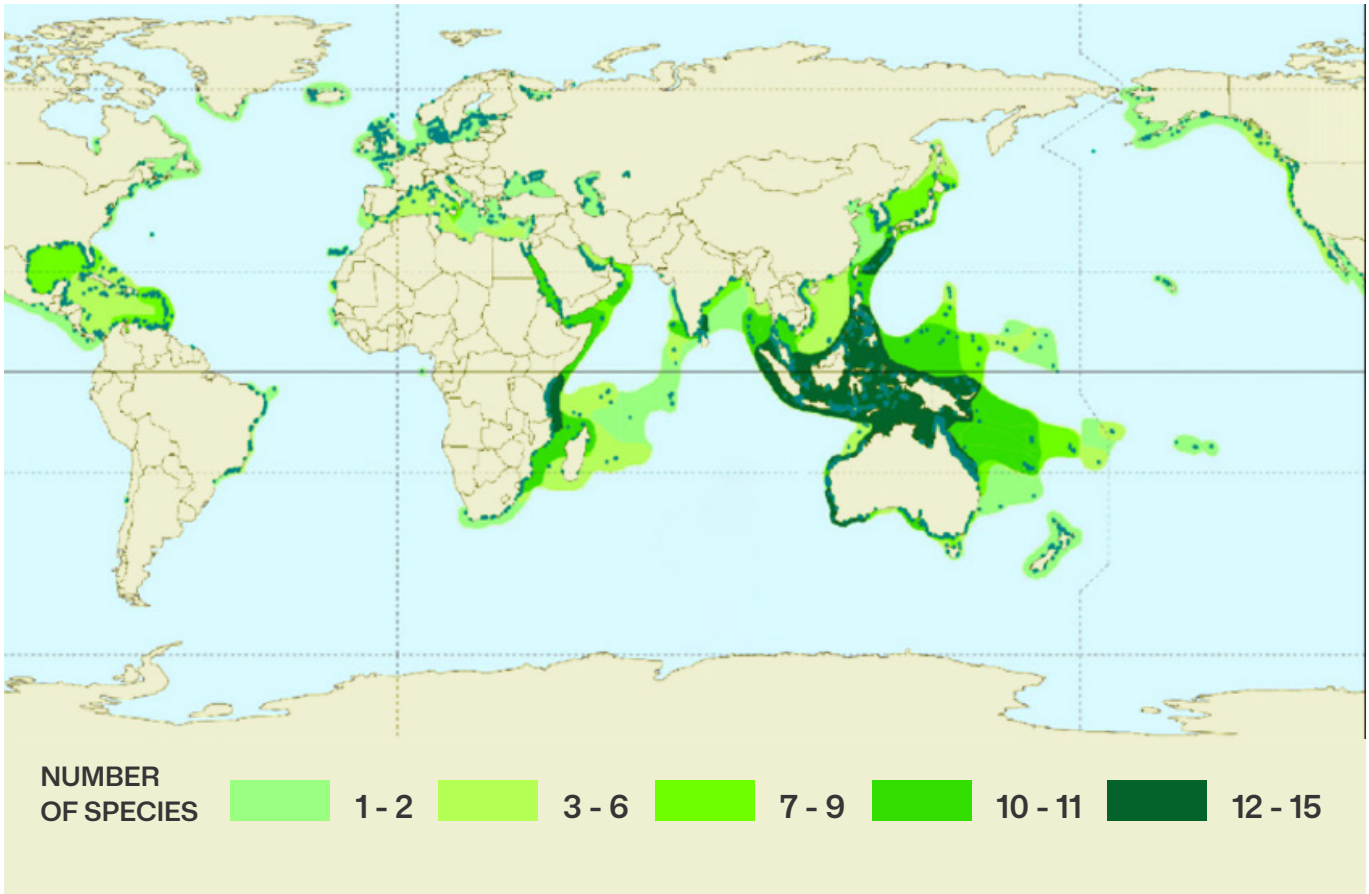


Figure 1. Global seagrass diversity and distribution. Shades of green indicate numbers of species reported for an area; blue points and polygons indicate documented reports of seagrass occurence (Short et al. 2007, Journal of Experimental Marine Biology and Ecology 350: 3-20)

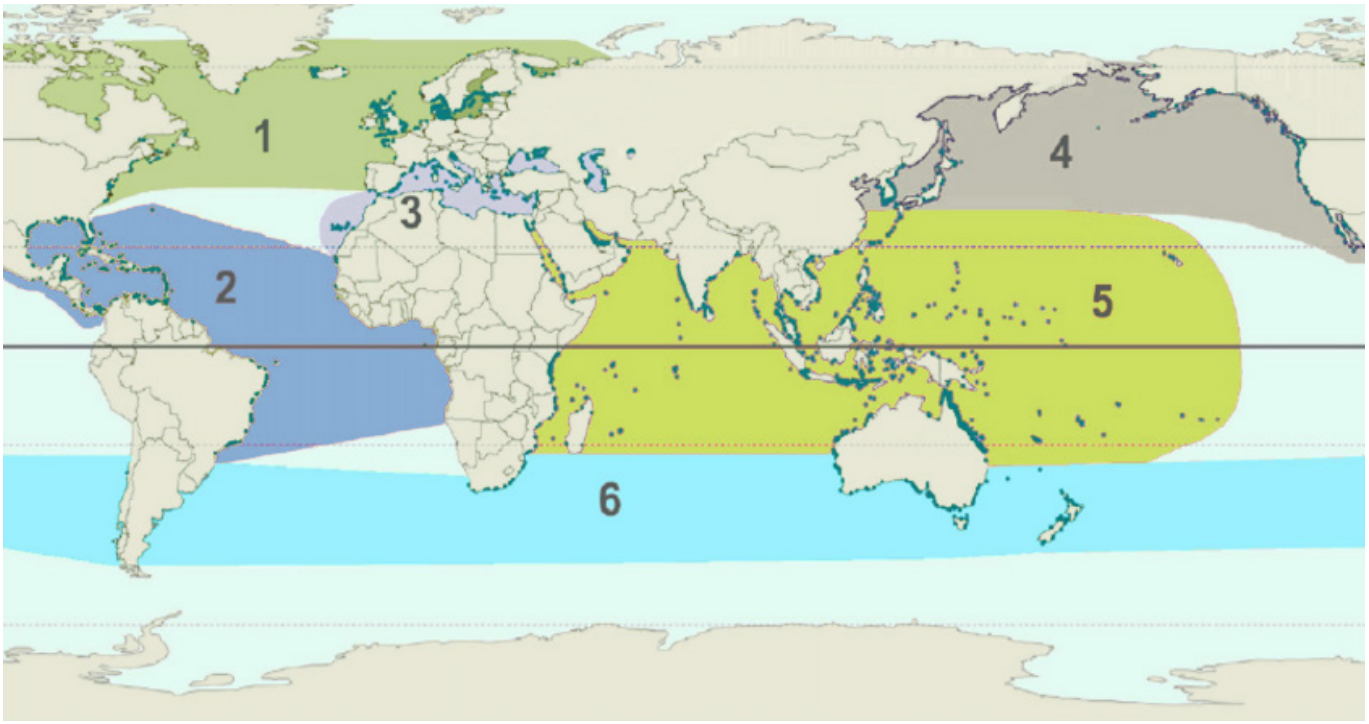


Figure 2. Global seagrass distribution shown as blue points (data from 2005 UNEP-WCMC) and geographic bioregions: 1. Temperate North Atlantic, 2. Tropical Atlantic, 3. Mediterranean, 4. Temperate North Pacific, 5. Tropical Indo-Pacific, 6. Temperate Southern Oceans (modified from Short, F., Carruthers, T., Dennison, W., Waycott, M., 2007. Journal of Experimental Marine Biology and Ecology 350, 3–20)



Figure 3. Mini world map

B3.

THEMATIC MODULE 3: SEAGRASSES FORM EXTENSIVE UNDERWATER MEADOWS

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LESSON PLAN 1. HABITAT REQUIREMENTS OF SEAGRASSES - ENVIRONMENTAL FACTORS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson introduces students to the environmental factors that determine where seagrasses can grow and thrive. Students will explore the critical physical parameters (e.g. light, salinity, temperature, depth, substrate, waves, currents) and natural phenomena (e.g. tidal exposure, nutrients) that regulate seagrass distribution in the marine environment. Through interactive activities and investigations, students will understand that seagrasses require specific conditions: a marine environment, sufficient immersion in seawater, adequate light availability, and suitable substrate. Students will learn key terminology including salinity gradients (freshwater, brackish water, seawater, hyperhaline water), intertidal zone, substrate types, and water clarity, connecting environmental conditions to seagrass presence or absence.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Identify the four essential requirements for seagrass growth: marine environment, sufficient immersion, adequate light, suitable substrate
- Explain what salinity is and understand key classification of water based on salinity levels: freshwater (<0.5), brackish water (0.5-30), seawater (~35), hyperhaline water (>40)
- Understand that several seagrasses tolerate wide salinity ranges but suffer stress at extreme values
- Define the intertidal zone as the shore area between high and low tide extremes
- Recognize that some seagrass species (e.g., *Zostera noltei, Phyllospadix species, Halophila species*) commonly occur in the intertidal zone
- Explain that light decreases rapidly with depth and that seagrasses require 10-20% of surface light to survive
- Understand that most seagrass meadows occur at depths less than 20 meters, with maximum reported depth of 90 meters
- Distinguish between soft substrate (sand, mud) and hard substrate (rocks, boulders)
- Recognize that most seagrasses grow on soft substrate, while some species (e.g., *Phyllospadix* species) can grow on hard substrate

Skills Objectives

By the end of this lesson, students will be able to:

- Interpret diagrams showing environmental gradients (salinity, light, depth)
- Use scientific terminology accurately when describing marine habitats

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Recognize that environmental conditions determine where seagrasses can live
- Understand that human activities affecting water quality and light penetration can impact seagrass survival

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Use scientific terminology accurately (salinity, substrate, intertidal zone, brackish water, etc.)
- Analyse relationships between environmental conditions and seagrass distribution in the marine environment

Environmental Literacy Competencies:

- Understand key environmental parameters that affect seagrass distribution and growth in the marine environment
- Identify how environmental variability affects seagrass presence

Social and Civic Competencies:

- Work collaboratively during group investigations

MATERIALS NEEDED

Per Team (3-4 students):

- Environmental scenario cards (see activities below)
- Salinity gradient diagram worksheet
- Light penetration depth diagram worksheet
- Substrate type identification images
- Markers/coloured pencils
- Large paper for creating posters

Whole Class Materials:

- Large world map
- Images of different coastal environments (estuary, coastal lagoon, marine coast, rocky shore, sandy beach, shallow coastal, deep coastal)
- Visual representations of salinity gradient (river → estuary → ocean)
- Depth and light penetration diagram (showing 0m, 5m, 10m, 20m, 50m, 90m, 200m)
- Samples or images of different substrate types (sand, mud, rock)

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "Why Don't Seagrasses Grow Everywhere?"

Opening Question

Teacher displays images of four different coastal locations:

1. A river estuary head (the landward limit of a river estuary) (salinity <5)
2. A rocky cliff coastline (hard substrate, high wave action)
3. A shallow sandy bay (protected, clear water)
4. A deep ocean area (very deep, dark)

Prompt: "We know seagrasses live in the sea. But look at these four places—all are coastal or marine. In which location would you expect to find seagrass meadows?"

Students vote by raising hands for each location.

Discussion

Teacher facilitates:

- "Why did you choose the sandy bay?"
- "What might prevent seagrasses from growing in the river estuary head?" (Not salty enough)
- "What about the rocky cliff?" (No soft substrate, too much wave action)
- "What about the deep ocean?" (Too deep, not enough light)

Key point: "Seagrasses don't grow everywhere in the sea. They need very specific environmental conditions"

Learning Intention

"Today we'll discover exactly what environmental factors seagrasses need to survive. We'll learn about salinity, light, depth, substrate, and other conditions that determine where seagrass meadows can exist."

PHASE 2: EXPLORATION

Activity: "Environmental Factor Investigation Stations"

Students rotate through 4 investigation stations:

STATION 1: Salinity - How Salty is the Water?

Materials: Salinity gradient diagram showing river → estuary → ocean

Diagram shows (Fig. 1)**:**

- Freshwater (river): Salinity < 0.5
- Brackish water (estuary): Salinity 0.5 - 30
- Seawater (open ocean): Salinity ~35
- Hyperhaline water (coastal lagoons isolated from the ocean): Salinity > 40

Investigation Questions:

1. What is salinity? (Total amount of dissolved salts in water)
2. Where is salinity lowest? Highest?
3. Can seagrasses grow in freshwater? (No)
4. Can seagrasses grow in brackish water? (Yes, several species tolerate brackish conditions)

Key Learning: Several seagrasses can tolerate salinity from brackish to hyperhaline conditions, but seawater (~35) is optimal.

STATION 2: Light & Depth - How Deep Can Seagrasses Grow?

Investigation Questions while showing Fig. 2:

1. What happens to light as you go deeper? (Decreases rapidly)
2. What is the minimum light seagrasses need? (10-20% of surface light)
3. At what depth is most seagrass found? (Less than 20 meters)
4. What is the maximum depth ever recorded for seagrass? (90 meters, for a *Halophila* species)
5. Why can't seagrasses grow in very deep water? (Not enough light for photosynthesis)

Additional factor: Water clarity affects light penetration. In turbid water, light penetrates less, so maximum depth is shallower.

Key Learning: Light availability determines maximum depth for seagrasses.

STATION 3: Intertidal Zone - Can Seagrasses Survive Exposure?

Materials: Diagram of intertidal zone showing high tide, low tide and exposure

Diagram shows (Fig. 3)**:**

- High tide: Seagrasses fully submerged
- Low tide: Some seagrasses exposed to air

Investigation Questions:

1. What is the intertidal zone? (Shore area between high and low tide extremes)
2. What stresses do plants face when exposed at low tide? (desiccation, sun-burning, UV-B damage and freezing)
3. Can all seagrasses live in the intertidal zone? (No, only some species)
4. Which species are common in the intertidal zone?
   - *Zostera noltei* (Western Europe, North-West Africa)
   - *Phyllospadix* species (rocky shores, North Pacific)
   - Some *Halophila* species (mud flats, Indo-Pacific)

Key Learning: Some seagrass species are adapted to tolerate periodic exposure; others require permanent submersion.

STATION 4: Substrate - What Do Seagrasses Grow On?

Materials: Images of different substrate types and seagrasses growing on them

Images show (Figs 4-5) :

- Soft substrate: sand, mud (most common for seagrasses)
- Hard substrate: rocks, boulders (only certain species like *Phyllospadix*)

Investigation Questions:

5. What is substrate? (The material that forms the seabed)
6. What type of substrate do most seagrasses prefer? (Soft: muddy to sandy sediments)

7. Why do seagrasses prefer soft substrate? (Roots can easily penetrate for anchoring and nutrient uptake)
8. Can any seagrasses grow on rock? (Yes, e.g. *Phyllospadix* species anchor to the rock using specialised roots equipped with dense, sticky root hairs that act as a glue)

Key Learning: Substrate type determines whether seagrasses can establish and grow.

After Station Rotations:

Teams return to seats and briefly discuss:

- "Which environmental factor do you think is most important for seagrasses?"
- "Can seagrasses survive if just one factor is wrong?"

PHASE 3: EXPLANATION

Teacher-Led Interactive Presentation:

The Four Essential Requirements

"Seagrasses require four things to grow:"

Summary Table on Board:

Requirement/Parameter	**Effect on Seagrass**
Marine environment/Salinity	Must be marine or brackish; extreme salinity values cause stress
Marine environment/ Immersion in seawater	Seagrasses suffer stress to air exposure
Adequate light/Depth, water clarity	Light availability determines maximum depth
Appropriate substrate	Must be suitable for root anchoring; most need soft substrate

Several other factors are critical for seagrass establishment and growth, including **water temperature**, which affects physiological activity, **waves and currents**, which can damage plants or prevent establishment, and **nutrients** which can limit seagrass photosynthetic activity.

Key Concept: "Combinations of these parameters determine whether seagrass will occur at any location. They work together to either **permit, encourage, or eliminate** seagrass from a specific place."

PHASE 4: ELABORATION

Activity: "Can Seagrass Grow Here? Environmental Scenarios"

Teams receive scenario cards describing different coastal locations. For each scenario, teams must decide:

- Can seagrass grow here? (Yes/No/Maybe)
- Why or why not? (Which factors support or prevent growth?)

SCENARIO CARDS:

Scenario 1: Middle reaches of River Estuary

- Location: Where river meets ocean
- Salinity: 5-18 (brackish, variable)
- Depth: 1-5 meters (shallow)
- Substrate: Muddy sediment
- Water clarity: Low (some sediment from river)
- Waves: Sheltered, calm

Answer: MAYBE–Many seagrasses tolerate brackish water; soft substrate suitable; sheltered conditions favorable; low water clarity result in low-light conditions and prevent some seagrass species growth. Species like *Zostera* or *Ruppia* species can tolerate the dynamic, muddy, and low-light conditions. Other species, like *Posidonia oceanica*, are not found due to high input of fresh water and fine sediments.

Scenario 2: Deep Offshore Area

- Location: Open ocean
- Salinity: 35 (normal seawater)
- Depth: >50 meters
- Substrate: Sandy bottom
- Water clarity: Very clear
- Waves: Low to moderate

Answer: MAYBE: Seagrasses generally inhabit shallow coastal waters, typically at depths less than 20 meters. Some species can survive at depths greater than 50 meters in exceptional circumstances with high water clarity.

Scenario 3: Rocky Coastline

- Location: Exposed rocky shore
- Salinity: 35 (seawater)
- Depth: Intertidal zone
- Substrate: Solid rock
- Water clarity: Very clear
- Waves: Very strong, exposed

Answer: MAYBE–Hard substrate eliminates most species, but *Phyllospadix* species can grow here with specialised roots. However, very strong waves might prevent establishment.

Scenario 4: Shallow Protected Bay

- Location: Calm coastal bay
- Salinity: 30-35 (nearly full seawater)
- Depth: 2-10 meters
- Substrate: Sandy sediment
- Water clarity: High (clear water)
- Waves: Very calm, sheltered

Answer: YES–Ideal conditions! Appropriate salinity, shallow with good light, soft substrate, calm waters. Perfect seagrass habitat.

Scenario 5: Hypersaline Coastal Lagoon

- Location: Enclosed coastal lagoon
- Salinity: 45 (hyperhaline, very salty)
- Depth: 1-2 meters (very shallow)
- Substrate: Muddy sand
- Water clarity: Moderate
- Waves: Calm

Answer: MAYBE–Salinity is very high (45 > 40). Depth, substrate, and wave conditions are favorable, but extreme salinity is limiting. Some species, like *Ruppia* species can tolerate hyperhaline conditions.

Scenario 6: Freshwater Lake

- Location: Lake (no connection to ocean)
- Salinity: 0.2 (freshwater)
- Depth: 3 meters
- Substrate: Mud
- Water clarity: Clear
- Waves: Calm

Answer: NO–Seagrasses require marine environment. Freshwater salinity (<0.5) is too low.

Team Discussion & Presentation :

Each team presents 1-2 scenarios to the class:

- State their decision (Yes/No/Maybe)
- Explain which factors support or prevent seagrass growth
- Class discusses and teacher confirms/clarifies

Key Teaching Points:

- No single factor determines presence–it's the combination
- Even if most factors are favorable, one critical factor (e.g., no adequate light, wrong salinity) can eliminate seagrasses
- Different species have different tolerances–some more adaptable than others to certain conditions

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket - "Seagrass Habitat Requirements"

Students complete individually:

Part 1: Essential Requirements

1. List the four essential requirements for seagrasses to grow:
   a. _____
   b. _____
   c. _____
   d. _____

Part 2: Environmental Terms

Match the term to the correct definition:

Term	Definition
Brackish water	A. Shore area between high and low tide
Intertidal zone	B. Water with salinity 0.5-30
Soft substrate	C. Sandy or muddy sediment

Part 3: Light & Depth

2. Seagrasses need at least _____% of surface light to survive.
3. Most seagrass meadows are found at depths less than _____ meters.

Part 4: Application

4. A coastal area has these conditions:
    - Salinity: 32 (seawater)
    - Depth: 6 meters
    - Substrate: Sandy
    - Water clarity: moderate (moderately turbid/cloudy)

Can seagrasses grow here? _____ (Yes/No/Maybe)

Explain why: _____
_____

ASSESSMENT STRATEGIES

Formative Assessment (During Lesson):

1. **Questioning Throughout:**
    - "Why can't seagrasses grow in freshwater?"
    - "What happens to light as depth increases?"
    - "Which substrate type is easiest for seagrass roots to penetrate?"
    - "Can seagrasses survive if exposed to air at low tide?"
2. **Scenario Analysis:**
    - Monitor team discussions during scenario activity
    - Assess reasoning quality (using environmental factors appropriately)
    - Check for misconceptions about factor interactions
3. **Class Discussions:**
    - Quality of explanations during scenario presentations
    - Use of scientific terminology
    - Understanding of factor combinations

Summative Assessment (End of Lesson):

Exit Ticket Evaluation Rubric:

- Essential Requirements
- Environmental Terms
- Light availability & Depth Knowledge
- Application & Reasoning

Success Criteria Shared with Students:

- I can name the four essential requirements for seagrasses to grow
- I can explain what salinity is and identify different water types (freshwater, brackish water, seawater, hyperhaline water)
- I can describe how light availability decreases with depth
- I can explain what the intertidal zone is
- I can distinguish between soft and hard substrate
- I can predict whether seagrasses can grow in a location based on environmental conditions
- I can explain how combinations of factors determine seagrass presence

Appendix



Figure 1. Saline water classification

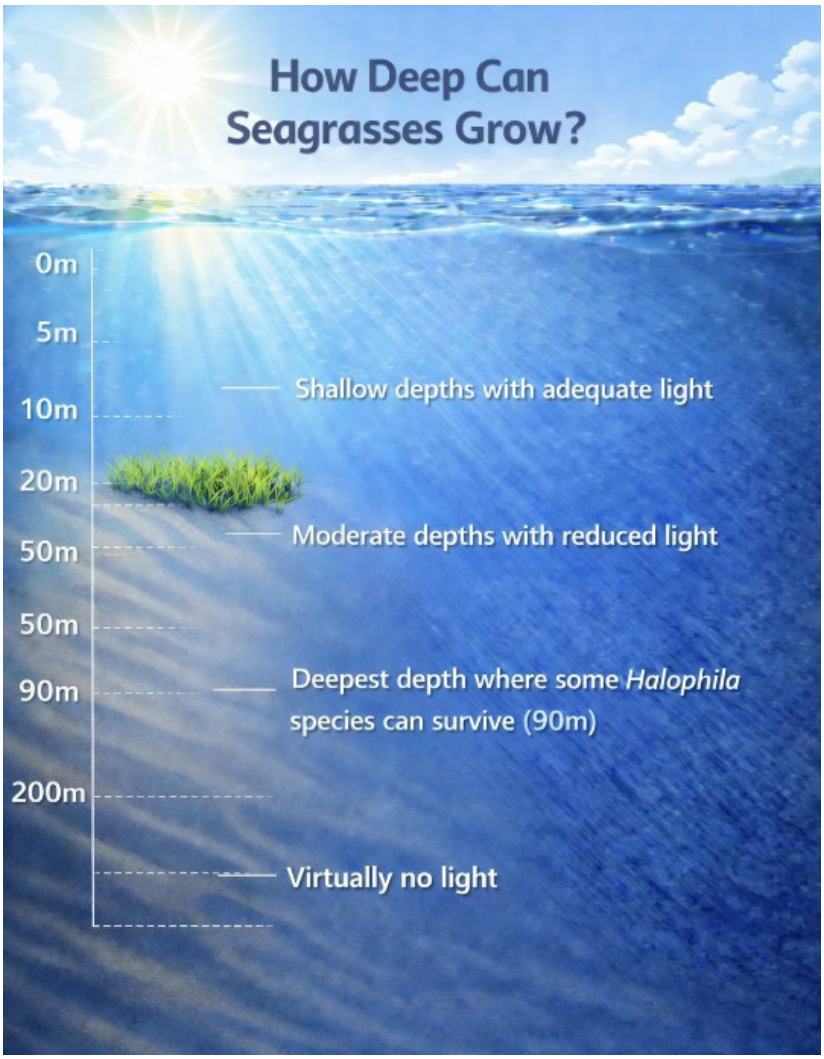
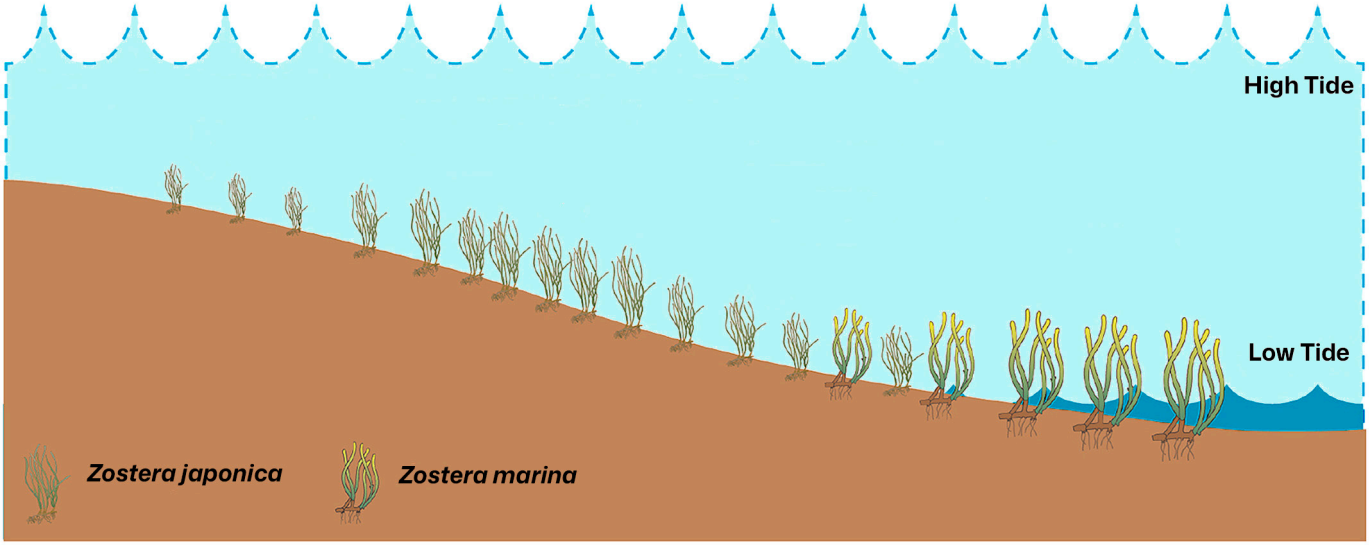


Figure 2. Seagrass bathymetric distribution in the intertidal zone



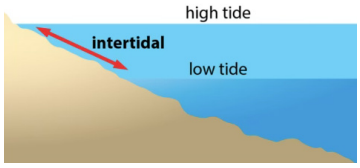


Figure 3. Distribution of *Zostera* species in the intertidal zone (modified from Kim et al., 2016. Estuarine, Coastal and Shelf Science 175, p. 1-9)



Figure 4. Seagrass growing over sandy sediments (photo credit Lilly Palmer/ Ocean Image Bank)



Figure 5. *Phyllospadix iwatensis* growing on intertidal platforms, Sotogawa-cho, Choshi, Chiba Prefecture, Japan (photo credit Hideki Haga/ AlgaeBase)

LESSON PLAN 2. SEAGRASS MEADOWS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson explores seagrass meadows (also called seagrass beds) as unique marine ecosystems with global ecological significance. Building on previous lessons about environmental requirements and distribution, students will investigate seagrass meadows as extensive underwater ecosystems, examining their number of seagrass species (monospecific vs. multispecific) and global abundance. Students will learn that seagrasses cover approximately 10% of the coastal ocean globally (160,000-600,000 km^2), comparable to seaweeds, mangroves, and coral reefs. The lesson emphasizes the distinction between monospecific meadows (formed by only one seagrass species, being common in tropical, but particularly in temperate areas) and multispecific meadows (containing multiple co-occurring species, being more common in tropical regions like the Indo-Pacific and the Red Sea). Special attention is given to *Posidonia oceanica* meadows as a climax community and with unique features such as matte formation. Students will understand seagrass meadows not as isolated plants but as complex ecosystems supporting high biomass and biodiversity.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Define seagrass meadows (or seagrass beds) as extensive and dense underwater ecosystems
- Distinguish between monospecific meadows (one species) and multispecific meadows (multiple species)
- Recognize that most seagrass meadows are monospecific, particularly in temperate zones
- Understand that multispecific meadows are more common in tropical/subtropical areas, especially the Indo-Pacific and Red Sea
- Know that Indo-Pacific and Red Sea meadows can contain up to 12 co-occurring seagrass species
- Explain that seagrasses can also grow in isolated patches or as part of habitat mosaics with corals, mangroves, bivalve reefs, rocky benthos, or bare sediments
- State that seagrasses cover approximately about 10% of coastal ocean globally
- Recognize that seagrass global area is comparable to seaweeds, mangroves, and coral reefs
- Understand that seagrass meadows support high biomass
- Know that *Amphibolis, Phyllospadix*, and *Posidonia* species support particularly high biomass
- Recognize that *Halophila* species (small leaves) rarely display high biomass
- Define biomass as the total weight or mass of living organisms in a specific area
- Understand that *Posidonia oceanica* meadows are climax communities
- Explain the unique features of *P. oceanica*: long-living, slow-growing, matte formation, beach cast ("banquettes")

Skills Objectives

By the end of this lesson, students will be able to:

- Compare monospecific and multispecific meadows
- Analyse relationships between species morphological characteristics and biomass
- Recognize seagrass meadows as complex ecosystems rather than simple plant collections
- Connect meadow characteristics to geographical regions

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Understand that seagrass meadows are common coastal ecosystems worthy of conservation

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Use ecological terminology accurately (ecosystem, monospecific, multispecific, biomass, climax community)
- Compare ecosystem characteristics across regions

Social and Civic Competencies:

- Work collaboratively on ecosystem investigations
- Understand marine ecosystems as globally important natural resources

MATERIALS NEEDED

Whole Class Materials:

- World map showing seagrass distribution hotspots (e.g. SEAQUEST Curriculum for teachers, Fig. 2.8)
- Maps comparing global coverage: seagrasses, coral reefs, mangroves, saltmarshes (e.g.
    - UNEP-WCMC Ocean+ Habitats https://habitats.oceanplus.org/
    - GRID-Arendal https://www.grida.no/resources/7766)
- Images of seagrass meadows (e.g. from SEAQUEST Curriculum for teachers, section B5.3.3 and Ocean Image Bank (https://oceanimagebank.theoceanagency.org/ by typing 'seagrass')
- Images of habitat mosaic (e.g. from SEAQUEST Curriculum for teachers, section B5.3.3 and Ocean Image Bank https://oceanimagebank.theoceanagency.org/ by typing 'seagrass')
- Videos of seagrass meadows (e.g. Aquawork Productions Seagrass https://www.google.com/search?q=Aquawork+Productions&oq=Aquawork+Productions&gs_lcrp=EgZjaHJvbWUyBggAEEUYOdIBCDc0MTJqMGo3qAIAsAIA&sourceid=chrome&ie=UTF-8#fpstate=ive&vld=cid:4975b455,vid:KcyUgj30vL8,st:0)
- Bar graph template for biomass comparison by species (Fig. 1)
- Images of temperate monospecific seagrass meadows (e.g. *Zostera marina, Posidonia oceanica*) (e.g. from SEAQUEST Curriculum for teachers, section B5.3.3 and algaebase.org typing the scientific species name)
- Images of tropical multispecific seagrass meadows (e.g. Fig. 2)
- Images of *Posidonia oceanica* matte structure (e.g. from Google)
- Photo of *Posidonia oceanica* beach cast/"banquettes" (Fig. 3)

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "What is a Meadow?"

Concept Introduction

Teacher shows two images side by side:

1. A terrestrial grass meadow (field of grass on land)
2. An underwater seagrass meadow

Question: "What do these two places have in common?"

- Both are dominated by grass-like plants
- Both are extensive areas covered by similar plants
- Both support other organisms (animals, etc.)

Teacher introduces term: "When seagrasses form extensive underwater areas, we call them seagrass meadows or seagrass beds. They're like underwater fields of grass"

Ecosystem Concept

Teacher explains:

"A meadow is more than just plants. It's an ecosystem—a community of organisms and their physical environment interacting together."

Quick brainstorm: "What might live in a seagrass meadow besides seagrasses?"

- Students suggest: fish, crabs, shellfish, worms, algae, etc.

"Today we'll learn about seagrass meadows as complete ecosystems with different structures and characteristics around the world"

Global Perspective

Teacher shows world map with seagrass distribution:

"Seagrass meadows exist on coastlines all around the world. Some meadows have just one species of seagrass. Others have more than one species growing together. Some are enormous, covering hundreds of square kilometres."

Hook question: "How much of the ocean do you think is covered by seagrass meadows? And how does that compare to coral reefs or mangrove forests?"

PHASE 2: EXPLORATION

Activity: "Number of seagrass species in a meadow"

Part A: Monospecific vs. Multispecific Meadows

Teacher Explanation:

Seagrass meadows can be organized in two main ways:

1. **Monospecific Meadows:**
    - **"Mono"** = one
    - Meadow consists of **only one seagrass species**
    - Most seagrass meadows worldwide are monospecific
    - Especially common in the temperate zone (colder waters)

- Example: Pure *Zostera marina* meadow in the Baltic Sea
- Example: Pure *Posidonia oceanica* meadow in the Mediterranean Sea

2. **Multispecific Meadows:**
   - **"Multi"** = many
   - Meadow contains **multiple co-occurring seagrass species** growing together
   - More common in **tropical and subtropical areas**
   - Example: Mixed meadows in Indo-Pacific and Red Sea
   - Can contain **up to 12 different seagrass species** in the same meadow

Team Investigation:

Teams receive image sets showing:

Set A: Monospecific meadow (single species visible)

Set B: Multispecific meadow (species visible with different leaf types/sizes)

Investigation Questions:

1. **Looking at Set A** (Monospecific):
   - How many different seagrass species can you identify? (One)
   - Do all the plants look similar? (Yes)
   - Where might this meadow be located? (Temperate area: e.g. Europe, North America)
2. **Looking at Set B** (Multispecific):
   - How many different leaf shapes/sizes do you see? (Multiple)
   - Why might multiple species grow together here? (Different species use resources differently; high environmental variability)
   - Where might this meadow be located? (Tropical: Indo-Pacific, Red Sea)
3. **Comparison:**
   - Which type of meadow do you think is more common worldwide? (Monospecific)
   - Which type has the highest seagrass species diversity? (Multispecific)

Meadow Patterns - Isolated Patches vs. Continuous Meadows

Teacher explains with visuals:

"Seagrasses don't always form continuous meadows. They can exist in different patterns"

1. **Isolated Patches:**
   - Small, separate groups of seagrasses
   - Scattered across the sea-floor
   - Common in areas with patchy suitable habitat
2. **Continuous Meadows:**
   - Large, unbroken areas of seagrass
   - Can extend for kilometres

3. **Habitat Mosaics:**
    - Seagrasses growing alongside other habitats
    - Mixed with: corals, mangroves, bivalve reefs, rocky benthos, bare sediments
    - Creates a "patchwork" of different ecosystem types

Visual Activity:

Teacher shows underwater images of:

- Continuous meadow
- Habitat mosaic (seagrass + coral, or seagrass + mangrove)

Students identify which pattern each image represents.

PHASE 3: EXPLANATION

Teacher-Led Presentation: "Seagrass Meadows Globally"

Global Coverage & Abundance

Key Data Points:

1. **Total Global Area:**
    - Estimates vary: 160,000 to 600,000 km²
    - Why such variation? (The lower estimates tend to represent only documented or mapped areas, whereas higher estimates attempt to account for inferred or potential habitat in uncharted, remote, or deep-water regions)
    - Up to 10% of the coastal ocean

Key Point: "Seagrass meadows cover an area **comparable** to coral reefs, mangroves, and seaweeds. They're just as important"

Discussion: "Have you heard more about coral reefs or seagrass meadows? Why do you think seagrasses get less attention even though they cover similar areas?"(they are considered less charismatic/attractive)

Biomass

Teacher explains concept:

"What is Biomass?"

- Biomass = the total weight or mass of living organisms in a specific area or volume
- Can measure:
    - **Species biomass**: weight of one species
    - **Community biomass**: weight of all species together

Usually measured per unit area (e.g., grams per square meter, g/m²)

Seagrass Meadow Biomass:

"Seagrass meadows support very high biomass compared to marine phytoplankton (tiny floating algae)."

Average global seagrass meadow biomass: ~460 g dry weight per m²

Species / Genus	Biomass Level
Amphibolis	
Phyllospadix	
Posidonia	
Zostera	
Cymodocea	
Halophila	

Biomass Varies by Species:

- Teacher shows bar graph comparing species (Fig. 1):

Key Pattern: "Dense meadows of larger, more robust species tend to support higher biomass."

Examples:

- *Posidonia oceanica*: Large leaves, thick rhizomes, very dense meadows → high biomass
- *Halophila species*: Small, delicate leaves → rarely display high biomass

Discussion: "Why might larger plants create more biomass?"

Larger seagrasses can produce more "biomass" because they have advantages in their structure, the way they function, and how they live. This allows them to produce and accumulate more material than smaller plants.

Special Focus: *Posidonia oceanica* meadows as a Climax Community

Teacher explains with visuals:
"In the Mediterranean, *Posidonia oceanica* meadows are special. They're what ecologists call a climax community."

Climax Community:

- **Definition**: Ecological community where populations remain **stable** and in **balance** with each other and environment
- **Final stage of ecological succession** (ecological succession = process where species/habitat mix changes over time)
- Remains relatively **unchanged** until destroyed by an event or human interference

What are the key characteristics of *Posidonia oceanica* meadows:

Posidonia oceanica is a long-lived species that forms meadows which:

1. anchor in place and survive in a steady state within their environment
2. support thousands of species, creating a diverse ecosystem that thrives in a stable state
3. offer high productivity and crucial ecological services, indicating a mature ecosystem
4. have low resilience to rapid changes caused by human activities, leading to slow recovery times

Unique Characteristics of *Posidonia oceanica*:

- Long-living but slow-growing
- Shoots live at least 30 years
- Rhizomes grow horizontally only a few centimetres per year
- Slow decay, builds up over time
- Forms "matte": a unique, stable soil structure, which is composed of rhizomes, roots and trapped sediment, and enables the meadow to build up the seabed, allowing it to survive for thousands of years.
- "Matte" can be several meters thick
- "Matte" can be thousands of years old

Beach Cast / "Banquettes":

Show photos of *Posidonia oceanica* beach cast piled on Mediterranean beaches (Fig. 3)

- Dead leaves wash ashore
- Form **beach cast** or **"banquettes"** on beaches
- Protect beaches from erosion
- Habitat for beach organisms

Discussion: "Have you seen piles of seagrass on beaches?"

PHASE 4: ELABORATION

Meadow Type Scenarios

Teacher presents scenarios; students predict meadow characteristics:

Scenario 1: "You're diving in the Indo-Pacific region near a coral reef. What type of seagrass meadow would you likely encounter?"

- **Answer**: Multispecific meadow (up to 12 species); possibly habitat mosaic with coral; tropical diversity

Scenario 2: "You're exploring the Baltic Sea in northern Europe. What type of meadow structure would you expect?"

- **Answer**: Monospecific meadow (likely *Zostera marina*); temperate area; continuous or extensive meadows

Scenario 3: "You're in the Mediterranean Sea at 25 meters depth on a sandy bottom that hasn't been disturbed in hundreds of years. What would you find?"

- **Answer**: Possibly *Posidonia oceanica* meadow; likely monospecific; climax community; possibly matte structure visible

Scenario 4: "You're visiting a Mediterranean beach. You see large piles of brown, fibrous material on the shore. What is it and why is it there?"

- **Answer**: *Posidonia oceanica* beach cast (banquettes); dead leaves washed ashore; natural part of coastal ecosystem; helps protect beach from erosion

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket - "Seagrass Meadows as Ecosystems"

Students complete individually:

Part 1: Meadow Types

1. What is the difference between a monospecific and a multispecific meadow?

   Monospecific: _____
   _____

   Multispecific: _____
   _____

2. Most seagrass meadows worldwide are _____ (monospecific/multispecific).

Part 2: Global Importance

3. Seagrasses cover approximately _____% of the coastal ocean globally.
4. Name ONE coastal ecosystem type that has comparable global coverage to seagrasses: _____
5. What is biomass? _____

Part 3: *Posidonia oceanica*

6. What is a climax community?_____
7. What is "matte" in *Posidonia oceanica* meadows? _____
8. *Posidonia oceanica* shoots can live for at least _____ years.

Part 4: Application

9. The Indo-Pacific region has meadows with up to _____ co-occurring seagrass species.
10. Why do *Halophila* species rarely display high biomass?

ASSESSMENT STRATEGIES

Formative Assessment (During Lesson):

1. **Questioning Throughout:**
   - "What does 'monospecific' mean?"
   - "Why are seagrass meadows as important as coral reefs?"
   - "What are the key characteristics of *Posidonia oceanica* meadows?"
2. **Scenario Predictions:**
   - Quality of reasoning for meadow type predictions
   - Connection to previous lessons

Summative Assessment (End of Lesson):

Exit Ticket Evaluation Rubric:

1. Meadow Types
2. Global Importance
3. *Posidonia oceanica* Knowledge

Success Criteria Shared with Students:

- I can explain what a seagrass meadow/bed is
- I can distinguish between monospecific and multispecific meadows
- I can explain that seagrasses cover about 10% of coastal ocean
- I can compare seagrass coverage to coral reefs, mangroves, and seaweeds
- I can define biomass and explain why it's important
- I can describe the key characteristics of *Posidonia oceanica* meadows
- I can explain *Posidonia oceanica* "matte" formation and beach cast
- I can recognize that number of seagrass species in a meadow can vary by region (temperate vs. tropical)

Appendix

Global dataset on seagrass meadow biomass

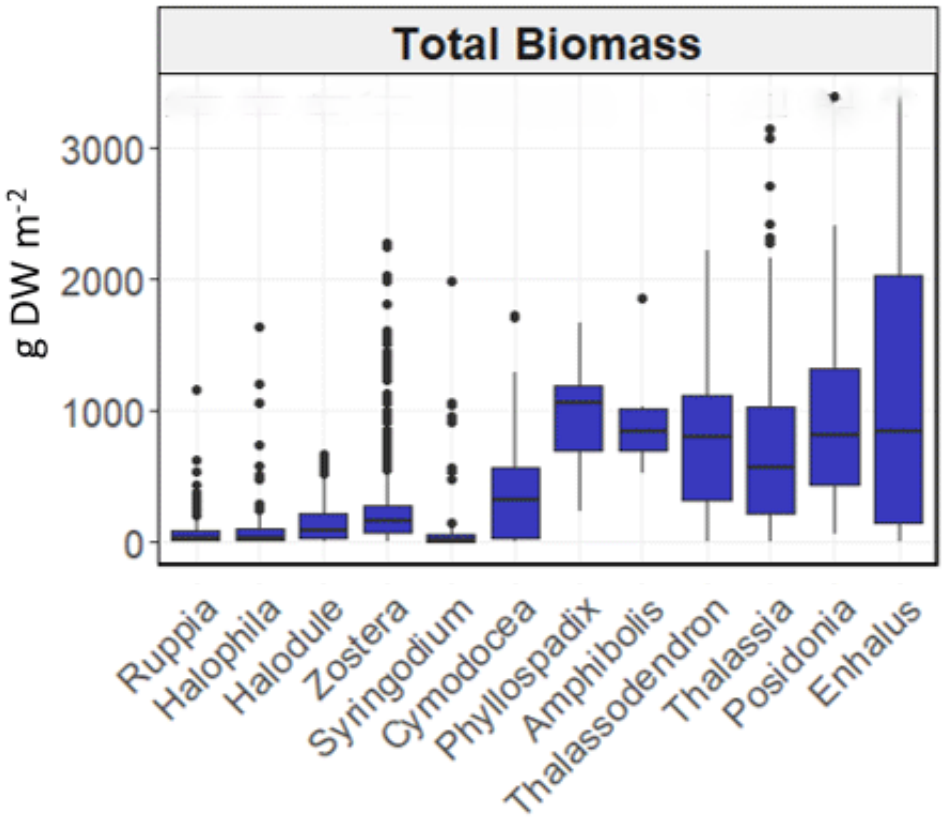


Figure 1. Global dataset on seagrass meadow biomass per genera; the box plots show the median value (black line within the box; modified from Strydom et al. 2023. Earth System Science Data 15, 511–519) https://essd.copernicus.org/articles/15/511/2023/

Multispecific seagrass meadows

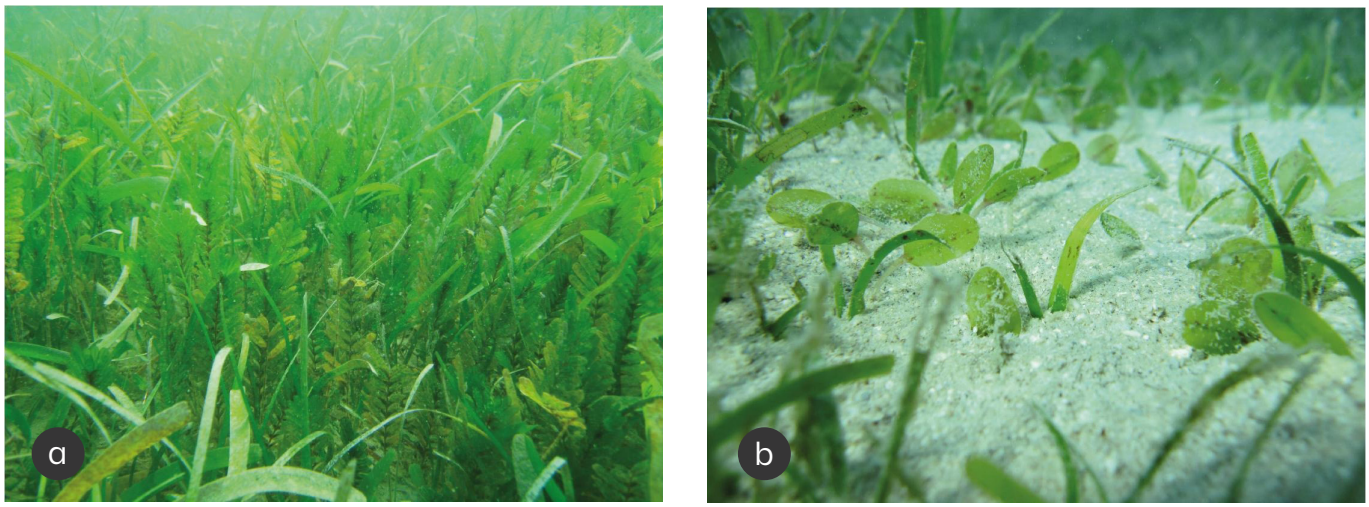


Figure 2.. Examples of tropical multi-specific seagrass meadows comprised of (a) *Cymodocea serrulata, Halodule uninervis*, and *Halophila spinulosa* at Magnetic Island, and (b) *Halophila ovalis* and *Halodule uninervis* at Green Island, Queensland, Australia (from Collier et al., 2021. Ecological indicators, 121, 107156) https://www.sciencedirect.com/science/article/pii/S1470160X20310955

Posidonia oceanica “banquettes”



Figure 3. A banquette formed on a beach from dead *Posidonia oceanica* leaves (Mesi Beach, coastal waters of Thrace, Northern Aegean Sea, Greece; photo credit Paraskevi Malea)

LESSON PLAN 3. SEAGRASS MEADOWS IN EUROPE'S COASTAL WATERS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson explores the geographic distribution of six key seagrass species (*Zostera marina, Zostera noltei, Cymodocea nodosa, Posidonia oceanica, Halophila stipulacea*, and *Ruppia maritima*, see Lesson Plan 3 Seagrass Taxonomy and Species Identification, Thematic Module 2: Seagrasses are Unique Plants) across Europe's coastal waters, from Arctic Norway to the Mediterranean and Black Seas, through map-based activities. It also examines the coastal environments where these species occur (e.g., intertidal zone, shallow and deep coastal waters, estuaries, coastal lagoons), linking species presence to environmental conditions such as light availability, substrate, and salinity. Building on prior knowledge, students will connect species-specific requirements to meadow distribution and be introduced to key concepts including endemic, invasive, and emblematic species.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Identify the six seagrass species found in Europe's coastal waters (*Zostera marina, Zostera noltei, Cymodocea nodosa, Posidonia oceanica, Halophila stipulacea, Ruppia maritima*)
- Describe the geographical distribution of each species across European seas (Arctic, Atlantic, Baltic, Mediterranean, Black Sea)
- Explain how environmental factors (light availability, substrate, salinity) influence species distribution
- State the depth range, coastal environment type, and substrate preferences for each species
- Recognize key ecological characteristics of each species (e.g. cold tolerance, occurrence in the intertidal zone, adaptability, salinity tolerance, invasive species characteristics)
- Understand and correctly use the terms: endemic species, introduced (non-native) species, invasive species, climax community, emblematic species
- Explain why certain species (e.g. *Posidonia oceanica*) have restricted distributions, while others (e.g. *Zostera marina, Ruppia maritima*) are more widespread

Skills Objectives

By the end of this lesson, students will be able to:

- Locate and map the distribution of seagrass species on a European map
- Analyse and explain environmental distribution patterns based on environmental conditions
- Compare species and identify similarities and differences in their ecological requirements
- Predict which species are likely to occur in specific environmental scenarios (e.g. estuaries, deep coastal waters, high salinity habitats)
- Communicate scientific information clearly through group discussion and presentation
- Work collaboratively to investigate and present species-specific information

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Interpret and analyse geographical distribution maps of seagrass species
- Use scientific (Latin) species names accurately and appropriately
- Understand and apply ecological concepts (e.g. environmental distribution, habitat, environmental factors)
- Relate species traits (depth range, salinity tolerance, substrate preference) to their environmental distribution patterns

Social and Civic Competencies:

- Collaborate effectively in group-based investigation tasks
- Share responsibilities and contribute to team-based learning activities
- Communicate findings clearly using scientific language
- Engage in discussion, comparison, and argumentation based on evidence

MATERIALS NEEDED

Per Team (3-4 students):

- Species Profile Cards (one species per team)
- Blank map of European waters (coastlines showing: Norwegian Sea, North Sea, Baltic Sea, Atlantic coast, Mediterranean Sea, Black Sea)
- Image of Temperate North Atlantic and Mediterranean bioregions (Fig. 1)
- Coloured pencils/markers for mapping
- Species characteristic checklist worksheet

Whole Class Materials:

- Large wall map of Europe showing seas and coastlines
- Six different coloured markers/pins for marking species distributions
- Images of each species (for visual reference)

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: "European Seagrass Diversity"

Teacher displays large map of Europe with seas labelled:

- Norwegian Sea
- North Sea
- Baltic Sea
- Atlantic Ocean (eastern coasts)
- Mediterranean Sea
- Black Sea
- Azov Sea
- Caspian Sea

Opening question: In which geographical areas are seagrasses meadows found, in what environmental factors?

Teacher shows 6 images of different seagrass species (unlabelled) side by side.

"These are the six seagrass species found in European waters. Some can grow in cold Arctic waters, some in the warmer Mediterranean, some in many places, and one is found only in the Mediterranean. Let's find out where they grow"

Quick Poll

Teacher asks:

1. "Which sea do you think has the most seagrass species?" (Students guess)
2. "Which species do you think can survive in the coldest waters?" (Students observe images and guess)
3. Do you think all European seagrasses are native, or might some have been introduced from other regions? (Discuss concept of native vs. introduced)
4. In what types of coastal environments do we find seagrasses?
5. At what depths do seagrasses typically grow?
6. What kind of seabed do they prefer?
7. How does salinity affect where different seagrass species can live?

Learning Intention

"Today we'll discover that each species has its own preferred seas, depths, and coastal environment types. By the end, you'll be able to look at a European map and know which seagrasses live where"

PHASE 2: EXPLORATION

Activity: "Species Profile Investigation"

Divide class into 6 teams. Each team receives a Species Profile Card for one species and investigates:

1. Where the species is found (geographical distribution)
2. Depth range
3. Substrate preference
4. Special characteristics
5. Coastal environment types
6. Salinity

SPECIES PROFILE CARDS:

TEAM 1: *Zostera marina* (Eelgrass)

Distribution:

- Circumglobal in northern latitudes
- Occurs in subarctic and temperate regions
- Widely distributed across Europe's coastal waters
- From Arctic Norway to the Mediterranean, Black Sea and Sea of Azov

Depth Range:

- Low intertidal to 15 m

Substrate:

- Sandy or muddy substrates

Habitat Types:

- Mainly inhabits the subtidal zone (typically down to 10–15 m)
- Can also occur in the intertidal zone
- Sheltered coastal environments: shallow bays, inlets, estuaries, coastal lagoons

Special Feature:

- Most widespread species
- Cold-tolerant

Your Task:

1. Colour the seas where *Zostera marina* occurs on your map
2. List 3 key characteristics of this species
3. Fill in the picture (Fig. 1) where this species is found
4. Explain why this species has such a wide distribution (what makes it adaptable?)

TEAM 2: *Zostera noltei* (Dwarf eelgrass)

Distribution:

- NE Atlantic, Baltic Sea, Mediterranean, Black, Caspian and Aral Seas
- Western Africa (Mauritania)
- Canary Islands and Cape Verde

Depth Range:

- Intertidal to 10 m

Substrate:

- Sandy to muddy substrates

Habitat Types:

- Primarily intertidal zone
- Can occur in subtidal areas up to 10m depth
- Estuaries and coastal lagoons
- Often grows with *Zostera marina*, which extends to greater depths

Special Feature:

- Small species
- Predominantly intertidal

Your Task:

1. Colour the seas where *Zostera noltei* occurs on your map
2. Fill in the picture (Fig. 1) where this species is found
3. Compare with *Zostera marina*—what's similar and different about their geographical distributions?
4. Why might *Zostera noltei* be common in the intertidal zone?

TEAM 3: *Cymodocea nodosa* (Slender seagrass)

Distribution:

- Mediterranean Sea (widespread)
- Atlantic, northward of Portugal and southward of Senegal
- Canary Islands, Madeira, Cape Verde

Depth Range:

- Intertidal to ~30–35 m

Substrate:

- Coarse sand to muddy sediments

Habitat Types:

- Open coastal waters
- Estuaries
- Coastal lagoons
- Can colonize different environmental types

Special Feature:

- Highly adaptable to environmental variability
- Good colonizer of new substrates

Your Task:

1. Colour the seas/regions where *Cymodocea nodosa* occurs on your map
2. Fill in the picture (Fig. 1) where this species is found
3. What makes this species a "good colonizer"? (adaptability, wide tolerances)
4. Where does it replace *Posidonia oceanica* and why?

TEAM 4: *Posidonia oceanica* (Neptune grass)

Distribution:

- Endemic to the Mediterranean Sea
- Widely distributed throughout the Mediterranean

Depth Range:

- 0.5 to 45 m
- ~9 m lower limit in turbid waters

Substrate:

- Primarily sandy sediments

Habitat Types:

- Open coastal waters
- Does not tolerate salinity fluctuations and turbidity
- Not found in estuaries

Special Feature:

- Slow-growing species
- Extenisive, dense meadows
- Climax community
- Forms matte
- Emblematic Mediterranean species

Your Task:

1. Colour only the Mediterranean Sea on your map (endemic)
2. Fill in the picture (Fig. 1) where this species is found
3. What does "endemic" mean?
4. What is a climax community?

TEAM 5: *Halophila stipulacea*

Distribution:

- Native to Red Sea, Persian Gulf and Indian Ocean
- Introduced in the Mediterranean (Egypt to southern Italy and Tunisia)

Depth Range:

- 0 to 70 m (scarce below 50 m)

Substrate:

- Soft substrates in the eastern Mediterranean

Habitat Types:

- Shallow waters
- Also in much deeper water (> 50m)

Special Feature:

- Fast-growing species
- Can expand rapidly due to fast growth
- Introduced (non-native) in the Mediterranean

Your Task:

1. Colour the Mediterranean region where *Halophila stipulacea* occurs
2. Fill in the picture (Fig. 1) where this species is found
3. What does "introduced species" mean? How is it different from "endemic"?
4. What advantage does fast growth give to this species?

TEAM 6: *Ruppia maritima* (Beaked tasselweed)

Distribution:

- Circumglobal
- Temperate and tropical regions

Depth Range:

- 0 to 2 m

Substrate:

- Occurs across multiple substrate (not substrate-specific)

Habitat Types:

- Freshwater, brackish, and hyperhaline environments
- Estuaries
- Coastal lagoons
- Salinity tolerance: 0–70

Special Feature:

- Very wide salinity tolerance (0–70)
- Brackish water specialist

Your Task:

1. Fill in the picture (Fig. 1) where this species is found
2. What is special about this species' salinity tolerance?
3. Why can it live in more places than other species?

Team Investigation Time:

Teams work together to:

1. Read and discuss their species profile
2. Complete their map (colouring distribution areas)
3. Fill out characteristics checklist
4. Prepare to present 2-3 key facts about their species to the class

PHASE 3: EXPLANATION

Teacher-Led Class Compilation: "Building the European Seagrass Map"

Species-by-Species Presentations

Each team presents their species:

- Shows their coloured map
- States where species is found
- Shares 2-3 key characteristics
- Teacher adds information to large wall map using coloured markers/pins

As each species is presented, teacher creates a summary chart on board:

Key Concepts Explanation

Teacher highlights the following:

Environmental Connections:

- "Remember our lesson on environmental factors? Now we see how they determine environmental distribution"
- "*Zostera marina* tolerates cold (Arctic) because it's adapted to low temperatures"
- "*Posidonia oceanica* doesn't tolerate salinity fluctuations—that's why it's not in estuaries"
- "*Ruppia maritima* can live from freshwater to hyperhaline coastal lagoons because it tolerates a wide range of salinity values!"

Important Terminology:

Species	Distribution	Depth Range	Special Feature	Ecology – Habitat
Zostera marina	Widespread and circumglobal in northern latitudes. Widely distributed across Europe's coastal waters, from the Arctic waters of Norway to the Mediterranean Sea, the Black Sea and the Sea of Azov.	Low intertidal -15 m	Most widespread; cold-tolerant	Mainly inhabits the subtidal zone, typically down to 10-15 m. Can also occur in the intertidal zone. Euryhaline. Prefers sandy or muddy substrates and sheltered coastal environments such as shallow bays, inlets, estuaries, and coastal lagoons.
Zostera noltei	NE Atlantic, Baltic, Mediterranean, Black, Caspian and Aral Seas, western Africa in Mauritania and in the Canary and Cape Verde Islands	Intertidal – 10 m	Small species; predominantly inhabits the intertidal zone	Grows in the intertidal zone, often with *Zostera marina*, which extends to greater depths. Occurs also in subtidal areas in sandy to muddy substrates, estuaries, and coastal lagoons
Cymodocea nodosa	Mediterranean Sea, NE Atlantic northward of Portugal and southward of Senegal; Canary Islands, Madeira, Cape Verde; widespread in Mediterranean Sea	Intertidal – ~30–35 m	Highly adaptable to environmental variability; good colonizer of new substrates	Grows from the intertidal to 33-35 m depths. Can occur from coarse sand to muddy sediments. Can colonize different environmental types, e.g. open coastal waters, estuaries, coastal lagoons
Posidonia oceanica	Endemic Mediterranean seagrass; widely distributed along the Mediterranean	0.5- 45 m	Slow-growing; climax community; forms matte; Emblematic species of Mediterranean	Forms continuous meadows from 0.5 to 45 m depth. In turbid waters, the lower limit is about 9 m. Forms very dense meadows. Its meadows are considered a climax community. Not tolerate slightly salinity fluctuations and turbidity and, thus, not found in estuaries
Halophila stipulacea	Native to Red Sea, Persian Gulf and Indian Ocean, introduced in Mediterranean, where it occurs from Egypt to southern Italy and Tunisia	0-70 m Scarce below 50m	Fast-growing; introduced in Mediterranean	Occurs in the shallows , but also in much deeper water and has been recorded to depths > 50 m. Euryhaline species. In the eastern Mediterranean, occurs in soft substrates. Is fast-growing, and thus can expand rapidly.
Ruppia maritima	Circumglobal species, widespread in temperate and tropical regions	0-2 m	Wide salinity tolerance, brackish water species	Has a wide salinity tolerance, can survive in salinity values from 0 to 70. Occurs in fresh water, brackish water, marine environments and hyperhaline conditions. Occurs in estuaries and coastal lagoons

Endemic Species:

- **Definition**: Found naturally in only ONE specific, restricted geographical area
- **Example**: *Posidonia oceanica* in Mediterranean
- **Importance**: If Mediterranean meadows are destroyed, species could go extinct globally

Introduced/Invasive Species:

- **Definition**: Species introduced by human activities, intentionally or accidentally, into a region outside its natural, historic range
- **Example**: *Halophila stipulacea* in the Caribbean Sea
- Can become invasive if it spreads rapidly and affects native species and causes harm to the new environment

Emblematic species:

- iconic animals, plants, or fungi that symbolize a region's unique biodiversity
- species are typically threatened
- serve as indicators of ecological health
- are used to foster public engagement in conservation

PHASE 4: ELABORATION

Activity: "Species Distribution Detective"

Comparison Questions

Students work in pairs to answer comparison questions using the class map and chart:

Questions:

1. **Which species can survive in the coldest waters?**
   - Answer: *Zostera marina* (survives ice cover in Arctic Norway)
2. **Which species is found in the most European seas?**
   - Answer: *Zostera marina* (Norwegian Sea, North Sea, Baltic, Atlantic, Mediterranean, Black Sea)
3. **Which species is found only in the Mediterranean?**
   - Answer: *Posidonia oceanica* (endemic)
4. **Which species commonly grow in the intertidal zone?**
   - Answer: *Zostera noltei*
5. **Which species can survive in freshwater?**
   - Answer: *Ruppia maritima* (salinity tolerance 0-70)
6. **Which species can grow at the deepest depths?**
   - Answer: *Halophila stipulacea* (>50 meters)
7. **If you were in an estuary where freshwater meets salt-water, which species might you find?**
   - Answer: *Zostera marina, Zostera noltei, Cymodocea nodosa*, or *Ruppia maritima* (not *Posidonia*—doesn't tolerate salinity fluctuations)
8. **Which species has been introduced in the Mediterranean Sea?**
   - Answer: *Halophila stipulacea* (introduced from Indian Ocean/Red Sea)

Prediction Scenarios

Teacher presents location scenarios; students predict which species might be found:

Scenario 1: "You're visiting the Baltic Sea in northern Europe. The water is cold, depth is 5 meters, substrate is sandy. Which seagrass species would you expect to find?"

- Answer: Most likely *Zostera marina* (abundant in Baltic)

Scenario 2: "You're in a shallow western Mediterranean coastal lagoon. Salinity varies from 25 -35. Depth is about 1 meter. Which species might grow here?"

- Answer: *Cymodocea nodosa, Zostera species, Ruppia maritima*; NOT likely *Posidonia* (doesn't like salinity fluctuations)

Scenario 3: "You're diving in clear eastern Mediterranean water at 25 meters depth on sandy substrate. Which species might you see?"

- Answer: *Posidonia oceanica, Cymodocea nodosa, Halophila stipulacea*

Scenario 4: "You're exploring a coastal lagoon where salinity is extremely high (50). Which species might you see?

- Answer: Most likely *Ruppia maritima* (tolerates salinity 0-70)

PHASE 5: EVALUATION

Assessment Activity: Exit Ticket - "European Seagrass Distribution"

Students complete individually:

Part 1: Species Identification

Match the species to its description:

1. Endemic to Mediterranean Sea: _____ _____
2. Introduced (non-native) species in Mediterranean: _____
3. Has widest salinity tolerance (0-70): _____ _____

Part 2: Distribution Knowledge

4. Which species is found in Arctic waters of Norway? _____
5. Which two species are most widespread in the Mediterranean Sea? _____ and _____
6. *Posidonia oceanica* is not found in estuaries. Why?

Part 3: Depth & Habitat

7. Which species commonly occurs in the intertidal zone? _____
8. Which species can grow at the deepest depths (>50m)? _____

Part 4: Terminology

9. What does "endemic species" mean? _____ _____
10. What is an emblematic species? _____ _____

ASSESSMENT STRATEGIES

Formative Assessment (During Lesson):

Map Accuracy:

- Check coloured maps for correct geographical regions
- Verify understanding of species ranges

Comparison Activity:

- Monitor pair discussions during comparison questions
- Assess reasoning for prediction scenarios
- Note use of environmental factors in explanations

Summative Assessment (End of Lesson):

Exit Ticket Evaluation Rubric:

1. Species Identification
2. Geographical distribution Knowledge
3. Depth & Habitat
4. Terminology

Success Criteria Shared with Students:

- I can name six seagrass species found in European waters
- I can locate where each species is distributed on a map
- I can explain the terms: endemic species, introduced species, climax community
- I can connect species characteristics (depth range, salinity tolerance) to their environmental distributions

Appendix

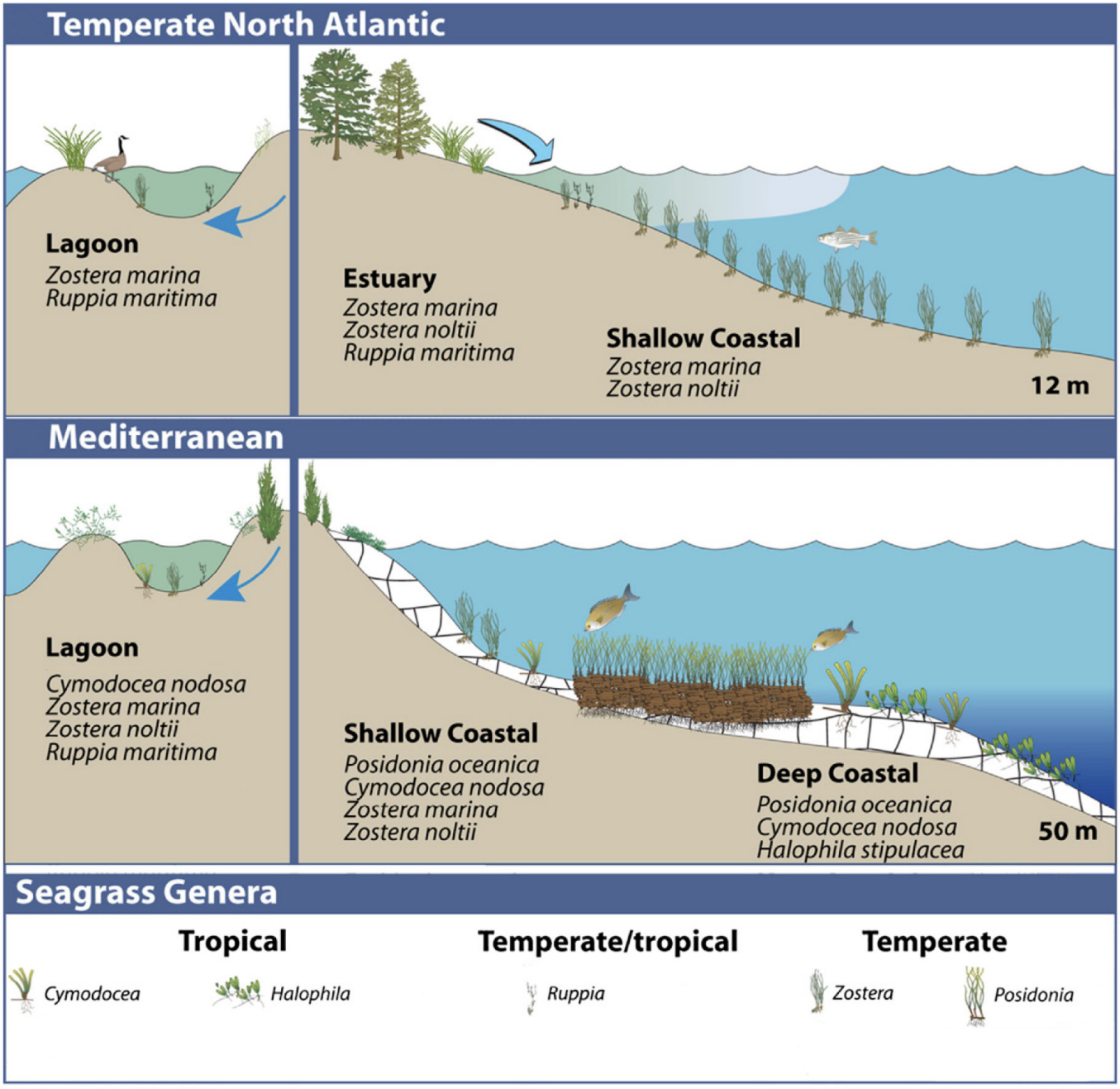


Figure 1. Seagrass habitat diagrams for (a) the Temperate North Atlantic Bioregion and (b) the Mediterranean Bioregion (modified from Short et al., 2007. Journal of Experimental Marine Biology and Ecology 350, 3–20)

LESSON PLANS 4, 5 & 6. SEAGRASS FIELD SAMPLING

DURATION: 180 MINUTES (FIELD ACTIVITY)

Due to its extended duration (3 hours) and its structure into three distinct instructional phases (pre-field preparation, field investigation, and post-field reflection), this field trip is equivalent to three lesson plans.

LESSON OVERVIEW

This outdoor field lesson provides students with hands-on experience in seagrass sampling techniques used by marine scientists, creating meaningful connections between classroom learning and the marine environment. By collecting, observing, and handling real seagrass plants, students deepen their understanding and engagement in ways that classroom activities alone cannot replicate. Students will visit a marine coastal site, an estuarine site or a coastal lagoon site to collect seagrass samples at the intertidal and/or upper subtidal zone using scientific field methods. Working in teams, they will learn proper sampling procedures, field safety protocols, and plant handling techniques while gaining experience with authentic scientific practices. The activity links classroom knowledge of seagrass morphology, taxonomy, and identification with real-world fieldwork. Students will also prepare their samples for subsequent laboratory analysis, experiencing key stages of the marine research process. Throughout the lesson, emphasis is placed on careful observation, teamwork, safety awareness, and respect for marine ecosystems.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Describe how the seagrass sampling is done
- Explain the importance of rinsing samples carefully to preserve plant structure

Skills Objectives

By the end of this lesson, students will be able to:

- Use a PVC corer correctly and safely to extract seagrass samples
- Work collaboratively in field teams to collect samples
- Rinse plants in seawater using a strainer without damaging plant structures
- Record field observations systematically (location, date, conditions, preliminary species identification)
- Follow safety protocols in marine field environments

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Appreciate the challenges and rewards of field research
- Value teamwork and collaboration in scientific fieldwork

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Use instruments (corers) for data collection
- Collect biological samples using standardized field methods
- Follow scientific sampling protocols accurately

Environmental Literacy Competencies:

- Appreciate the importance of field research for environmental monitoring

Social and Civic Competencies:

- Work effectively in field teams under varying conditions
- Share responsibilities for equipment and sample handling
- Support team members during challenging field tasks

PRE-ACTIVITY PREPARATION

(Teacher guidance):

Prior to the implementation of the activity, the teacher should have carefully identified, visited, and assessed a suitable coastal site with a seagrass bed, ensuring that it is accessible and safe for student participation. It is also recommended that the teacher consults both reliable information sources and local knowledge (e.g., fishermen) to determine the most appropriate period for conducting the activity.

Recommended sampling period

Generally May - September

Reasons:

- Higher water temperatures make fieldwork more comfortable and safer allowing easier sampling conditions
- Better phase of seagrass growth cycle - plants are larger and more robust allowing easier morphological observation and identification

Expected Species:

- *Cymodocea nodosa*
- *Ruppia maritima*
- *Zostera marina*
- *Zostera noltei*

Sampling site options

1. Intertidal Zone
2. Upper Subtidal Zone

MATERIALS NEEDED

Field Equipment (per team of 3-4 students):

- 1 PVC corer (20 cm diameter) (Fig. 1)
- 1 large plastic strainer (colander) for rinsing samples
- 5-10 large plastic bags with labels for sample storage
- Waterproof marker for labelling
- Field notebook
- Pencils/waterproof pens
- One cooler with ice packs for all teams (for transporting samples back to school/lab)

Safety & Personal Equipment (per student):

- Rubber boots or water shoes
- Weather-appropriate clothing (see Appendix: Field Safety & Dress Code)
- Sun protection (hat, sunscreen)
- Water bottle
- First aid kit (teacher's responsibility)





Figure 1. A PVC corer (20 cm diameter)

LESSON STRUCTURE & ACTIVITIES

PHASE 1: PRE-FIELD PREPARATION

Sampling Protocol Overview

Teacher demonstrates or explains the sampling procedure:

Step 1: Selecting sampling spots

- Look for visible seagrass meadows
- Space out teams to avoid overlapping areas
- Note water depth and substrate type

Step 2: Taking the core sample

- Push corer vertically into substrate to about 15 cm depth
- Twist gently if needed to penetrate sediment
- Cover top opening with hand
- Carefully lift corer out of water while keeping one hand over top and the other at the bottom of the corer (Figs 2 and 3)
- Transport to rinsing area

Step 3: Extracting the sample

- Let excess sediment drain through bottom
- Gently push sample out into strainer

Step 4: Rinsing

- Hold strainer in seawater
- Gently swirl and rinse to remove sediment
- Be very careful not to damage plant structures (roots, rhizomes, leaves)
- Continue until sample is clean but intact

Step 5: Storage

- Place rinsed plants in labelled plastic bag
- Add small amount of seawater to keep moist
- Record: date, time, location, team name, preliminary observations



Figure 2. Seagrass sampling using a corer



Figure 3. View of the seagrass sample inside a transparent corer

Team Assignments & Responsibilities

- Divide class into teams of 3-4 students
- Assign roles within each team:
  - **Sampler**: operates the corer
  - **Rinser**: handles plant rinsing
  - **Recorder**: writes observations and labels
  - **Equipment Manager**: manages bags and strainer
  - **Photographer**: takes photos of the sampling area, the seagrass meadow, and the sampling procedure
- Rotate roles if necessary
- Each team receives one corer and supporting equipment

PHASE 2: FIELD SAMPLING

A. Site Orientation

- Teacher leads brief walk to show seagrass meadow locations
- Students observe seagrass beds in situ before sampling
- Identify visible differences in density, depth, exposure

B. Demonstration

- Teacher demonstrates complete sampling procedure with one team
- Shows proper coring technique
- Demonstrates careful rinsing

Questions during demonstration:

- "Why do we only go about 15 cm deep?" (To capture rhizomes and roots without excessive sediment)
- "Why must we rinse carefully?" (To see plant structures clearly while not damaging them)
- "What should we record about the sampling location?" (Location, date, time, possible special features of the area)

C. Team Sampling

- Teams may collect 1-3 samples depending on time and conditions.
- Each team briefly shows their sample(s) to the rest teams
- Preliminary species identifications discussed (will be confirmed in lab)

Sample Preparation for Transport

- Check that samples are moist
- Verify labels are readable and complete
- Place all sample bags in cooler with ice packs
- Rinse corers and strainers in seawater
- Count and collect all equipment
- Dispose of any waste properly (leave no trace)
- Final site check - ensure nothing left behind

Reflection in the bus while returning to school

- "What was most challenging about sampling?"
- "What surprised you about the seagrass meadow?"
- "How was this different from looking at photos in class?"
- "What did you learn about working as a field team?"

PHASE 3: POST FIELD PROCEDURES

Sample Storage at School

Upon return to school:

- Transport cooler directly to refrigerator
- Store samples at cool temperature (4-8°C) until laboratory processing
- Samples should be processed within 24 hours for best results
- Rinse field equipment with fresh water
- Dry and store corers and strainers

PHASE 4: EVALUATION / POST-FIELD ASSESSMENT

Written Reflection

1. Describe the steps you followed to collect your seagrass sample.

_____

_____

_____

2. Describe the seagrass meadow habitat where you sampled (depth, substrate, density, other organisms observed).

_____

_____

_____

3. What species do you think you collected? What features made you think so?

_____

_____

_____

4. What was the most challenging part of field sampling?

_____

_____

5. What was the most interesting thing you learned or observed?

_____

_____

6. How is working in the field different from studying seagrasses in the classroom?

_____

_____

Success Criteria Shared with Students:

- I can use a corer safely and correctly to collect seagrass samples
- I can rinse samples carefully without damaging plant structures
- I can record accurate field observations
- I can work effectively as part of a field research team
- I can identify at least one seagrass species from field plants
- I can follow safety protocols in marine field environments
- I can explain why proper sampling technique matters

Appendix

FIELD SAFETY & DRESS CODE

SAFETY PROTOCOLS

General Safety Rules:

1. Always work in teams; never separate from your team
2. Remain in designated safe sampling area marked by teacher
3. Do not enter water without teacher's permission and do not go deeper than knee-height
4. Watch for sharp shells, rocks, slippery surfaces
5. If you need help, raise your hand and call teacher
6. Carry equipment carefully; no running with sharp or heavy items
7. Observe but do not touch unfamiliar animals or plants

DRESS CODE & RECOMMENDED CLOTHING

Essential Items

- Rubber boots
- Quick-dry clothes preferred (athletic wear, swimwear)
- Wide-brimmed hat or cap
- Sunscreen
- Water bottle (labelled with student name)

Recommended Items:

- Towel
- Complete change of dry clothes in bag (to change after sampling if needed)

What NOT to Bring:

- Valuable jewellery or electronics
- Open-toed shoes, flip-flops, sandals
- Heavy cotton jeans (very uncomfortable when wet)
- Excessive cash or valuables
- Minimize noise and avoid unnecessary movements during the activity, as these may disturb wildlife (e.g., birds)
- Do not leave any litter on site
- Collect and properly dispose of all waste before leaving the area

LESSON PLANS 7, 8 & 9. SEAGRASS LABORATORY PROCESSING & ANALYSIS

DURATION: 180 MINUTES (LABORATORY SESSION)

This laboratory session requires an extended duration (3 hours) to ensure the continuity and integrity of the measurement and analysis procedures. As the activities involve sequential steps in sample processing and data analysis, interrupting the session would compromise the learning process. In addition, students work collaboratively in groups, which requires the teacher to provide ongoing guidance, monitoring, and support to each group, further increasing the time needed for effective implementation. Therefore, it is considered equivalent to three lesson plans.

LESSON OVERVIEW

This laboratory lesson follows the field sampling activity and provides students with hands-on experience in processing and analysing seagrass specimens using standardized scientific methods. Working in teams with their field-collected samples, students will perform species identification based on morphological features, geographical distribution, and habitat type. Students will then conduct quantitative measurements, including shoot density, leaf density, leaf length measurements, and biomass determination. Through systematic data collection and calculations, students will transform raw field samples into meaningful ecological data, learning how scientists quantify seagrass meadow health and abundance. This lesson emphasizes precision, mathematical application in science, and understanding the connection between individual measurements and ecosystem-level patterns.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Identify seagrass species using distinctive morphological features, geographical distribution, and habitat type
- Define key seagrass metrics: shoot density, leaf density, leaf length, biomass
- Explain what shoot density (number of shoots/m^2) may indicate about meadow health
- Understand that long leaves with sheath are adult leaves; shorter leaves with short sheath or without sheath are intermediate leaves, and short leaves without sheath are juvenile leaves

Skills Objectives

By the end of this lesson, students will be able to:

- Count shoots accurately in a corer sample
- Classify leaves as adult, intermediate or juvenile
- Measure leaf length precisely using a ruler (to nearest mm)
- Count leaf scars on vertical rhizomes
- Determine wet biomass by drying the plant surface and weighing
- Record data systematically in laboratory data sheets
- Calculate means (averages) from multiple measurements
- Compare their team's data with class data to identify patterns

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Demonstrate patience and precision during detailed measurements
- Value accuracy and careful recording in scientific work
- Collaborate effectively during complex multi-step procedures
- Recognize that individual measurements contribute to understanding larger patterns

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Systematically process biological samples using standardized protocols
- Collect quantitative and qualitative data accurately

Environmental Literacy Competencies:

- Understand quantitative measures of seagrass meadow biomass
- Recognize variation within and between seagrass species
- Appreciate the scientific basis for environmental monitoring

Digital Competencies:

- Use calculators for mathematical conversions

Social and Civic Competencies:

- Work effectively in laboratory teams with defined roles
- Share responsibilities during multi-step procedures

MATERIALS NEEDED

Per Team (3-4 students working with their field corer sample):

- 1 field-collected corer sample (refrigerated from field trip)
- Shallow pan for sample processing
- Metric ruler (30 cm, graduated in mm)
- Hand lens or magnifying glass
- Tweezers/forceps (for separating plant parts)
- Filter paper or paper towels for drying specimens
- Small labelled containers for separating plant components
- Laboratory data sheet (see Appendix)
- Pencils/pens
- Calculator

Shared Laboratory Equipment:

- Digital scale (precision to 0.1 g) - 1 per 2-3 teams
- Large workspace tables
- Waste containers for plant material disposal
- Paper towels/absorbent paper in quantity
- Trays for transporting samples

Optional Enhancement Materials:

- Stereo-microscope for detailed observation

LESSON STRUCTURE & ACTIVITIES

PHASE 1: PREPARATION & SAMPLE RETRIEVAL

Activity: "From Field to Lab"

- Assign team workspaces
- Distribute basic materials (trays, rulers, data sheets)
- Ensure each team has their labelled sample from refrigerator
- Teams retrieve their refrigerated core sample
- Open bag carefully over dissection tray
- Pour contents (plant + remaining water) into tray
- Initial observations:
    - Overall condition of specimen
    - Preliminary species observations
- Teacher outlines the session's workflow:
    1. Species identification
    2. Shoot counting and density calculation
    3. Leaf counting and classification
    4. Leaf density calculation
    5. Scar counting on rhizomes (for *Cymodocea nodosa*)
    6. Leaf length measurements
    7. Biomass determination

Learning Intention Shared: "Today you'll analyse your field samples like professional marine scientists, taking precise measurements that help us understand seagrass meadow abundance and health"

PHASE 2: SPECIES IDENTIFICATION

Activity: What Species Did We Find?"

A. Identification Criteria Review

Teacher reminds students and specifies that the definition is based on morphological factors, and is controlled by geographical distribution and habitat

1. **Morphological Features (distinctive characteristics):**

- Refer to species identification guides from Lesson Plan 3: Seagrass Taxonomy and Species Identification, Thematic Module 2: Seagrasses are Unique Plants

2. **Geographical Distribution:**

- Where was sample collected?
- Which species occur in that region? (information in Lesson Plan 3: Seagrass Meadows in Europe's Coastal Waters, Thematic Module 3: Seagrasses Form Extensive Underwater Meadows)

3. **Habitat Type:**

- Marine coastal area? Coastal Lagoon? Intertidal? Upper Subtidal?
- Species habitat preferences:
  - *Cymodocea nodosa*: Mainly subtidal, marine coast, estuary, coastal lagoon
  - *Ruppia maritima*: Brackish water, estuary, coastal lagoon
  - *Zostera marina*: Mainly subtidal, marine coast, estuary, coastal lagoon
  - *Zostera noltei*: Mainly intertidal, marine coast, estuary, coastal lagoon

B. Team Identification Process

Each team examines their sample:

1. Observe morphological features carefully
   - Use hand lens for detailed examination
   - Check leaf width, sheath type, rhizome characteristics
2. Consider sampling location and habitat
3. Refer to identification guide
4. Discuss as team and reach consensus
5. Record preliminary identification on data sheet

PHASE 3: SHOOT DENSITY MEASUREMENT

Activity: "Counting Shoots & Calculating Density"

Shoot: Leaves plus rhizome, horizontal or vertical

Procedure:

1. Carefully separate shoots in sample
   - Include: shoots with any living leaves
2. Record: Number of shoots per corer in data sheet

Example:

- Team finds shoots in their corer sample
- Record: shoots/corer

Teacher explains conversion concept:

The corer has a diameter of 20 cm, thus its surface area is **0.0314m²**. So it samples a small circular area of 0.0314 m². To estimate shoot density per square meter, we divide the number of shoots by 0.0314. This allows us to scale up our sample to represent 1 m² of the meadow. Scientists report density as **shoots per square meter (shoots/m²).**"

Conversion formula: Shoot density (shoots/m²) = Number of shoots in corer ÷ 0.0314

Class Discussion:

- "Which team had the highest shoot density?"
- "Which had the lowest?"

PHASE 4: LEAF COUNTING & CLASSIFICATION

Activity: "Analysing Leaves - Adult, intermediate and juvenile"

Procedure for each team:

1. Select 10 shoots from your sample
2. For each shoot, carefully count leaves
3. Record count for each shoot in data table
4. Classify leaves as adult, intermediate and juvenile

Key distinction:

- **Adult leaves:** Have a visible sheath (basal portion wrapping around shoot) and they are long
- **Intermediate leaves:** No sheath or very reduced sheath, intermediate length
- **Juvenile leaves:** no sheath, short

Teacher demonstrates with sample shoot, pointing out sheath presence/absence

Teams examine several shoots:

- Note proportion of adult vs. intermediate vs. juvenile leaves
- Record observations (e.g., "Most leaves are adult with visible sheaths")

Calculate Mean Leaves per Shoot

Mathematical concept: Mean (Average)

Formula: Mean leaves/shoot = Total living leaves counted ÷ Number of shoots

Calculate Leaf Density

- **Concept**: How many leaves per square meter in the meadow?

Formula: Leaf density (nu of leaves/m²) = Shoot density (shoots/m²) × Mean nu of leaves per shoot

Class comparison:

- "Which sample had the most leaves per square meter?"
- "How does leaf density relate to shoot density?"

PHASE 5: RHIZOME SCAR COUNTING (for *Cymodocea nodosa*)

Activity: "Reading Rhizome History"

A. Understanding Leaf Scars

Teacher explanation:

"When old leaves fall off, they leave marks called scars on the orthotropic rhizome. By counting scars, we can estimate how many leaves the plant has produced over time"

Key points:

- Scars appear on **orthotropic (vertical) rhizomes**
- Each scar represents one leaf that has fallen off

Teacher demonstrates scar identification using sample.

B. Scar Counting Procedure

Procedure:

1. Identify 5 vertical (orthotropic) rhizomes in your sample
2. For each vertical rhizome, count visible leaf scars
3. Record count for each rhizome

D. Calculate Mean Scars

Formula: Mean nu of scars = Total scars counted ÷ 5 rhizomes

PHASE 6: LEAF LENGTH MEASUREMENTS

Activity: "Precision Measurement"

Measurement Technique Demonstration

Teacher demonstrates proper technique:

1. Gently straighten leaf without tearing
2. Measure from base of blade (where it meets sheath) to tip
3. Record in millimetres (mm)

Measurement tips:

- Place leaf flat on white paper for visibility
- Measure along the centre of leaf
- Be consistent with starting point for all measurements

Team Measurements

Procedure:

1. Select 5 shoots from your sample
2. For each shoot, measure all living leaves
3. Record each measurement in data table

Calculate Mean Leaf Length

Formula: Mean leaf length = Total of all leaf lengths ÷ Total number of leaves measured

Class comparison:

- Create histogram on board showing distribution of mean leaf lengths
- Discuss variation between species and samples

PHASE 7: BIOMASS DETERMINATION

Activity: "Weighing Success - Wet Biomass Measurement"

Understanding Biomass

Teacher explanation:

"**Biomass** is the total weight or mass of living organisms in a specific area. It tells us about the **abundance** of seagrasses."

Why measure biomass?

- Indicates how much seagrass is present
- Allows comparison between sites and over time

Components measured together:

All leaves, all rhizomes, all roots

B. Sample Preparation for Weighing

Critical step: Removing excess water

Procedure:

1. Remove sample from tray
2. Place sample on several layers of filter paper or paper towels
3. Blot gently but thoroughly
4. Test: Press gently sample with clean paper towel - should not leave wet imprint
5. If still wet, continue blotting

Why this matters:

- Water in plant surface adds weight not related to plant tissue
- Wet biomass represents the weight of the seagrass directly after harvesting (and cleaning), containing natural moisture

Weighing Procedure

Teams take turns at shared digital scales:

Procedure:

1. Zero/tare scale with empty container
2. Place entire sample (leaves + rhizomes + roots together) in container
3. Record subweight in grams (to 0.1g precision)
4. Record: Wet biomass (g/m^2)

Biomass Density Calculation

Concept: Convert corer measurement to per square meter

Formula: **Wet biomass (g/m^2) = Wet weight (g/corer) ÷ 0.0314**

This number represents abundance:

- Higher biomass = more abundant seagrass
- Lower biomass = sparser meadow or smaller plants

Class discussion:

- "What factors might affect biomass?" (Species, season, depth, water quality, nutrients)

PHASE 8: DATA COMPILATION & ANALYSIS

Activity: "What Do Our Numbers Tell Us?"

Team Data Summary

Each team completes summary section of data sheet with all calculated values:

Summary Table:

Measurement	Value	Units
Species Identified		
Nu of shoots per corer		shoots
Shoot density		shoots/m^2
Mean nu of leaves per shoot		leaves/shoot
Leaf density		leaves/m^2
Mean nu of scars (if applicable)		scars/rhizome
Mean leaf length		mm
Wet weight per corer		g
Wet biomass		g/m^2

PHASE 9: EVALUATION & REFLECTION

Assessment Activity: Laboratory Report & Data Analysis

A. Individual Exit Report

Students complete individually:

Part 1: Species Identification

1. What species did your team identify?
2. List two things of evidence that helped you identify this species:_____ _____

Part 2: Measurements & Calculations

3. Our sample had _____ shoots/corer, which equals _____ shoots/m^2.
4. Our mean leaves per shoot was _____, and our leaf density was _____ leaves/m^2.
5. Our wet weight was _____ g/corer, which equals _____ g/m^2 biomass.
6. Show your calculation for shoot density (shoots/m^2):

Part 3: Reflection

7. What was the most challenging measurement to take accurately? Why?
8. How does analysing samples in the lab help scientists understand seagrass meadows?

Discussion questions:

- "What surprised you about your sample?"
- "How do our individual samples contribute to understanding the whole meadow?"

ASSESSMENT STRATEGIES

Formative Assessment (During Laboratory Work):

1. **Observation Checklist (Teacher monitoring throughout):**

   For each team, observe:

   ○ Correctly identifies species using multiple evidence types

   ○ Counts shoots accurately

   ○ Performs calculations correctly (shoot density, leaf density, biomass)

   ○ Measures leaf length precisely using proper technique

   ○ Distinguishes between adult and juvenile leaves

   ○ Handles specimens carefully without excessive damage

   ○ Records data neatly and completely in data sheet

   ○ Works collaboratively with defined roles

   ○ Uses calculator appropriately for conversions

   ○ Asks clarifying questions when uncertain

2. **Questioning During Procedures**:"How can you tell if this leaf is adult, intermediate or juvenile?"
   - "What does high biomass tell us about the meadow?"

3. **Calculation Checks:**
   - Circulate to review calculations in progress
   - Identify common mathematical errors for whole-class correction
   - Provide immediate feedback on unit usage
   - Ensure proper rounding and significant figures
   - Team Dynamics Observation:
   - Monitor role distribution and rotation
   - Assess communication quality within teams
   - Note collaborative problem-solving

Summative Assessment (End of Lesson):

Laboratory Report Evaluation:

- Species Identification
- Measurements & Calculations
- Data Interpretation
- Reflection
- Completed Data Sheet

Success Criteria Shared with Students:

- I can identify seagrass species using morphology, distribution, and habitat
- I can count shoots and calculate shoot density (shoots/m^2)
- I can measure leaf length accurately to the nearest millimetre
- I can calculate means (averages) from multiple measurements
- I can determine wet weight and convert to biomass (g/m^2)
- I can explain what density and biomass measurements tell us about meadow health

Appendix
LABORATORY DATA SHEET TEMPLATE

SEAGRASS LABORATORY ANALYSIS DATA SHEET

Team Name: _____ Date: _____ Team Members: _____

Sampling Location: _____

Habitat Type: ○ Intertidal ○ Subtidal ○ Coastal lagoon ○ Marine coastal area ○ Estuary

SECTION 1: SPECIES IDENTIFICATION

Preliminary Identification: _____

Evidence Used:

1. Morphological features: _____
2. Geographical distribution: _____
3. Habitat type: _____

Teacher-Confirmed Species: _____

SECTION 2: SHOOT DENSITY

Number of shoots per corer: _____ shoots

Calculation: Shoot density (nu of shoots/m^2) = _____ shoots ÷ 0.0314 = _____ shoots/m^2

SECTION 3: LEAF COUNTING

Shoot	**Number of leaves**
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Total	

Calculation: Mean nu of leaves/shoot = Total nu of leaves _____ ÷ Number of shoots _____ = _____ leaves/shoot

Leaf Classification Observations:

- Approximate % adult leaves: _____%
- Approximate % intermediate leaves: _____%
- Approximate % juvenile leaves_____%

SECTION 4: LEAF DENSITY

Calculation: Leaf density = Shoot density _____ shoots/m^2 × Mean nu of leaves/shoot _____ = _____ leaves/m^2

SECTION 5: RHIZOME SCAR COUNTING (for *Cymodocea nodosa*)

Vertical Rhizome	Number of Leaf Scars
1	
2	
3	
4	
5	
TOTAL	

Calculation: Mean nu of scars = Total nu of scars _____ ÷ 5 = _____ scars/vertical rhizome

SECTION 6: LEAF LENGTH MEASUREMENTS

Measure all living leaves on 5 shoots:

Shoot	Leaf 1	Leaf 2	Leaf 3	Leaf 4	Leaf 5	Leaf 6
1						
2						
3						
4						
5						

All measurements in millimetres (mm)

Calculation: Total length of all leaves measured: _____ mm. Number of leaves measured: _____ .
Mean leaf length = Total length _____ mm ÷ Number of leaves _____ = _____ mm

SECTION 7: WET BIOMASS

Wet biomass (entire sample: leaves + rhizomes + roots):

Weight measured: _____ g/corer

Calculation: Wet biomass (g/m^2) = Weight measured _____ g ÷ 0.0314 = _____ g/m^2

SECTION 8: SUMMARY TABLE

Measurement	Value	Units
Species Identified		
Nu of shoots per corer		shoots
Shoot density		shoots/m^2
Mean nu of leaves per shoot		leaves/shoot
Leaf density		leaves/m^2
Mean nu of scars		scars/rhizome
Mean leaf length		mm
Wet weight per corer		g
Wet biomass		g/m^2

OBSERVATIONS & NOTES:

LESSON PLANS 10, 11 & 12. *POSIDONIA OCEANICA* LABORATORY STUDY

DURATION: 180 MINUTES (LABORATORY SESSION)

This laboratory session requires an extended duration (3 hours) to ensure the continuity and integrity of the measurement and analysis procedures. As the activities involve sequential steps in sample processing and data analysis, interrupting the session would compromise the learning process. In addition, students work collaboratively in groups, which requires the teacher to provide ongoing guidance, monitoring, and support to each group, further increasing the time needed for effective implementation. Therefore, it is considered equivalent to three lesson plans.

LESSON OVERVIEW

This specialized laboratory lesson focuses on *Posidonia oceanica*, a Mediterranean seagrass species that forms vast meadows (Figs 1 and 2). Unlike the previous field sampling lesson, students cannot collect *Posidonia oceanica* themselves because this species typically grows at depths requiring SCUBA diving (Fig. 3). Instead, students will work with samples collected by a certified diver and watch underwater videos of *Posidonia oceanica* meadows. Through detailed morphological examination, students will measure leaf length and width, classify leaves by age, determine leaf wet weight by age class, examine dead leaf sheaths (scales) and observe the leaf vascular bundles using magnification.

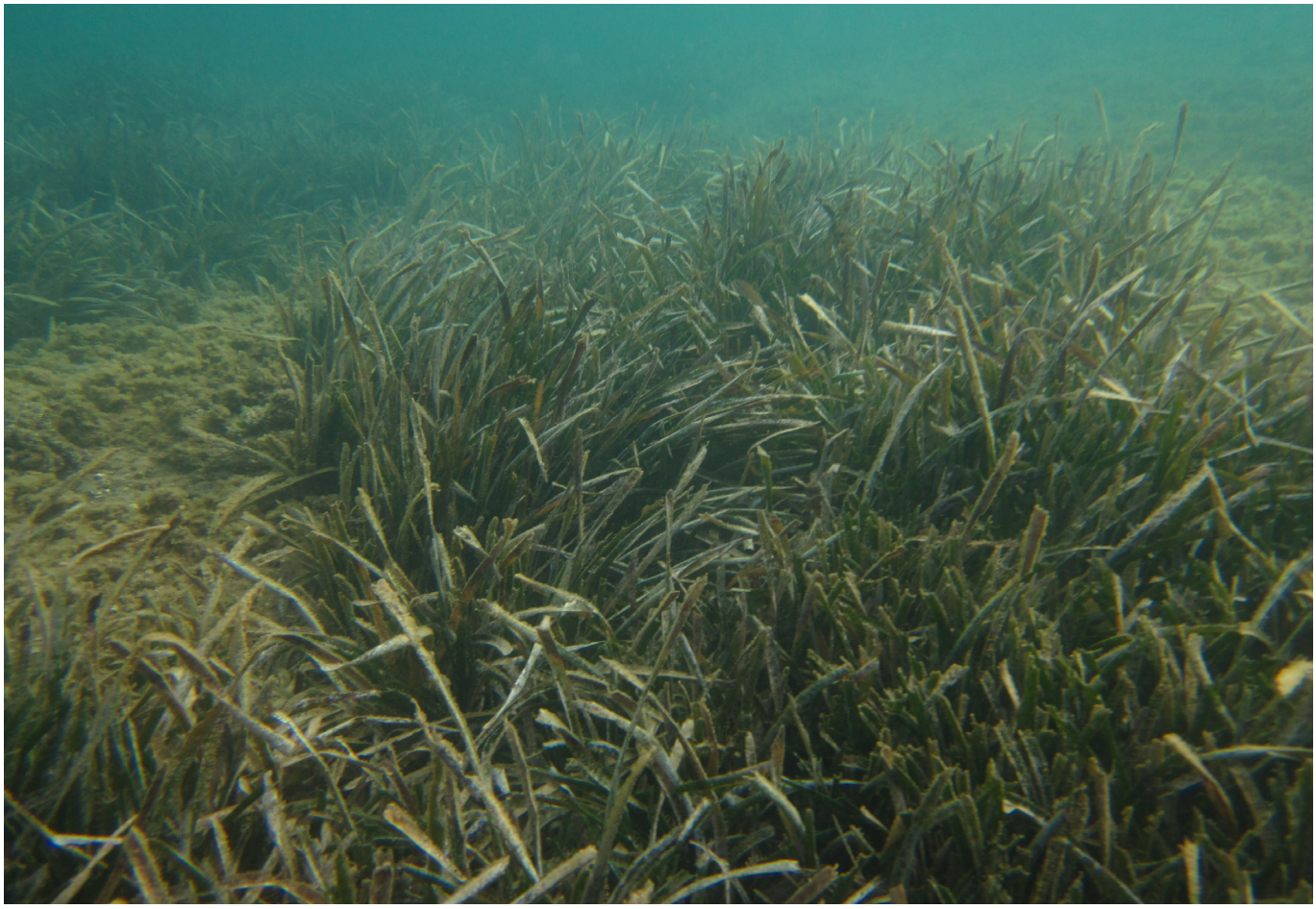


Figure 1. *Posidonia oceanica* meadow in the coastal waters of Thrace, Northern Aegean Sea, Greece (photo credit Stavros Bachtsevanidis/ Theodoros Kevrekidis)

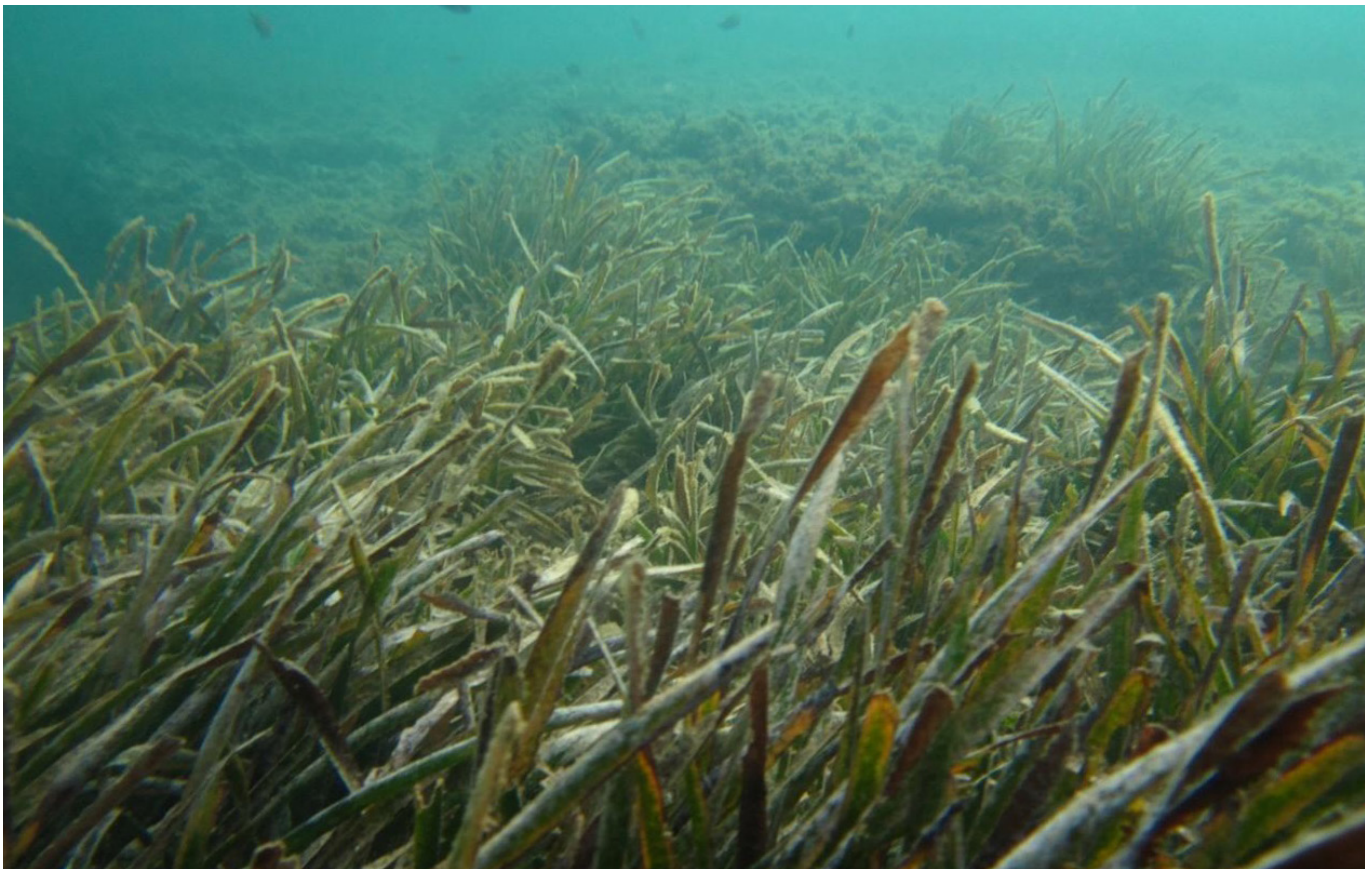


Figure 2. *Posidonia oceanica* meadow in the coastal waters of Thrace, Northern Aegean Sea, Greece (photo credit Stavros Bachtsevanidis/ Theodoros Kevrekidis)

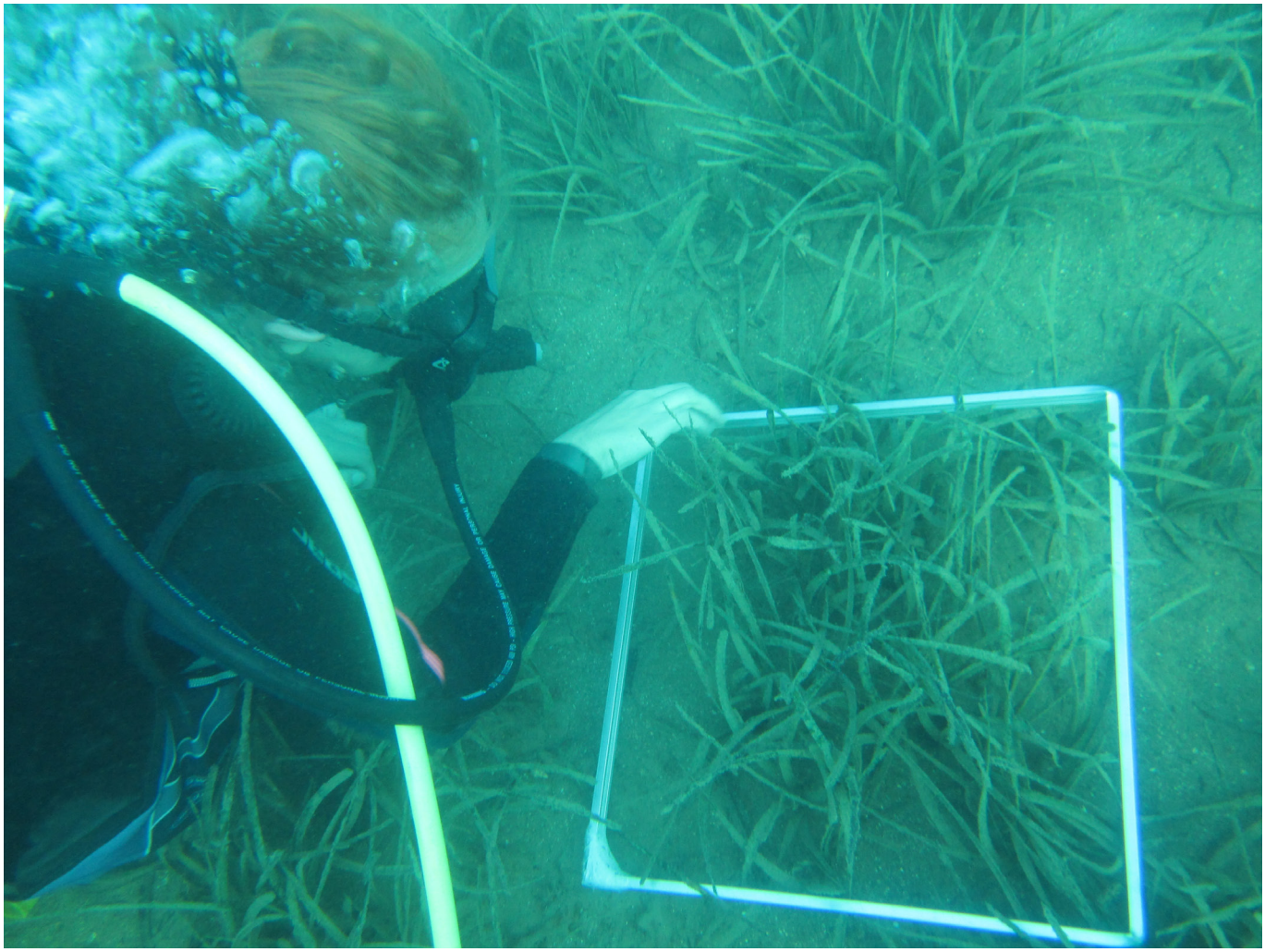


Figure 3. *Posidonia oceanica* sampling and field-based monitoring to provide information on the meadow health status; data on several meadow variables, including shoot density, leaf and rhizome coverage, biomass, etc., are collected (coastal waters of Thrace, Northern Aegean Sea, Greece; image credit Stavros Bachtsevanidis/Paraskevi Malea)

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Recognize *Posidonia oceanica* by its distinctive features: wide strap-shaped leaves, brown fibrous remains of old sheaths (scales) on rhizomes, robust structure (see Lesson Plan 3: Seagrass Taxonomy and Species Identification, Thematic Module 2: Seagrasses are Unique Plants)
- Classify leaves into age classes (adult, intermediate, juvenile)
- Understand that dead sheaths (scales) on vertical rhizomes represent fallen adult leaves
- Explain that approximately 7-8 dead sheaths correspond to one year of growth
- Recognize that comparing dead sheath numbers among years shows trends in leaf production over time (indication of past conditions)
- Identify vascular bundles on leaf surfaces and in leaf cross-sections
- Understand that air spaces (lacunae) in leaves facilitate oxygen transport from leaves to rhizome and roots

Skills Objectives

By the end of this lesson, students will be able to:

- Count leaves per shoot accurately
- Classify leaves by age class based on sheath presence, and blade and sheath length
- Measure leaf length and width precisely (mm)
- Remove and count dead sheaths from vertical rhizomes using proper technique
- Calculate mean values from multiple measurements
- Determine wet weight separately for different leaf age classes
- Use hand lens and microscope to observe vascular bundles on leaf surfaces
- Observe microscopic cross-sections to identify vascular bundles and air spaces
- Interpret video documentation of underwater meadows
- Compare living leaves with beach-cast material (if field visit conducted)

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Understand that different species require different sampling and study approaches
- Recognize the connection between plant structures and past environmental conditions (bioindicator concept)
- Define the longevity of *Posidonia oceanica* (indicated by multi-year dead sheath records)

KEY COMPETENCIES DEVELOPED

Scientific Literacy Competencies:

- Systematically process specialized biological samples
- Use microscopy and magnification for detailed observation
- Collect quantitative data (counts, measurements, wet weight)
- Calculate means and compare data across leaf age classes
- Use appropriate units and precision in measurements
- Document observations through drawings and descriptions

Environmental Literacy Competencies:

- Connect plant past growth patterns to past environmental conditions

Digital Competencies:

- Interpret video documentation of underwater environments

Social and Civic Competencies:

- Work effectively in laboratory teams with complex procedures
- Communicate detailed observations clearly
- Appreciate professional scientific diving and research careers

MATERIALS NEEDED

Per Team (3-4 students):

- 1 vertical rhizome with attached shoots of *Posidonia oceanica* (collected by diver)
- Metric ruler (30 cm, graduated in mm)
- Hand lens (magnifying glass, 10x magnification)
- Tweezers/forceps
- razor blade (for removing dead sheaths) - teacher-supervised use
- Small labelled containers for separating leaf age classes
- Filter paper or paper towels
- Laboratory data sheet (see Appendix)
- Pencils/pens
- Calculator
- Rubber bulb with water
- Microscope slides
- Coverslips

Shared Laboratory Equipment:

- Digital scale (precision to 0.1g) - 1 per 2-3 teams
- Microscope (1 per 2-3 teams) for observing vascular bundles on leaf surface
- Waste containers for plant material
- Paper towels in quantity

LESSON STRUCTURE & ACTIVITIES

PHASE 1: INTRODUCTION & VIDEO OBSERVATION

Activity: "Discovering the Underwater Forest"

A. Why We Can't Sample *Posidonia oceanica* Ourselves

Teacher explanation:

"*Posidonia oceanica* grows typically at 0.5 to 45 meters depth—far beyond where we can wade or snorkel safely."

Video Viewing: *Posidonia oceanica* Meadows

- https://www.istockphoto.com/search/2/film?phrase=posidonia%20oceanica
- https://www.shutterstock.com/el/video/clip-1079476352-close-up-dense-thickets-green-marine-grass-posidonia?trackingId=b75a263e-ac88-413b-a836-bcd3f7a4dc08&listId=searchResults

Underwater Meadow

Viewing prompts (teacher guides observation):

- "Notice the depth—look at the light levels"
- "See how dense the meadow is»
- "What organisms do you see living in the meadow?"
- "How tall are the leaves?"

Post-Video Discussion

Discussion questions:

- "What surprised you about the *Posidonia oceanica* meadow?"
- "How is this different from the shallow sea-grass meadows we visited?"
- "Why might *Posidonia oceanica* meadows be important for fish and other animals?" (habitat, food, nursery)

B. Introduction to Today's Analysis

Teacher explains:

"Because we don't have quantitative samples (measured area like a corer), we won't calculate density or meadow-level wet weight today. Instead, we'll focus on:

1. Leaf characteristics and age classes
2. Individual shoot measurements
3. Dead sheaths as a 'history book' of the plant
4. Microscopic structures

Learning Intention Shared: "Today you'll examine *Posidonia oceanica* in detail, and learn to read its growth history from dead sheaths."

PHASE 2: SAMPLE EXAMINATION & LEAF COUNTING

Enter all measurements and calculated values into the respective tables on the worksheet

Activity: "Meet Your *Posidonia oceanica*"

Each team receives:

- 1 orthotropic (vertical) rhizome with attached shoots (Fig. 4)
- Each orthotropic (vertical) rhizome should have visible dead sheaths (fibrous brown scales)
- Shoots should have multiple intact leaves



Figure 4. *Posidonia oceanica* sample: twelve orthotropic rhizomes attached to a plagiotropic rhizome.

Initial observations (teams discuss and record):

- Overall size and robustness
- Colour of leaves (bright green to olive green)
- Texture of fibrous dead sheaths on rhizome
- Number of shoots
- Distinctive features noticed

Teacher circulates:

- "What do you notice about the rhizome covering? Does it look like 'paintbrush' bristles?"
- "How wide are the leaves compared to other seagrasses?"
- "Can you see where old leaves have fallen off?"

Counting Leaves per Shoot

Procedure:

1. Select all shoots from your sample (typically 1-2 shoots per team)
2. For each shoot, count all leaves per category
    - intact
    - cut
3. Record count for each shoot
4. Calculate mean number of leaves per shoot

Formula: Mean nu of leaves per shoot = Total nu of leaves ÷ Number of shoots

PHASE 3: LEAF AGE CLASSIFICATION

Enter all measurements and calculated values into the respective tables on the worksheet

Activity: "Adult, intermediate, or juvenile leaves?"

Age Classification Criteria

Teacher explains with demonstration:

Just like with other seagrasses, we can classify *Posidonia oceanica* leaves by age using sheath presence and leaf length (Fig. 5).

- **Adult leaves**: leaves with a well-developed sheath of >0.5 cm length.
- **Intermediate leaves**: leaves without a sheath or with a no well-developed sheath of <0.5 cm length, and measuring over 5 cm.
- **Juvenile leaves:** leaves without a sheath and measuring < 5 cm.

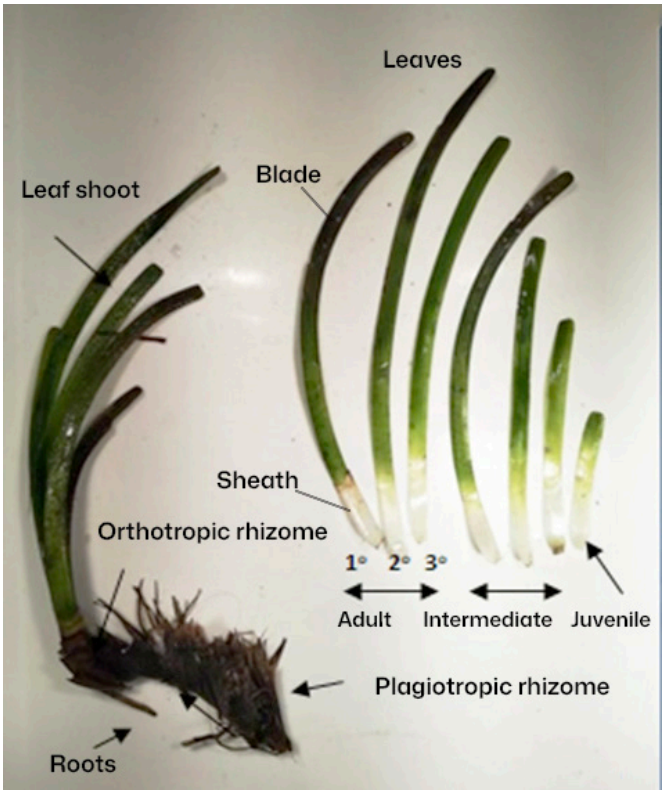


Figure 5. *Posidonia oceanica* plagiotropic rhizome, orthotropic rhizome, roots, leaf shoot and leaves classified per age (from Kevrekidou et al., 2024. Marine Drugs 22, 130)

Visual demonstration: Teacher shows example shoot.

Team Classification & Counting

- For each shoot, separate and count leaves by age class:
- Calculate the proportion

Calculations:

Percentage of each category of leaves = (nu of leaves in each category ÷ total nu of leaves) × 100

Class discussion:

- "What percentage of leaves are adult, intermediate and juvenile in your sample?"

PHASE 4: LEAF MEASUREMENTS - LENGTH & WIDTH

Enter all measurements and calculated values into the respective tables on the worksheet

Activity: "Precision Measurement of *Posidonia oceanica* **Leaves"**

Measurement Technique Review
Teacher demonstrates:

Length:

- Measure from base of blade (where sheath ends) to blade tip
- Record in millimetres (mm)

Width:

- Measure at mid-blade
- Record in millimetres (mm)
- *Posidonia oceanica* leaves typically 5-12 mm wide

Tips for accuracy:

- Gently flatten leaf on white paper
- Don't stretch or compress
- Measure to nearest mm

Team Measurement

Procedure:
Select all shoots and measure all intact leaves

Calculate Mean Dimensions

Calculate separately for each age class:

Adult Leaves:

- Mean adult length = (sum of all adult lengths) ÷ (number of adult leaves)
- Mean adult width = (sum of all adult widths) ÷ (number of adult leaves)

Do the same for the rest categories of leaves

Observations:

- Adult leaves are longer and wider
- *Posidonia oceanica* leaves are among the largest of Mediterranean seagrasses

PHASE 5: WET WEIGHT BY AGE CLASS

Enter all measurements and calculated values into the respective tables on the worksheet

Activity: "Weighing Leaves by Age"

Preparation for wet weight Measurement

Why measure by age class?

- .....
- .....

Procedure overview:

1. Separate all leaves by age class
2. Dry each group on filter paper
3. Weigh each age class separately

Procedure overview:

For each team:

1. Separate all leaves into three groups:
    - Container 1: All adult leaves
    - Container 2: All intermediate leaves
    - Container 3: All juvenile leaves
2. Blot dry each leaf separately on filter paper:
    - Remove the epiphytic algae from the surface of the leaf with a razor
    - Remove water from leaf surface
    - Press gently until paper doesn't show wet imprint
    - Keep leaf groups separate

Weighing & Recording

Teams take turns at scale:

Procedure:

1. Zero/tare scale with empty container
2. Weigh all adult leaves together
3. Record: Wet weight of adult leaves (g)
4. Calculate the mean weight of adult leaves per shoot

Formula: **Mean weight of adult leaves per shoot = Total weight of adult leaves ÷ Number of shoots**

5. Do the same for intermediate and juvenile leaves

Discussion:

- "Which age class has more wet weight in your sample?"

Note: Unlike previous lesson, we do not convert to g/m² because we don't have quantitative area samples.

PHASE 6: DEAD SHEATH (SCALE) ANALYSIS - "Reading the Plant's History"

Enter all measurements and calculated values into the respective tables on the worksheet

Activity: "Leaf Scales Tell a Story"

Introduction to Dead Sheaths as past indicators

Teacher explanation with visual aids:

The vertical rhizome of *Posidonia oceanica* is covered with dead sheaths (Fig. 6). These are like a history book of the plant.

Key concepts:

1. What are dead sheaths?
    - When adult blades fall off, their sheaths remain on the vertical rhizome
    - They die and turn brown/fibrous
    - They persist for many years
2. Annual leaf production:
    - *Posidonia oceanica* produces approximately 7-8 leaves per year
    - Therefore: 7-8 dead sheaths = one year of past growth

3. Past indicator value:
    - Counting dead sheaths tells us about past leaf production
    - Comparing dead sheath numbers between years shows trends over time:
        - More sheaths in a year = increased leaf production (good conditions)
        - Fewer sheaths in a year = decreased leaf production (possible stress, pollution)
    - Indicator of past contamination or environmental change



Figure 6. *Posidonia oceanica* rhizomes with dead sheaths and leaves (photo credit Paraskevi Malea)

Dead Sheath Removal & Counting

Procedure:

1. Select one vertical rhizome from your sample
2. Starting at the base (oldest part) of the vertical rhizome:
    - Carefully remove dead sheaths using razor (dead sheaths are attached to the orthotropic rhizome alternately, one on the right and one on the left)
    - Place removed dead sheaths in order on paper towel (Fig. 7)
3. Count dead sheaths in groups of 7-8 to represent years:
    - Group 1 (e.g. sheaths 1-7): represents approximately Year 1 (oldest)
    - Group 2 (e.g. sheaths 8-14): represents approximately Year 2
    - Group 3 (e.g. sheaths 15-21): represents approximately Year 3
    - Continue until all dead sheaths removed

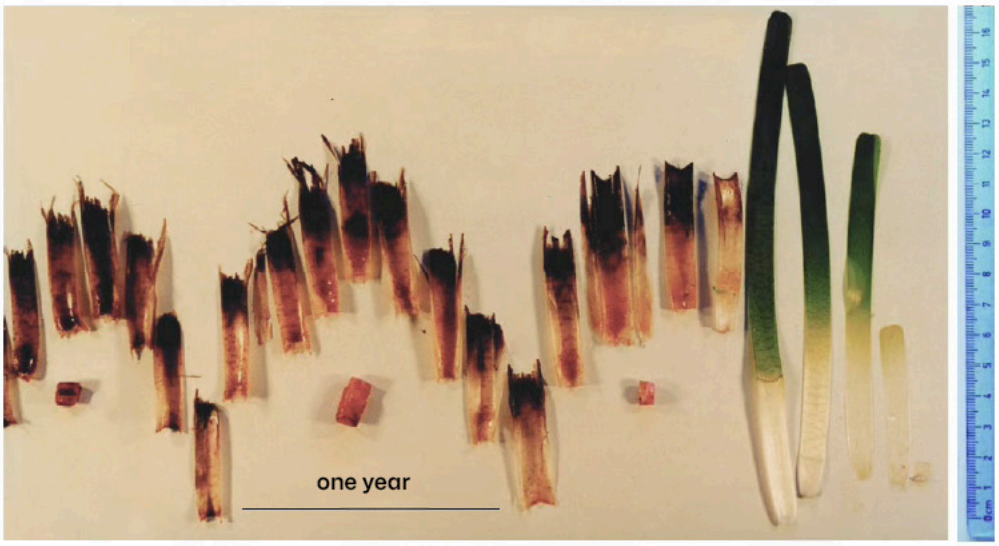


Figure 7. Dead sheaths and leaves that have been removed from a vertical rhizome of *Posidonia oceanica* and have been placed in order of decreasing age from left (oldest) to right (photo credit H. Amoutzopoulou)

Interpreting Sheath Data

Analysis questions:

1. "How many total dead sheaths did you count?"
2. "Approximately how many years of growth does this represent?"
3. "What environmental factors might affect leaf production?"
    - turbidity, light availability, nutrients, pollution

Key concept: "Scientists use this technique to look back in time and see how the plant, and the environment, have changed. It's like reading tree rings, but for seagrasses"

MICROSCOPIC OBSERVATION - VASCULAR BUNDLES & AIR SPACES

Enter all measurements and calculated values into the respective tables on the worksheet. Do your drawing at the end of the worksheet.

Activity: "Inside the Leaf - Discovering Hidden Structures"

Surface Observation with Hand Lens

Procedure:

1. Select one fresh leaf blade (adult or intermediate leaf)
2. Examine leaf surface with hand lens (Fig. 8):
    - Look for parallel lines running lengthwise
    - These are the parallel vascular bundles (veins)
    - Count how many vascular bundles you can see
3. Draw what you observe:
    - Simple sketch showing leaf outline
    - Draw parallel lines representing vascular bundles
    - Label: "vascular bundles"

Teacher explanation: Vascular bundles are like highways inside the plant, transporting nutrients and sugars."

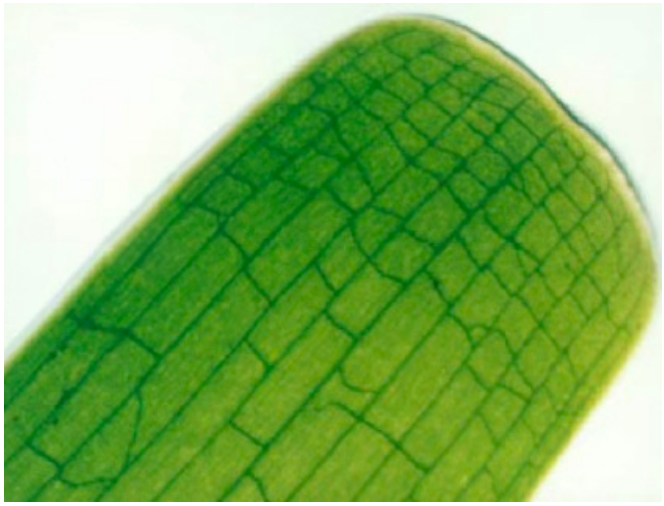


Figure 8. Vascular bundles (veins) at the leaf apex of *Posidonia oceanica* (photo credit H. Amoutzopoulou)

Cross-Section Observation with Compound Microscope

The teacher makes very fine incisions, puts a drop of water on the slide so that the incisions sit upright.

Observe Fig. 9 carefully and find the structures below:

1. **Vascular bundles**:
    - Appear as small black circles at regular intervals throughout the leaf
2. **Air spaces:**
    - Appear as large empty-looking spaces at regular intervals throughout the leaf
    - Function: facilitate oxygen transport from leaves to rhizomes and roots

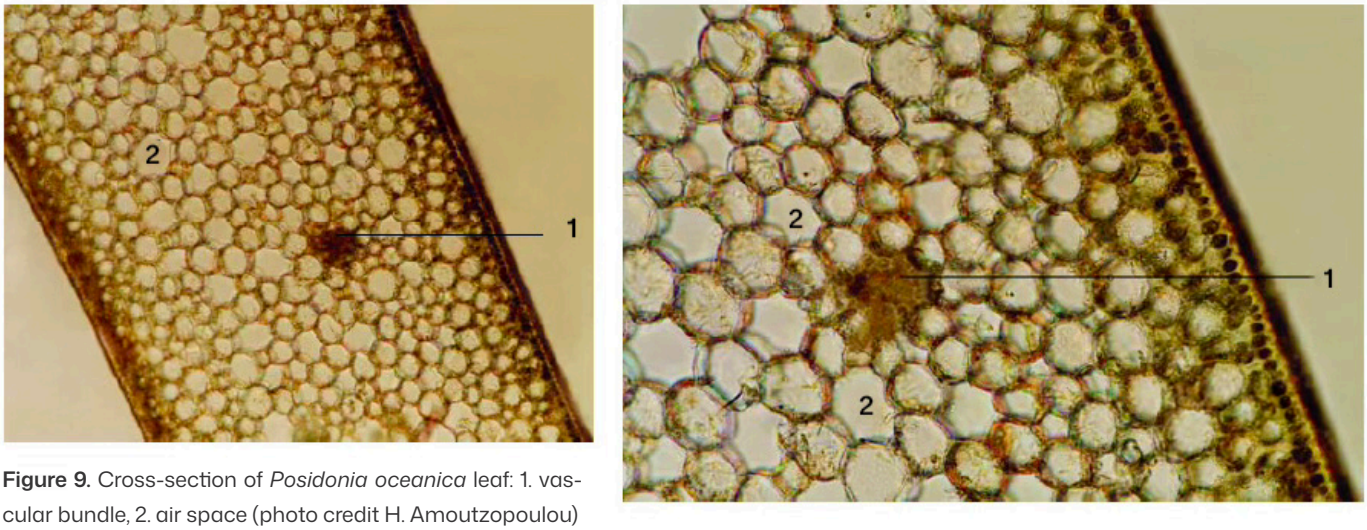


Figure 9. Cross-section of *Posidonia oceanica* leaf: 1. vascular bundle, 2. air space (photo credit H. Amoutzopoulou)

PHASE 8: DATA COMPILATION & REFLECTION

Enter all measurements and calculated values into the respective tables on the worksheet

Activity: "Synthesizing Our Findings"

Team Data Summary

Each team completes summary table in the worksheet.

Reflection Discussion

Questions:

- "What did you learn about *Posidonia oceanica* that surprised you?"
- "What does it mean that we can 'read' the plant's history from dead sheaths?"

PHASE 9: EVALUATION

Assessment Activity: *Posidonia oceanica* Laboratory Report

Students complete individually:

Part 1: Species Recognition

1. List three distinctive features of *Posidonia oceanica*:
   a. _____
   b. _____
   c. _____

Part 2: Measurements

2. Our sample had a mean of _____ leaves per shoot.
3. Adult leaves had a mean length of _____ mm and width of _____ mm.
4. We counted _____ dead sheaths, representing approximately _____ years of growth.

Part 3: Understanding Dead Sheaths

5. Explain how dead sheaths can tell us about the plant's past: _____
   _____
   _____

Part 4: Microscopic Structures

6. How many vascular bundles did you observe? _____
7. What is the function of air spaces in *Posidonia oceanica* leaves?

ASSESSMENT STRATEGIES

Formative Assessment (During Laboratory):

1. **Observation Checklist**

   ○ Correctly identifies *Posidonia oceanica* features

   ○ Accurately counts leaves per shoot

   ○ Properly classifies leaves by age

   ○ Measures leaf dimensions precisely

   ○ Correctly interprets dead sheath counts as years

   ○ Successfully observes vascular bundles with magnification

   ○ Records data completely and accurately

2. **Questioning**:

   - "How can you tell adult from young and intermediate leaves?"
   - "Why do we count sheaths in groups of 7-8?"
   - "What do vascular bundles do?"
   - "What advantage do air spaces give to *Posidonia oceanica*?"

Summative Assessment:

Laboratory Report Rubric

- Species Recognition
- Measurements
- Dead Sheath Understanding
- Microscopic Structures
- Reflection

Success Criteria Shared with Students:

- I can recognize *Posidonia oceanica* by its distinctive features
- I can classify leaves by age using sheath presence, and blade and sheath length
- I can measure leaf length and width accurately
- I can remove and count dead sheaths from vertical rhizomes
- I can estimate the age of an orthotropic rhizome by counting the dead sheaths
- I can explain how dead sheaths tell us about past environmental conditions
- I can identify vascular bundles and air spaces under magnification

Appendix
POSIDONIA OCEANICA LABORATORY ANALYSIS

Team: _____ Date: _____ Members: _____

SECTION 1: NUMBER OF LEAVES PER SHOOT

Shoot	Nu of intact leaves	Nu of cut leaves	Total
1			
2			
3			

Mean nu of leaves per shoot: _____ leaves/shoot

SECTION 2: LEAF AGE CLASSIFICATION

Shoot	Adult	intermediate	Juvenile	Total
1				
2				
3				
TOTAL				

Percentages: Adult _____% Intermediate _____% Juvenile _____%

SECTION 3: LEAF MEASUREMENTS

(Continue for all measured leaves)

Leaf	Age Class	Length (mm)	Width (mm)

Mean Adult size: Length _____ mm, Width _____ mm

Mean Intermediate size: Length _____ mm, Width _____ mm

Mean Juvenile size: Length _____ mm, Width _____ mm

SECTION 4: WET WEIGHT BY AGE

Age Class	Wet weight (g/shoot)
Adult	
intermediate	
juvenile	
TOTAL	

SECTION 5: DEAD SHEATHS

Year	Nu of Sheaths per orthotropic rhizome	Count
1	1-8	
2	8-14	
3	15-21	
....	.....	

Total nu of Dead Sheaths: _____

Estimated age of orthotropic rhizome in Years: _____

SECTION 6: MICROSCOPY

Vascular bundles counted: _____

Air spaces observed: O Yes ONo

Drawing:

SECTION 7. SUMMARY TABLE

Measurement	Value	Units/Notes
Mean nu of leaves/shoot		leaves/shoot
Percentage of adult leaves/shoot		%
Percentage of intermediate leaves/shoot		%
Percentage of juvenile leaves/shoot		%
Mean adult leaf length		mm
Mean adult leaf width		mm
Mean intermediate leaf length		mm
Mean intermediate leaf width		mm
Mean juvenile leaf length		mm
Mean juvenile leaf width		mm
Mean adult leaf wet weight/shoot		g
Mean intermediate leaf wet weight/shoot		g
Mean juvenile leaf wet weight/shoot		g
Mean total leaf wet weight/shoot		g
Nu of dead sheaths/orthotropic rhizome		sheaths
Estimated age of orthotropic rhizome		years
Number of vascular bundles		bundles

B4.

THEMATIC MODULE 4: SEAGRASSES SUPPORT A GREAT DIVERSITY OF LIFE

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LESSON PLAN 1. SEAGRASSES ARE IMPORTANT PRIMARY PRODUCERS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson focuses on the importance of seagrasses as primary producers. Primary producers are organisms that convert inorganic carbon into organic matter using sunlight, releasing oxygen as a by-product. In this lesson, the student will "see" photosynthesis through oxygen bubble formation on the surface of seagrass leaves exposed to a strong light source. By counting the number of oxygen bubbles by leaves exposed to different light intensities, students will also understand seagrass specific underwater light requirements. The lesson will also show how marine pollution, and the consequent decrease in light penetration, may limit seagrass oxygen production and affect the marine biota. The lesson aims to show that, through photosynthesis, seagrasses produce oxygen and biomass that are essential for the breathing and feeding of other organisms, supporting dependent food webs.

Alternative activity: If it is not possible to collect seagrasses, students may mimic this activity by using the printed images provided in Fig. 2.

Curiosity facts: Unlike land plants, seagrasses have a very thin cuticle, allowing for direct, efficient absorption of carbon dioxide (CO_2) and nutrients from the water column. They also lack stomata (pores) and instead rely on the entire leaf surface as photosynthetic tissue. Seagrass tissues contain specialized, air-filled spaces called lacunae to facilitate gas exchange, store oxygen produced during photosynthesis, and provide buoyancy, helping the leaves remain upright to capture sunlight.

LESSON OBJECTIVES

Knowledge Objectives

- Understand that oxygen is a result of photosynthesis.
- Understand that seagrasses have very high light requirements.
- Recognize the importance of clean waters for seagrass primary production and marine organisms/marine biota.

Skills Objectives

- Create varying seagrass underwater light environments.
- Compare seagrass primary production at varying light levels.
- Analyse how varying light environments affect photosynthesis.

Attitudes and Values Objectives

- Demonstrate capacity for observation and attentiveness.
- Demonstrate empathy for seagrass meadow protection and conservation.
- Develop awareness for the cleanliness of coastal environments.

KEY COMPETENCIES

Scientific Literacy Competencies:

- Understand that seagrasses are important primary producers.
- Understand that oxygen bubbling is a product of photosynthesis that can be measured.
- Understand that the amount of light affects seagrass photosynthesis.

Environmental Literacy Competencies:

- Recognize seagrasses as important oxygen producers in the ocean.
- Awareness that marine pollution can affect water clarity and seagrass photosynthesis.
- Awareness of the importance of preserving healthy seagrass meadows to support marine biodiversity.

Social and Civic Competencies:

- Collaborative working in groups.

MATERIALS AND RESOURCES

Required Materials

- Seagrass plants (plants with leaves, rhizomes and roots cleaned from sediments)
- Seawater (ca. 2 litres)
- A strong cool lamp as light source
- Assay tubes and racks
- Scissors
- Pencil (to take notes)
- Paper (to take notes)

Alternative activity (in case it is not possible to obtain seagrass plants)

- Printed images (Fig. 2)
- Scissors
- Pencil (to take notes)
- Paper (to take notes)

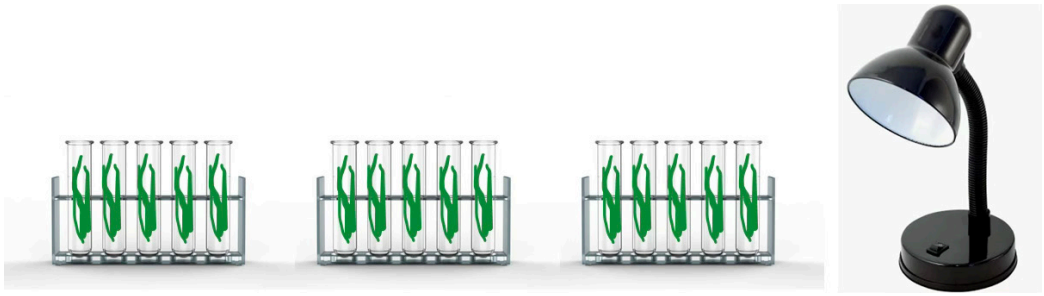

Figure 1. Scheme for the recreation of different light environments and bubble counting (created using Wikipedia under creative common license).

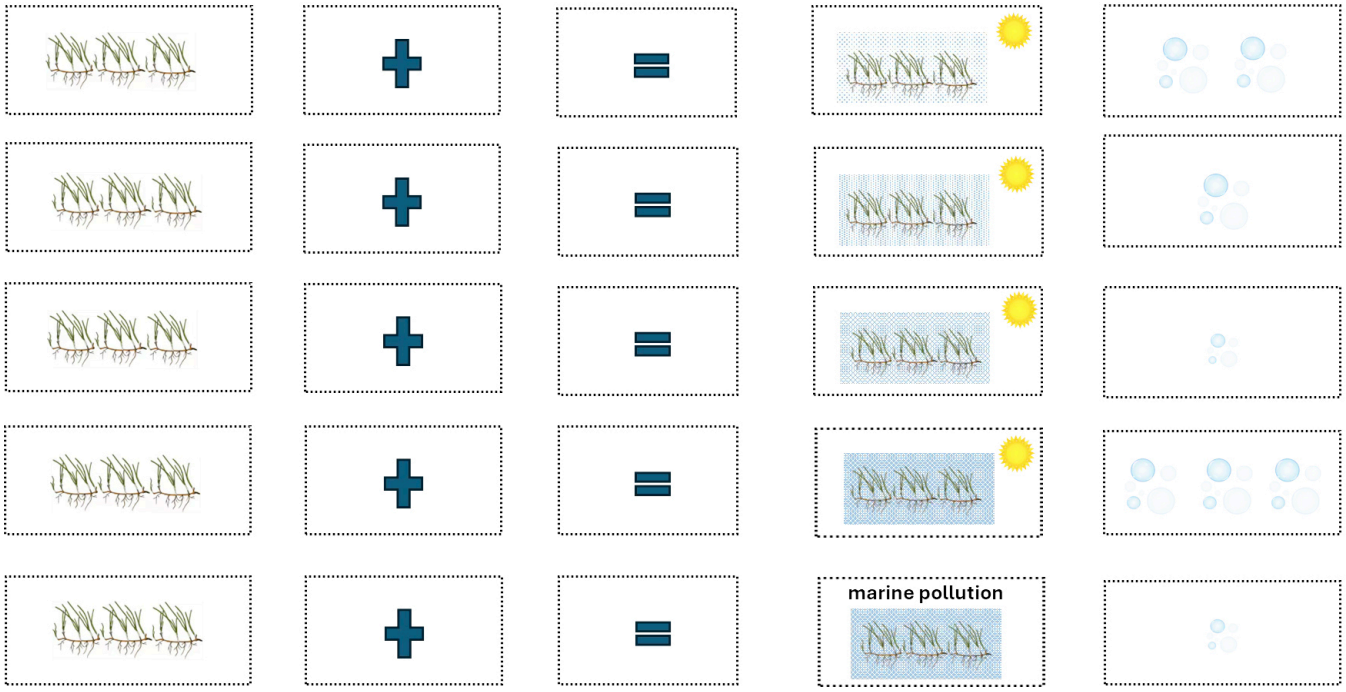

Figure 2. Printable images to associate light intensity with oxygen production (created using freesvg.org).

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Let's see photosynthesis!

- Teacher makes a small introduction explaining the principles of photosynthesis and the importance of light for seagrass photosynthesis.
- Teacher asks "What gas is produced during photosynthesis that is vital for all organisms?"
- Teacher asks "How does the amount of light affect seagrass photosynthesis?"

PHASE 2: EXPLORATION

Understand the importance of light for photosynthesis

- Students become familiar with seagrass plants.
- Students indicate which plant part will produce oxygen bubbles.
- Students indicate the environmental representative of assay tubes and the lamp.

Alternative activity

- Students become familiar with the different images in Fig. 1.
- Students indicate the meaning of each image.

PHASE 3: EXPLANATION

Photosynthesis can be seen and measured

Teacher explains that:

- the bubbles are oxygen released from the seagrass leaves.
- oxygen bubbles are a product of photosynthesis.
- assay tubes receiving a higher amount of light (the ones closer to the light source) produced a higher number of oxygen bubbles.
- seagrasses have high photosynthesis (and oxygen production) at higher light intensities.
- marine pollution decreases water transparency and, consequently, the amount of light for photosynthesis
- oxygen and biomass produced by seagrasses are used by other organisms.

PHASE 4: ELABORATION

Recreate varying seagrass light environments

- Students fill assay tubes with seawater and place seagrass plants inside them (Fig.1).
- Students place assay tubes at different distances from a light source (strong cool lamp).
- Students count the number of formed bubbles per minute in each assay tube.

Alternative activity

- Students cut the images in Fig. 2.
- Students complete the equations by associating the amount of light to the number of oxygen bubbles produced by seagrasses.

PHASE 5: EVALUATION

Exit ticket with digital quiz (e.g., can be done using Google Forms)

Students complete a quick exit ticket with the following questions:

- What are the bubbles?
- Is the bubble counting a measure of oxygen production?
- Why do assay tubes far distant from the light source have less bubbling?
- What does this mean in terms of seagrass light requirements for photosynthesis?
- How does less photosynthesis affect other organisms?

Teacher Notes:

Some bubbles may be also CO_2, as seagrasses do respire while photosynthesising.

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
   - Scientific accuracy and comprehension: students correctly answered the exit ticket quiz.
   - Engagement: students share knowledge among groups.
2. **Summative Assessment (End of Lesson)**
   - Self-evaluation: students indicate what was the most important thing they learned.

SUCCESS CRITERIA (Student-Facing)

Share these with students at the end of the lesson:

○ I can see oxygen bubbles

○ I can tell seagrasses are important primary producers

○ I can tell that light is important for seagrass photosynthesis

○ I can tell that clean water is important for seagrass photosynthesis

LESSON PLAN 2. SEAGRASSES PROVIDE FOOD FOR OTHER ORGANISMS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson focuses on the importance of seagrasses as food suppliers to a variety of animals, and how this translates into a great diversity of life in seagrass meadows. For instance, eelgrass (*Zostera marina*) ecosystems support complex food webs primarily driven by epiphytic algae growing on seagrass blades, and detritus from decaying leaves. Occasional direct grazing on seagrass leaves may occur. Primary consumers (herbivores) such as small fish (e.g. juvenile cod, mullet), snails, amphipods, isopods, all feed on seagrass epiphytes and occasionally eat seagrass leaves directly, as well as geese. Detritivores such as crabs, snails and worms feed on seagrass detritus. Secondary consumers (predators) such as eels, rockfish and herons feed on small fish, crabs, shrimps and worms. Carnivorous mammals such as sea otters are top predators and feed on crabs, shrimps, snails, clams and small fish.

The lesson will provide students with fundamental knowledge about seagrass food webs and their interconnected trophic levels. Through the exercise of building a seagrass food web and playing a card game, students will become familiar with the concepts of detritus, primary and secondary consumers, and top predators, and how the removal of specific trophic levels, particularly seagrasses, can affect the food web.

LESSON OBJECTIVES

Knowledge Objectives

- Define the concepts of herbivore, epiphytes, detritus and food web.
- Provide examples of organisms for each trophic level.
- Understand how the different trophic levels are interconnected.

Skills Objectives

- Create visual representations of a seagrass food web.
- Organize the food web according to "who feeds on what".
- Analyse the effects of removing specific trophic levels.

Attitudes and Values Objectives

- Development of critical thinking.
- Development of graphical and schematic models.
- Social interaction with colleagues.

KEY COMPETENCIES

Scientific Literacy Competencies:

- Recognize that seagrasses are the basis of the food web.
- Learn that most of seagrass biomass enters marine food-chains as detritus.
- Understand that many organisms depend on seagrasses for food.
- Identify potential threats to seagrass food webs (food web collapse).

Environmental Literacy Competencies:

- Recognize the importance of seagrasses as suppliers of organic food to a variety of dependent food webs
- Understand the vulnerability of seagrass food webs.

Social and Civic Competencies:

- Collaborative work during group activities.
- Sharing of observations and contribution to collective understanding.

MATERIALS AND RESOURCES

Required Materials

- Printed images (Fig. 1)
- Printed cards (Fig. 2)
- Scissors

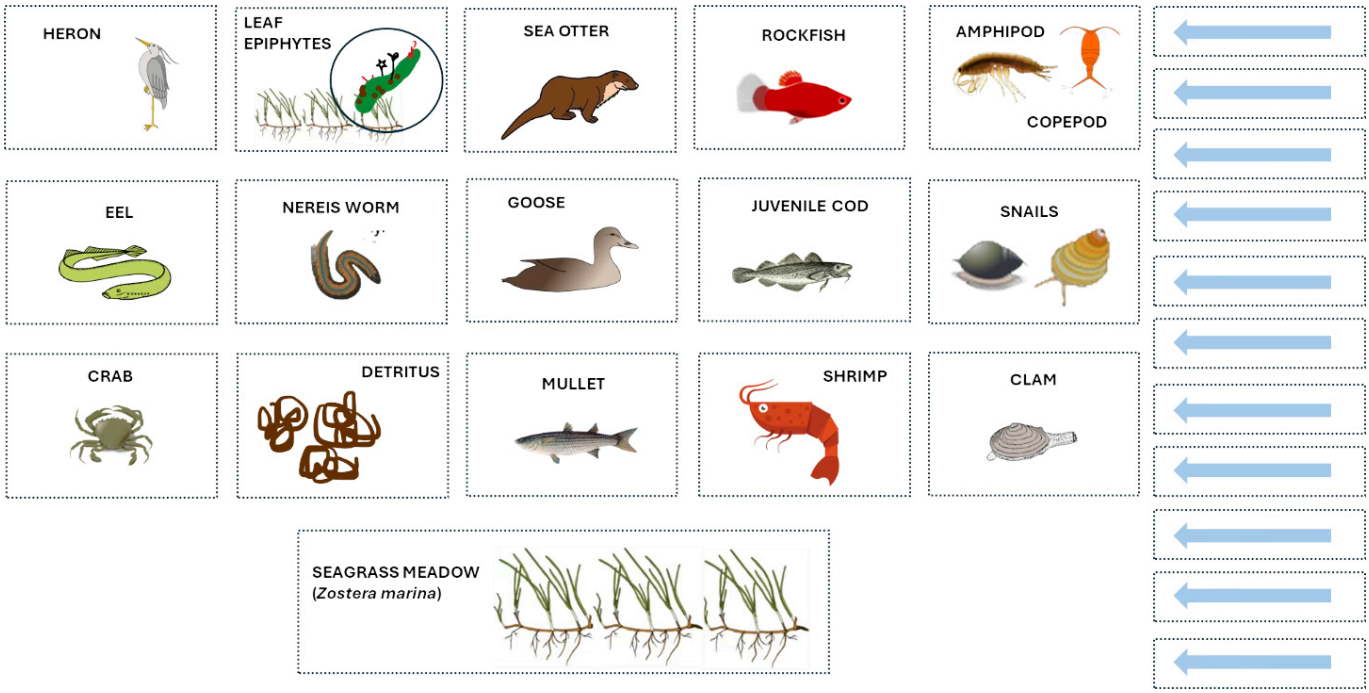

Figure 1. Printable images to build the seagrass food web (created using freesvg.org).



Figure 2. Printable cards for playing the game (created using freesvg.org).

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Who eats what?

- Teacher makes a small introduction explaining the main concepts of a seagrass food web (detritus, primary producers, primary and secondary consumers, top predators).
- Teacher provides examples of organisms in each trophic level using the printable images provided in Fig. 1.
- Teacher asks "Which animals are herbivores?"
- Teacher asks "Which animals feed on herbivores?"

Teacher Notes:

Herbivores: Primary consumers (herbivores) such as small fish (e.g. juvenile cod, mullet), snails, amphipods, isopods, all feed on seagrass epiphytes with occasional direct consumption of seagrass leaves, such as geese. Detritivores such as crabs, snails and worms feed on seagrass detritus. Secondary consumers (predators) such as eels, rockfish and herons feed on small fish, crabs, shrimps and worms. Carnivorous mammals such as sea otters are top predators and feed on crabs, shrimps, snails, clams and small fish.

PHASE 2: EXPLORATION

Let's take a look at a seagrass meadow!

- Students become familiar with the different organisms.
- Students indicate which animals feed directly on seagrasses (herbivores or primary consumers) and which feed on herbivores (secondary consumers).
- Students indicate which animals feed on seagrass detritus (detritivores).

Teacher Notes:

examples of animals that feed directly on seagrasses (herbivores or primary consumers) are geese, amphipods, isopods, small fish (mullet); animals that feed on herbivores (secondary consumers) are larger fish (e.g. rockfish, eel), top predators (sea otter); examples of detritivores are crabs, snails and worms.

PHASE 3: EXPLANATION

Understanding seagrass food webs

Teacher explains:

- that seagrasses are a direct food source for herbivores.
- that seagrass detritus support other food webs and offshore productivity.
- that seagrass epiphytes are a vital food source for primary consumers.
- the interdependence of trophic levels and the impact of seagrass loss on food availability.

PHASE 4: ELABORATION

Let's build a seagrass food web!

Working in small groups, the students:

- Cut the arrows and the images of organisms in Fig. 1.
- Create a food web, using the arrows to indicate how organisms connect with each other, from producers (seagrass and seagrass epiphytes) to consumers (primary and secondary consumers).
- Play a game where they remove a specific trophic level as indicated in each card.
- Restructure the trophic chain after the removal of the specific trophic level.

Teacher Notes:

Highlight that removing the basis of the food web, i.e., removing seagrasses and seagrass epiphytes, affects all trophic levels (primary and secondary consumers, and top predators) as opposed to removing top predators.

PHASE 5: EVALUATION

Exit ticket with digital quiz (e.g., can be done using Google Forms)

Students complete a quick exit ticket with five questions:

- What animals feed on seagrasses and seagrass epiphytes?
- What animals feed on seagrass detritus?
- What animals feed on other animals that live in seagrass meadows?
- What animals are top predators?
- What happens if we remove the seagrasses?

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
   - Scientific accuracy and comprehension: students correctly answered the exit ticket quiz.
   - Engagement: students share knowledge among groups.
2. **Summative Assessment (End of Lesson)**
   - Self-evaluation: students indicate what was the most important thing they learned.

SUCCESS CRITERIA (Student-Facing)

○ I can build a seagrass food web

○ I can recognize the importance of detritus

○ I can identify organisms in the different trophic levels

○ I can understand what happens if seagrass meadows are removed

LESSON PLAN 3. SEAGRASSES PROVIDE HABITAT FOR OTHER ORGANISMS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson focuses on the importance of seagrasses as habitat for multiple organisms. Many animals use seagrass beds as habitat, refuge and nursery areas. For example, fish and gastropods lay their eggs on seagrass leaves and fish juveniles (e.g. mullets, juvenile cod) grow inside the meadows until adult age. Many species of bacteria, microalgae, seaweeds and invertebrates grow on living seagrass leaves (epiphytes). Meadow sediments are also habitat for many organisms such as worms and clams, where they also seek food and refuge. Permanent residents are those organisms that use seagrass meadows for feeding and shelter permanently or for significant portions of their lifecycles, and include fish juveniles (e.g. juvenile cod), crustaceans (e.g. crabs and shrimps), and worms (e.g. nereis worm). Other animals use the meadow only temporarily for occasional feeding (e.g. eel, sea otter, heron, goose).

This lesson will teach how animals are distributed within a seagrass meadow in the different compartments: on and near the bottom, inside the sediments and on the surface of seagrass leaves. It will also show that seagrass meadows support a greater diversity of organisms compared to bare areas. Based on Fig. 1, students will build a habitat model representing a seagrass meadow and a bare area, i.e. no seagrasses. By playing a game, students choose to be one animal in Fig. 2 and position themselves in their appropriate location in the meadow according to the meadow compartment (on and near the bottom, in the sediment on seagrass leaves) in which they live, which they use and on which they depend. Students then realize that the seabed without vegetation harbour fewer animals than the seabed with vegetation.

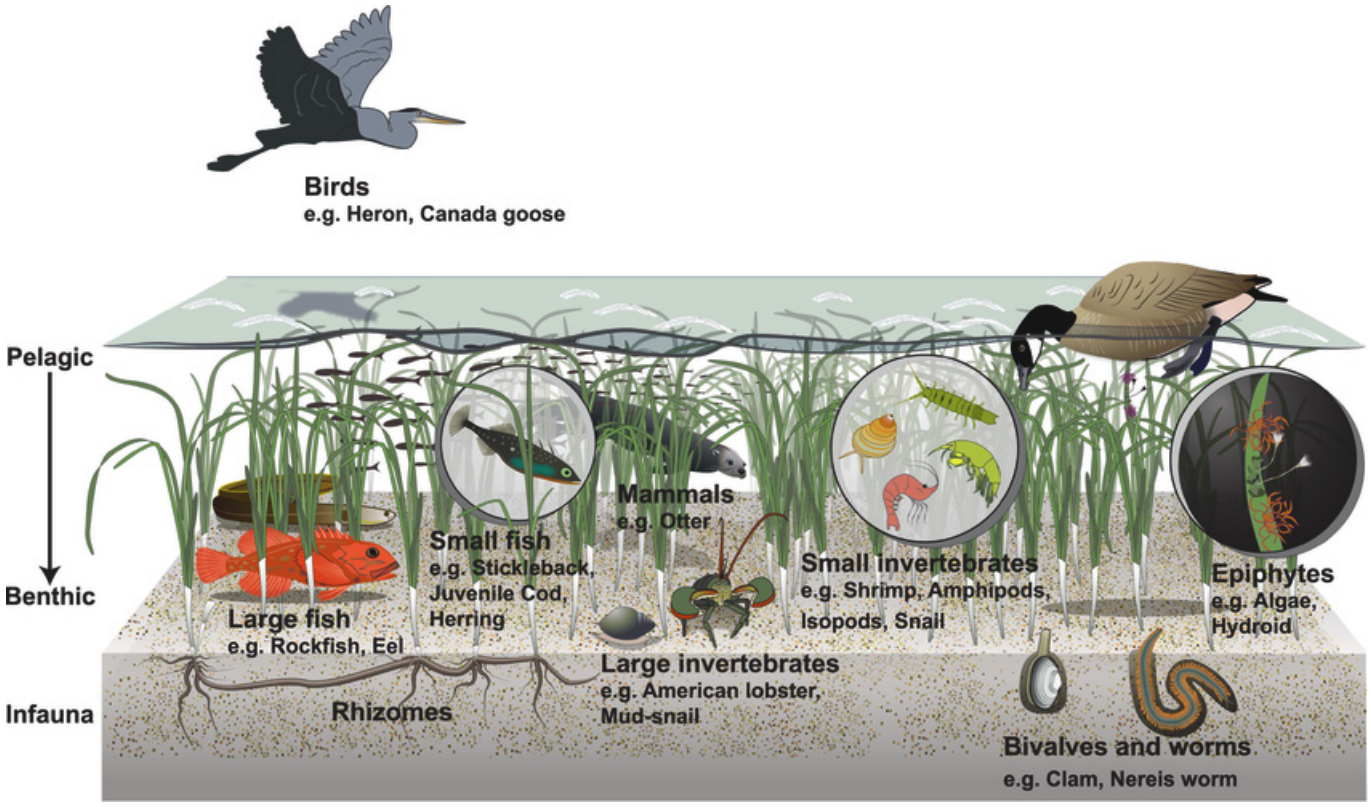

Figure 1. Generalized illustration of a seagrass meadow in a temperate region with simplified species assemblages, including epiphytic assemblages, small mobile invertebrates, small pelagic and benthic fish, larger benthic fish and invertebrates, sediment infauna, and mammals and birds (modified from Murphy et al., 2021. FACETS 6: 139–179)

LESSON OBJECTIVES

Knowledge Objectives

- Recognize the multiple functions of seagrass meadows (habitat, refuge and nursery).
- Understand the distribution of organisms according to the habitat in which they live, which they use and on which they depend.
- Identify permanent and temporary residents in the meadow.

Skills Objectives

- Create visual representations of a seagrass meadow and a bare area.
- Arrange organisms in each model.
- Evaluate the effects of removing seagrass meadows.

Attitudes and Values Objectives

- Development of critical thinking.
- Development of graphical and schematic models.
- Social interaction with colleagues.

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Understand that seagrass meadows are essential for many animals.
- Recognize the different compartments of seagrass meadows (on and near the bottom, in the sediment on seagrass leaves).
- Identify key species in the different compartments.

Environmental Literacy Competencies:

- Awareness of the importance of seagrass meadows for biodiversity.
- Awareness that many animals depend on seagrass meadows.

Social and Civic Competencies:

- Demonstrate concern about the importance of maintaining healthy seagrass meadows.
- Engage in collective environmental actions (e.g. cleaning, observation).

MATERIALS AND RESOURCES

Required Materials

- Printed images of the different animals in Fig. 2 (A4 size)
- Scissors
- Coloured tape

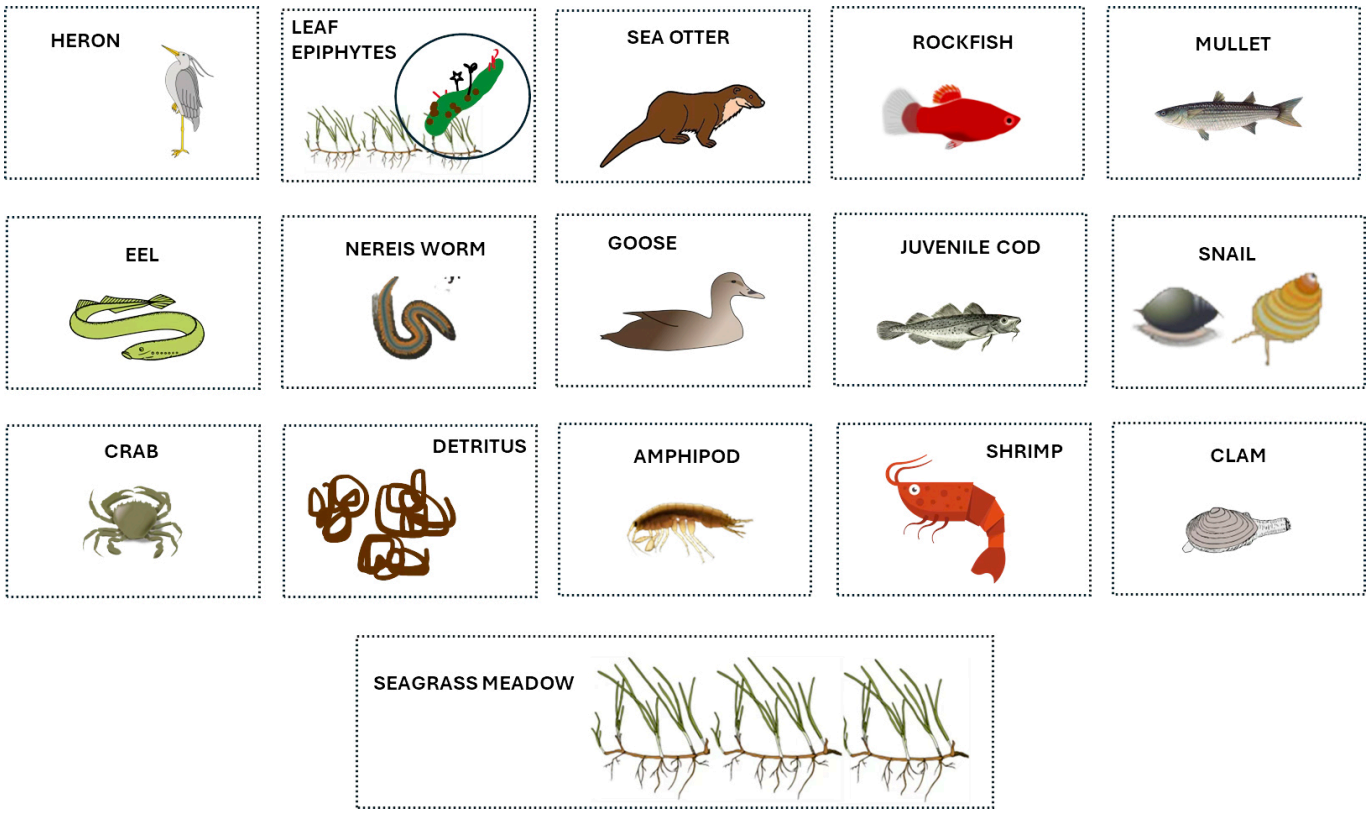

Figure 2. Printable images of animals that use seagrass meadows (created using freesvg.org).

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Let's explore a seagrass meadow!

Teacher introduces the topic, showing Fig. 1, and:

- Describes the three compartments of seagrass meadows.
- Illustrates the diversity and abundance of organisms in seagrass meadows.
- Provide examples of animals and their location in the meadow.
- Explains how determinant a seagrass meadow is for most animals.

Teacher Notes:

Teachers are encouraged to show relevant photographs and videos to the students, to arouse their greater interest. Relevant photographs that relate to the diversity of organisms that are hosted in seagrass meadows can be found in the Ocean Image Bank website (https://oceanimagebank.theoceanagency.org/), by entering the word 'seagrass' in the 'search images'. An amazing related video can be found on YouTube: https://www.youtube.com/watch?v=KcyUgj30vL8.

PHASE 2: EXPLORATION

Let's take a look at a seagrass habitat!

- Students become familiar with the organisms found in temperate seagrass habitats (Fig. 1).
- Teacher asks "What animals use the seagrass meadow for refuge?"
- Teacher asks "What animals use the seagrass meadow for nursery?"

PHASE 3: EXPLANATION

Understand the importance of seagrass habitats

Teacher explains that:

- some animals depend on seagrass bottoms (e.g. clams, worms).
- some organisms depend on seagrass leaves (e.g. epiphytes).
- animals use seagrass meadows for different purposes (habitat, food and shelter).
- the classroom game aims to compare species diversity between a seagrass meadow and a bare seabed.

Students have opportunity for questions and discussion.

PHASE 4: ELABORATION

Let's build a seagrass habitat model!

Working in small groups, the students:

- Cut the images of organisms in Fig. 2 and hang it around their neck or clothes.
- Delineate, in the classroom floor, two quadrat areas (e.g. 2 m x 2 m) using the coloured tape, one representing a seagrass meadow and another representing a bare area.
- Play a game where some of the students representing seagrass plants place themselves in the seagrass meadow quadrat.
- Build a model where the students representing an animal place themselves in the appropriate compartment of the meadow and in the bare area.

Teacher Notes:

Some organisms (students) may not find a place for them in the bare area; this is to show the importance of seagrass meadows as habitat, food and refuge compared to areas without vegetation. Teacher should draw attention to the smaller number of organisms (students) present in the bare area compared to the seagrass meadow area.

PHASE 5: EVALUATION

Community presentation

Each group of students is asked to prepare a small presentation for the community about seagrasses as habitats for many species, in which they:

- Use the printed images of animals.
- Explain the different types of functions seagrass meadows provide to organisms.
- Share with the audience recommendations for conservation of seagrass meadows.

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
    - Engagement: student's interest and attention revealed by the number of questions and enthusiasm.
    - Scientific accuracy and comprehension: students correctly answer teacher's questions.
2. **Summative Assessment (End of Lesson)**

    Evaluation of community presentation
    - Correctly explain the different functions of a seagrass habitat.
    - Correctly observe that seagrass meadows have higher diversity than bare areas.
    - Correctly convey the need to preserve healthy seagrass meadows.

SUCCESS CRITERIA (Student-Facing)

○ I can build a seagrass habitat model

○ I can identify the different compartments

○ I can provide examples of animals using each compartment

○ I can understand the importance of seagrass meadows for biodiversity

LESSON PLAN 4. TROPHIC INTERACTIONS WITH OTHER MARINE ECOSYSTEMS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson focuses on the interaction of seagrass habitats with other near and distant coastal environments, such as coral reefs, mangroves, salt marshes, mud flats, and oyster reefs. The lesson will provide students with the notion that seagrass meadows significantly support adjacent marine habitats, such as coral reefs and mangroves. The lesson will specifically focus that seagrass meadows export particulate organic matter of plant and animal biomasses as detritus. These are deposited in the deep-sea, and in near-shore and inland areas, providing habitat and food for invertebrate consumers. Students will also learn that seagrass dead parts (e.g. dead leaves) accumulated on the shore contribute to coastal protection from erosion.

In this lesson, students will develop a story with dialogues between characters of their choice that interact in a way that reproduces the connections between a seagrass meadow and the surrounding areas.

Trophic Transfers of Temperate Seagrass Meadows

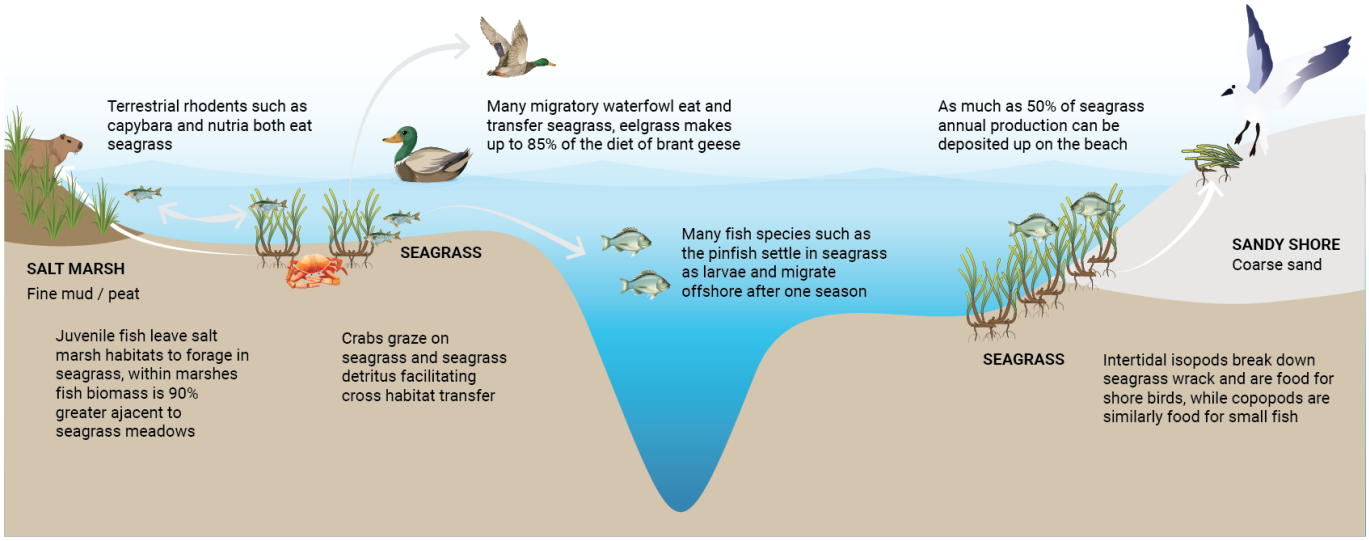

Figure 1. Conceptual diagram illustrating trophic transfers from seagrass meadows, and connectivity between seagrass meadows and marine and terrestrial habitats in temperate regions (modified from Heck et al. 2008. Ecosystems 11: 1198–1210)

LESSON OBJECTIVES

Knowledge Objectives

- Understand habitat connectivity.
- Identify the main nearby habitats with which seagrass meadows interact.
- Analyse specific relationships between seagrass meadows and nearby marine habitats.

Skills Objectives

- Creativity and critical thinking.
- Social-emotional skills.
- Memory and attention.

Attitudes and Values Objectives

- Development of story-telling capacity.
- Development of emotional empathy for seagrasses habitats.

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Recognize relationships between seagrass meadows and adjacent habitats.
- Develop scientific vocabulary.
- Interpret information to create informed messages.

Environmental Literacy Competencies:

- Understand habitat interconnections.
- Recognize the importance of seagrass beds to other habitats.

Social and Civic Competencies:

- Share the story in schools as wall panels.
- Contribute to collective understanding.

MATERIALS AND RESOURCES

Required Materials

- Printed cards (Fig. 2)
- Scissors
- Paper
- Pen/pencil



Figure 2. Printable cards of the story characters (created using freesvg.org and Wikipedia under creative commons licensing).

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

How to tell a story

Teacher shows Fig. 1, introduces the topic and:

- Provides details on the story's characters, their function and how they interact.
- Provides guidelines for creating the dialogues between the different characters.
- Asks "What do you think the goose will say to the seagrass bed if they meet and chat?"
- Asks "What do you think the detached and decomposing seagrass leaves (detritus) will say to the sandy shore if they meet and chat?"

PHASE 2: EXPLORATION

- Students become familiar with the different organisms/characters in seagrass meadows and nearby habitats.
- Students have opportunity for questions and discussion.
- Students select the characters they want to represent.

PHASE 3: EXPLANATION

Teacher explains that:

- the dialogues must focus on what functions the characters can provide to each other.

Teacher Notes:

Examples of dialogues can be: "Hey there! I'm a migratory waterfowl! Do you know that I eat seagrass leaves while in the meadow?".

PHASE 4: ELABORATION

Writing a seagrass tale!

Working in small groups, the students:

- Consider their own selected character and the potential dialogues.
- Discuss about the story they will write.
- Write the dialogues in a paper.

PHASE 5: EVALUATION

Storytelling

Each group of students is asked to present their story in the classroom. A short play can be performed.

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
    - Scientific accuracy and comprehension: students correctly understood concepts.
    - Engagement: students were able to transfer scientific reasoning to social tools.
2. **Summative Assessment (End of Lesson)**
    - Self-evaluation: students indicate what was the most important thing they learned.

SUCCESS CRITERIA (Student-Facing)

Share these with students at the end of the lesson:

○ I can understand that seagrass meadows are interconnected with adjacent habitats

○ I can understand that detached seagrass leaves are deposited on shores and prevent erosion

○ I can understand that seagrass meadows provide food for organisms in near or distant habitats

○ I can create a story that explains how the different organisms and habitats are interconnected

○ I can be a social actor for seagrass literacy

B5.

THEMATIC MODULE 5: SEAGRASSES STABILIZE THE SEABED, IMPROVE WATER QUALITY AND STORE CARBON

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LESSON PLAN 1. SEAGRASS MEADOWS STABILIZE SEDIMENTS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson focuses on the importance of seagrass meadows for sediment stabilization by showing how the physical structure of seagrasses attenuates wave and tidal energy, reducing erosion and water column turbidity. Students will learn how seagrass leaves, roots and rhizomes, illustrated in Fig. 1, play a key role in binding sediments, trapping suspended particulates and enhancing deposition.

Through the exercise of building two hydrodynamic models, one representing a seagrass meadow and another representing a bare seabed (Fig. 2) and using dye (or fine grain sand) as a substitute for suspended sediments, students will perceive the capacity of a dense meadow to trap the dying (or fine grain sand) particles compared to a sparse meadow or a bare seabed.

Alternative activity:

Representing the particles themselves, students walk in a straight line through a large space in the classroom with no obstacles (simulating a bare area), with obstacles arranged in a scattered manner (simulating a patchy meadow), or close to each other (simulating a dense meadow); students must stop when they encounter the obstacles. The goal is to perceive that dense seagrass meadows capture more particles compared to patchy meadows or areas without vegetation.

LESSON OBJECTIVES

Knowledge Objectives

- Identify the different seagrass physical structures: leaves, rhizomes and roots.
- Understand the role of these structures in binding sediments.
- Relate sediment stabilization with water clarity and coastline protection.

Skills Objectives

- Build visual dynamic models.
- Evaluate experimental results.
- Transpose field scenarios into classroom.
- Share perceptions through social interaction.

Attitudes and Values Objectives

- Value seagrass meadows as a nature-based solution for coastal protection.

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Recognize seagrass meadows as sediment stabilization agents.
- Understand the process of particle retention by seagrass meadows.
- Compare the presence/absence of seagrass meadows for sediment trapping and stabilization.
- Identify benefits of dense over sparse seagrass meadows for sediment trapping (alternative activity).

Environmental Literacy Competencies:

- Awareness of seagrass meadows as agents of water clarity and coastal protection.
- Awareness of the importance of dense versus fragmented seagrass meadows (alternative activity).

Social and Civic Competencies:

- Contribute to collective environmental understanding.
- Social interaction.

MATERIALS AND RESOURCES

Required Materials

- Printed images of seagrass physical structures (Fig. 1)
- Aquaria (transparent glass or plastic)
- Seawater/Tap water
- Water pumps
- Dye liquid (or fine grain sand)
- Sturdy green waterproof paper
- Scissors
- Flexible metal wire
- Cotton

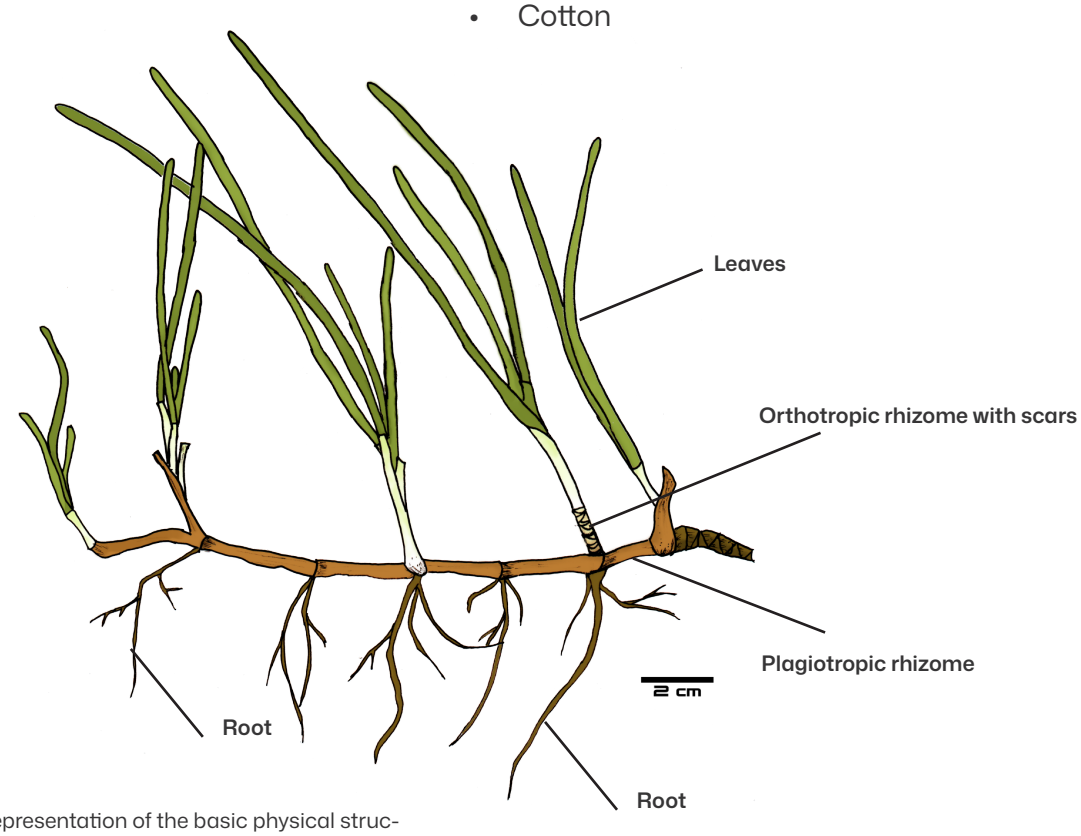


Figure 1. A schematic representation of the basic physical structures of a seagrass species (leaves, roots and rhizomes) involved in sediment stabilization.

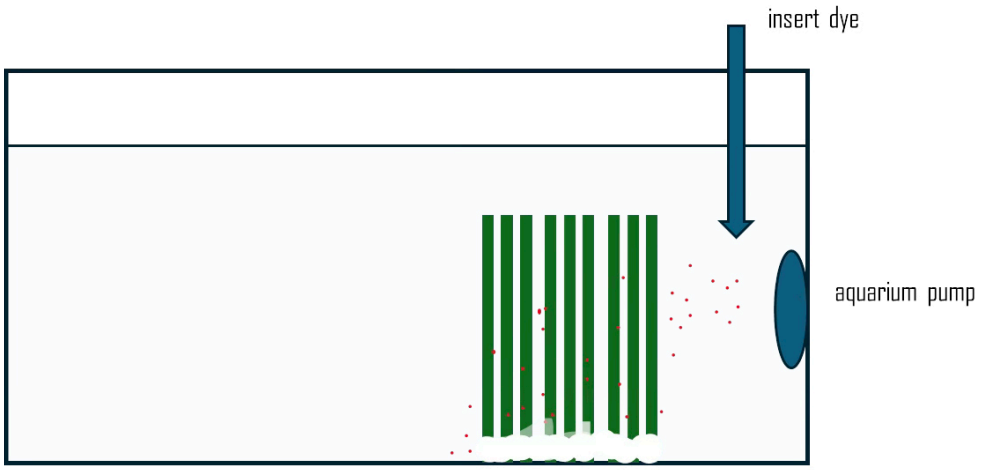


Figure 2. Illustration of a hydrodynamic model: aquarium containing seawater with green waterproof paper attached to a metal grid cover with cotton simulating a seagrass meadow, showing the exact location for the water pump and the insertion of the dying liquid (or fine grain sand).

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Let's understand particle trapping!

Teacher introduces the topic and:

- display images of the different structures of a seagrass plant (Fig. 1).
- explains how the different plant parts are involved in sediment trapping, wave attenuation and sediment deposition.
- describes the hydrodynamic models, indicating what each part represents (Fig. 2)

Teacher Notes:

seagrass leaves decrease water motion and retain particles inside the canopy; the intricate arrangement of roots and rhizomes inside the sediment increases the trapping of sediment particles; in the model, the water pump simulates wave movement and energy; the metal grids covered with cotton represent sediments where seagrasses attach and which trap particles; the green waterproof paper simulates seagrass leaves, and the dye (or fine grain sand) represents sediment suspended particles.

PHASE 2: EXPLORATION

Let's build hydrodynamic models!

1. Seagrass hydrodynamic model (Fig.2)

Working in groups, students:

- build the metal grids using the flexible metal wire (1cm x 1 cm).
- cut the green waterproof paper into leaf-like shapes.
- attach the green paper to each quadrat of the grid.
- place the structures into the aquarium.
- cover the metal grid with a thick layer of cotton.
- allocate the water pump in the aquarium sidewall.
- fill with aquarium with water.

2. Bare seabed hydrodynamic model

Working in groups, students:

- allocate the water pump in an aquarium covered with cotton and filled with water.

Teacher supervises and helps when needed.

PHASE 3: EXPLANATION

Seagrass meadows matter!

Students pour the dye (or fine grain sand) into the two aquaria and observe the particle movement.

Teacher explains that:

- the presence of seagrasses attenuates wave energy.
- wave energy attenuation leads to particle settling.
- belowground roots and rhizomes harness trapped particles.
- particle settling and harness leads to water clarity in meadow vicinities.

Teacher's notes: the water pump must be at low speed.

PHASE 4: ELABORATION

Knowledge test

Students complete a true/false test with the following questions:

- Seagrass leaves contribute to particle trapping (true/false)
- Seagrass canopy prevents particle resuspension (true/false)
- Sediment trapping makes seawater less transparent (true/false)
- Seagrass meadows in shore areas reduces wave energy and protect coastlines (true/false)
- Seagrass meadows reduce water velocity (true/false)
- Sediment particles travel faster in dense seagrass meadows (true/false)

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
   - Engagement: student's interest and attention during activities.
2. **Summative Assessment (End of Lesson)**

   Evaluation of the knowledge test
   - Scientific understanding: students correctly answered the knowledge test.

SUCCESS CRITERIA (Student-Facing)

Share these with students at the end of the lesson:

○ I can tell that seagrass leaves, roots and rhizomes are important for particle trapping

○ I can tell that seagrass meadows attenuate wave energy, reducing erosion

○ I can tell that seagrass leaves prevent sediment resuspension, improving water clarity

○ I can tell that dense seagrass meadows trap more particles than fragmented meadows or unvegetated areas (alternative activity)

LESSON PLAN 2. SEAGRASSES ARE FILTERS FOR NUTRIENTS

DURATION: 45 MINUTES

LESSON OVERVIEW

Nutrient cycles are natural processes where essential elements move between the biotic and abiotic parts of an ecosystem, keeping essential elements available to plants and other organisms. Seagrasses absorb nutrients from the water through the leaves and from the sediments through the roots for their own subsistence. They slowly release them back into the environment through a process of decomposition and consumption. In nutrient poor regions, the seagrass plants themselves help nutrient cycling by taking up nutrients from the sediment and releasing them into the water through their leaves, acting as a nutrient pump. Thus, seagrasses support overall ecosystem productivity. Seagrasses also act as filters for nutrients entering the coastal environment, thus improving water quality. Seagrasses and their epiphytes rapidly absorb excess nitrogen and phosphorus from the water column, which are key components of agricultural, urban, and industrial runoff. Once removed from the water column, these nutrients can be released only slowly through a process of decomposition and consumption. In this way, seagrasses can reduce problems of eutrophication.

This lesson focuses on the importance of seagrasses as nutrient filters. By teaching that seagrasses and their epiphytes are very efficient in absorbing nutrients, the lesson shows the critical function of seagrasses as filters for nutrients, improving water quality and ecosystem health and balance. The lesson also shows that seagrasses can reduce events of eutrophication, i.e., a state of excessive algal growth caused by high nutrient levels.

In this lesson, students will be asked to imagine the scenario of a Wastewater Treatment Plant (WWTP) that, because of its operational activities, discharges nutrients into a coastal area. Having in mind the fundamental role of seagrass meadows as nutrient filters, students are asked to rank the actions that the WWTP may take as compensation measures to minimize its environmental impact. Students must explain why they rank so.

LESSON OBJECTIVES

Knowledge Objectives

- Understand that seagrasses act as nutrient filters by absorbing excessive nutrients.
- Recognize the role of seagrasses in preventing or reducing eutrophication processes.
- Analyse the relationship between seagrass nutrient absorption capacity and coastal water quality.
- Understand that seagrasses improve water quality.

Skills Objectives

- Critical thinking about environmental problems and solutions.
- Critical analysis of hypothetical situations to make informed decisions.
- Communication of scientific concepts and conservation messages.

Attitudes and Values Objectives

- Appreciate seagrass meadows as natural seawater filters.
- Understand priorities and best practices for minimizing effects of nutrient pollution.
- Develop personal responsibility for ecosystem protection.

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Understand the role of seagrass leaves and roots in nutrient absorption.
- Recognize the role of seagrasses as nutrient filters in coastal waters.
- Understand the importance of seagrass meadows in preventing eutrophication events.

Environmental Literacy Competencies:

- Get familiar with symbol-based communication/iconography.
- Understand the concept of pollution compensation measures.

Social and Civic Competencies:

- Collaborative team-based roles.
- Discussion and argumentation.
- Contribution to collective environmental understanding.

MATERIALS AND RESOURCES

Required Materials

- Printed cards of the different compensation measures (Fig. 1)
- Scissors



Figure 1. Printable cards of compensation measures (created using freesvg.org)

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Let's understand the seagrass role as nutrient filters!

Teacher introduces the concept of nutrient filter and:

- emphasize the importance of seagrass meadows as natural nutrient filters.
- explains the functioning of seagrasses as nutrient filters.
- associates the nutrient filtering capacity of seagrasses with their role in preventing eutrophication events.

Teacher Notes:

Seagrasses are highly efficient in nutrient uptake; they take up nutrients from the water column through the leaves and from the sediment through the roots; to date, no absorption function is known for rhizomes.

PHASE 2: EXPLORATION

Let's solve an environmental problem!

Teacher presents the hypothetical scenario of the Wastewater Treatment Plant discharging nutrients into a coastal lagoon, and explains:

- what is a Wastewater Treatment Plant.
- that discharging high amounts of nutrients into coastal environments may cause eutrophication events.
- briefly explains what a eutrophication event is.
- recalls the regulatory function of seagrasses regarding nutrient levels in coastal areas.

Teacher notes: Eutrophication is the excessive enrichment by nutrients of a water body leading to excessive algae growth; when these algae die and decompose, the oxygen is depleted, creating "dead zones" that cause fish kills and reduced biodiversity.

PHASE 3: EXPLANATION

How can we solve this problem?

Describing the objective of the exercise, the teacher:

- explains the meaning of each action card.
- asks students to rank actions according to their perception of what is the best solution for the environment and society.
- informs that students may give equal importance to two or more cards.

Teacher's notes: as a brief rationale of the exercise, the main objective is that students identify actions related to seagrass and/or environment conservation as best compensation measures, given their importance for nutrient removal and ecosystem balance; it is expected that students understand that "stop WWTP operations" or "paying for polluting" are not solutions to the problem because WWTPs are needed to ensure sanitation and there is no indication that the money is applied in seagrass conservation measures; it is expected that students rank first "paying for seagrass restoration" and/or "paying

to clean seagrass meadows" as actions that help preventing eutrophication as well as in re-establishing the regulatory function of nutrient cycling of seagrass meadows.

PHASE 4: ELABORATION

Let's choose the best compensation measures! Working in small groups, the students:

- cut the printed cards in Fig. 1.
- rank the actions with a justification.

PHASE 5: EVALUATION

Think-pair-share

- Students are asked to show their rankings and share why they did so with colleagues.

Teacher's notes: The teacher explains whenever a chosen order is not the more correct or why one option should be preferred over another.

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**

   Observational checklist and think-pair-share exercise

   - Engagement: student's interest and attention during activities.

2. **Summative Assessment (End of Lesson)**

   Evaluation of the think-pair-share exercise

   - Scientific understanding: students correctly ranked the compensation measures.

SUCCESS CRITERIA (Student-Facing)

Share these with students at the end of the lesson:

○ I can understand that seagrasses act as filters for nutrient entering the coastal environment

○ I can tell that seagrass meadows help solving problems of nutrient pollution

○ I can tell that paying for seagrass restoration or clean meadows are excellent compensation measures to fight nutrient pollution

LESSON PLAN 3. SEAGRASSES IMPROVE WATER QUALITY

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson focuses on three water-quality related functions performed by seagrasses: the absorption and retention of trace metals, the trapping of micro-plastics, and the reduction of pathogens. Metal uptake into seagrasses can follow two pathways, from surrounding water to the leaves then rhizomes, or translocation from interstitial water in the sediment into roots to rhizomes and leaves (Fig. 1). Once removed, these contaminants can be released only slowly through a process of decomposition and consumption, reducing contamination and improving water quality. Seagrasses are also facilitators for micro-plastic accumulation and burial in the sediments, thus removing them from seawater and the pelagic food web. Micro-plastics are trapped by adhesion of particles to seagrass canopy, which promotes micro-plastic settlement on the sediment. Seagrass meadows also reduce the abundance of bacterial pathogens that harm both marine organisms and humans. Seagrasses suppress pathogens through the release of organic compounds called phenols into the seawater and retain pathogens in the sediments as well.

In this lesson, students are asked to indicate the quantity of metals, micro-plastics and pathogens that are expected in water samples collected after passing through 1) a dense seagrass meadow, 2) a fragmented seagrass meadow, and 3) an unvegetated area (bare sediment). The objective is to show students that they will find the purest water, i.e., containing the least amount of trace metals, micro-plastics and pathogens in a water sample collected after passing through a dense seagrass meadow, demonstrating the role of seagrasses in improving water quality (Fig. 2). Students should place in the sampling beakers the amount of contaminants they expect to find in the different scenarios using the images provided in Fig. 3 and 4. If computer use is possible, students should associate the data provided in the excel file with the contaminants and their amounts by moving the datasets representing contaminant concentrations to the corresponding areas.

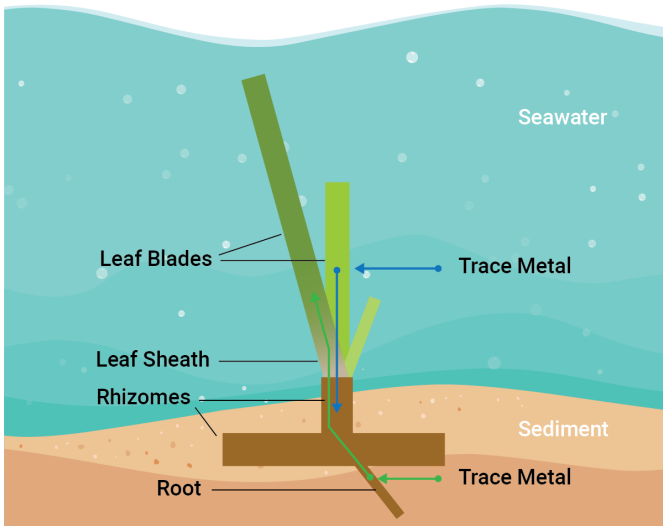
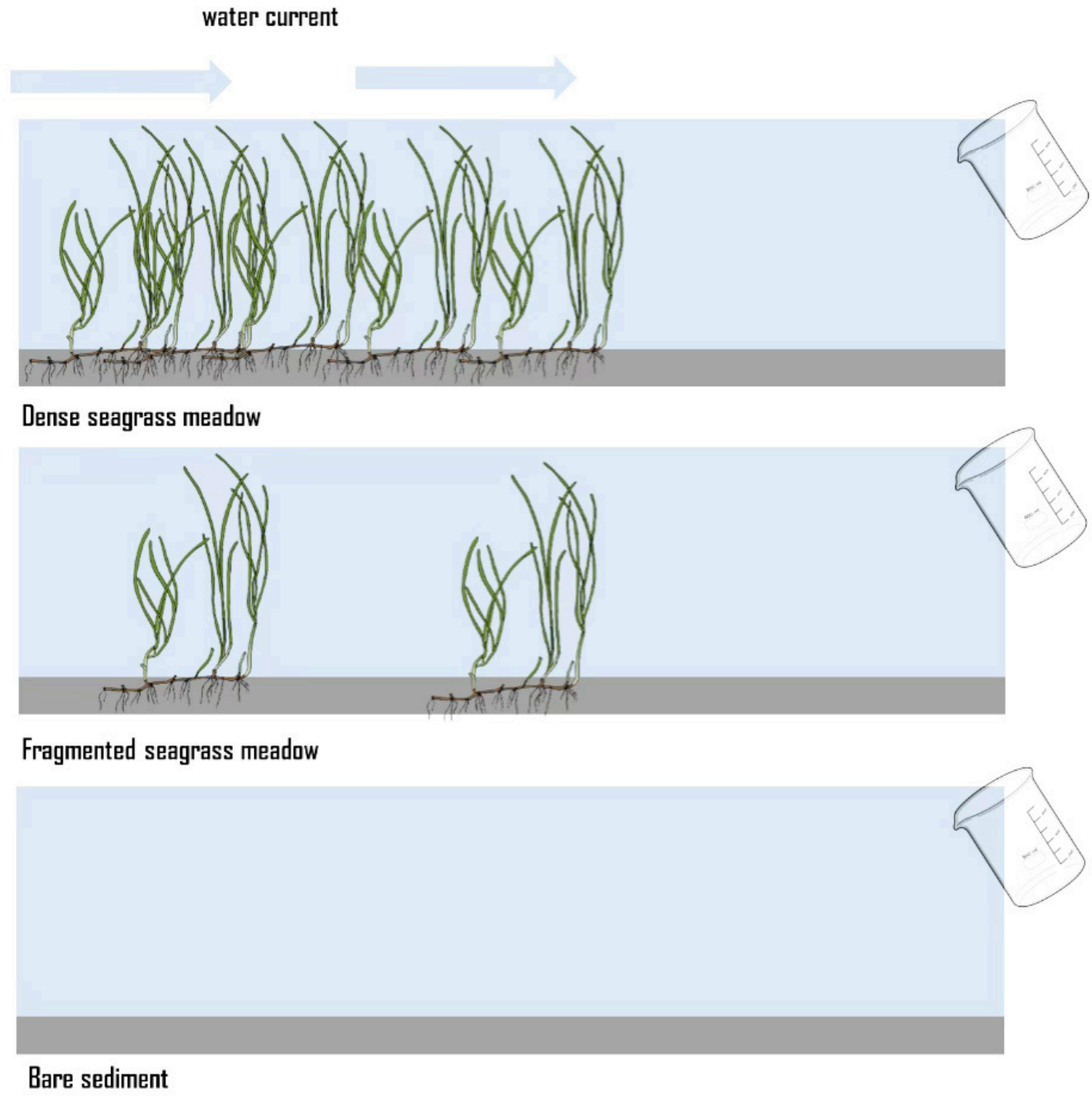


Figure 1. Representation of trace metal uptake by a seagrass: Metal uptake into seagrasses can follow two pathways, from surrounding water to leaves then rhizomes or translocation from interstitial water in the sediment into roots to rhizomes and leaves (modified from Malea et al. 2019).

Figure 2. Schematic illustration of a dense seagrass meadow, a fragmented seagrass meadow and a bare area, and the sampling of the water after passing by the meadows or the bare area.



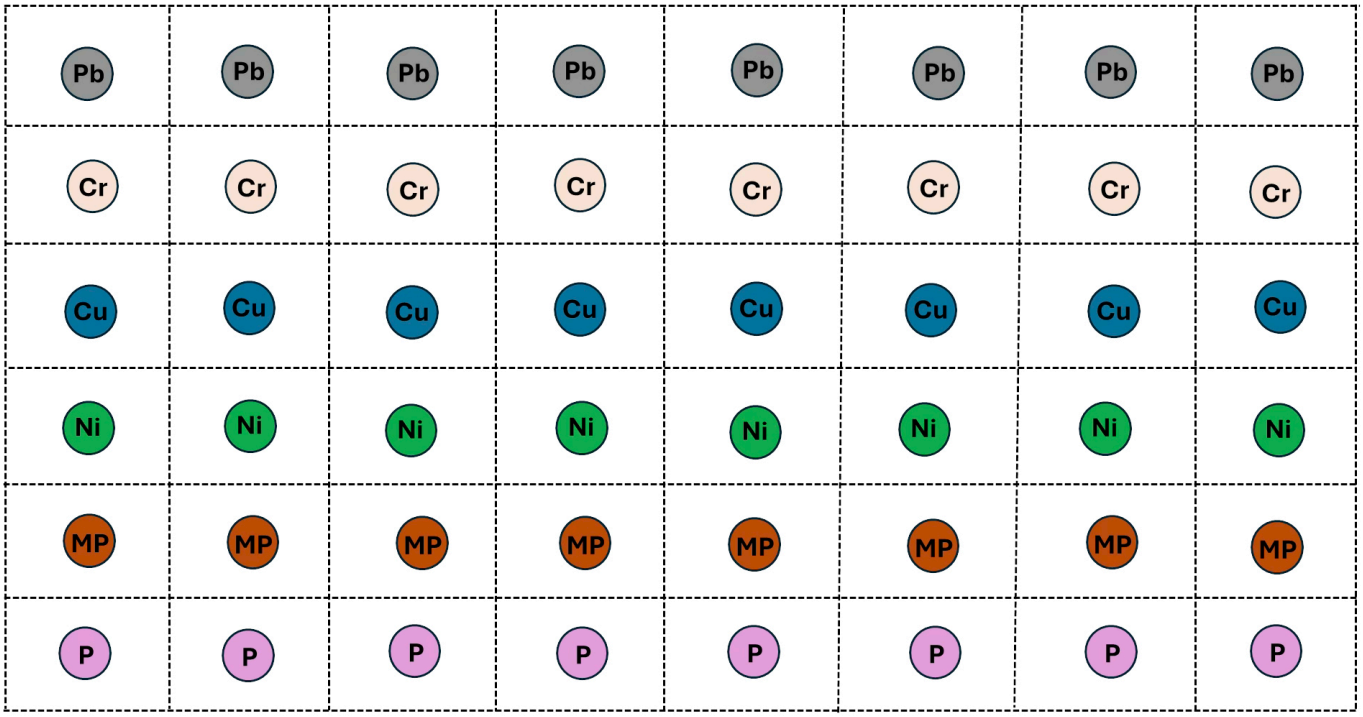


Figure 3. Printable images representing trace metals (Lead = Pb; Chromium = Cr; Copper = Cu; Nickel = Ni), micro-plastics (MP) and pathogens (P).

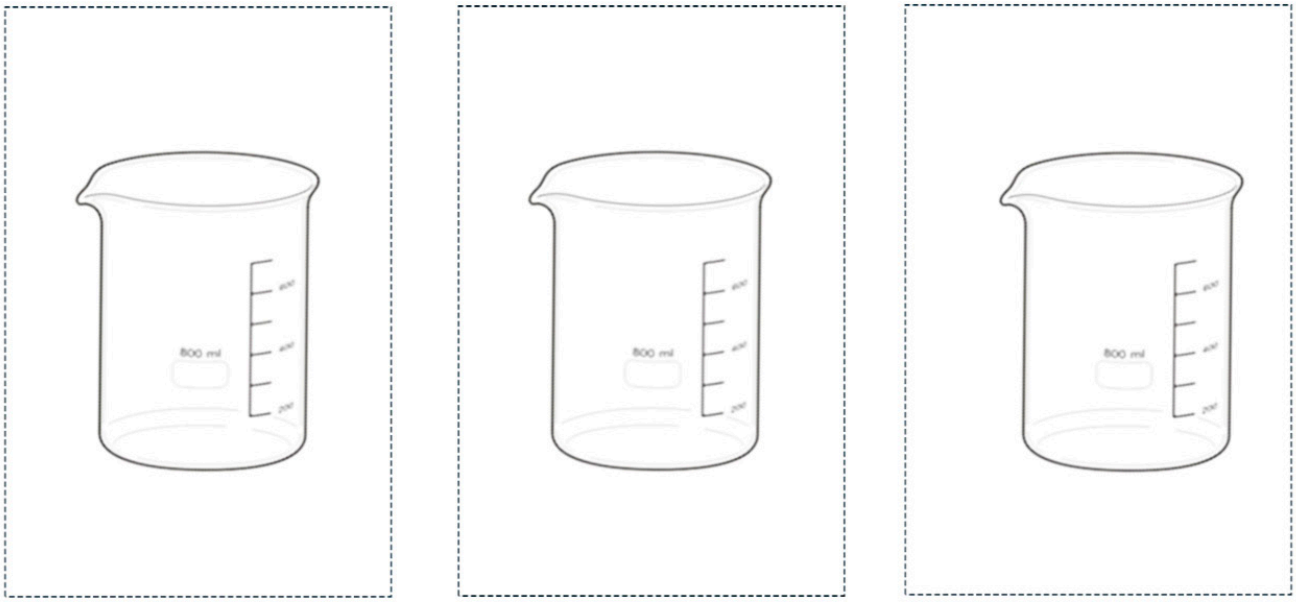


Figure 4. Printable images of sampling beakers.

LESSON OBJECTIVES

Knowledge Objectives

- Understand the importance of seagrasses for water quality.
- Identify the three main regulatory functions.
- Describe the processes by which seagrasses remove trace metals, micro-plastics and pathogens.

Skills Objectives

- Understand the notion of concentration of contaminants in water samples.
- Transfer knowledge to real-world situations.
- Explore excel spreadsheets (if available).

Attitudes and Values Objectives

- Appreciate seagrass meadows as natural agents of water purification.
- Raise conservation awareness towards seagrass meadows.

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Understand the concepts of trace metals, micro-plastics and pathogens.
- Get familiar with chemical symbols of common trace metals: Lead = Pb; Chromium = Cr; Copper = Cu; Nickel = Ni
- Get familiar with the notion of concentration as a measure of quantity.

Environmental Literacy Competencies:

- Awareness of seagrass meadows as agents of water purification.
- Awareness of the importance of dense versus fragmented seagrass meadows for particle retention (connection with lesson plan: Seagrass meadows stabilize sediments, Thematic module 5: Seagrasses stabilize the seabed, improve water quality and store carbon).

Digital Competences (if available)

- Get familiar with excel spreadsheets.

Social and Civic Competencies:

- Discussion and argumentation.
- Contribution to collective seagrass protection.

MATERIALS AND RESOURCES

Required Materials

- Printed images (Figs. 3 and 4).
- Scissors

If available:

- Computers.
- Excel worksheet with data (excel file).

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

How do seagrasses clean the seawater?

Teacher introduces the topic and:

- mentions the three types of contaminants of the lesson: trace metals, micro-plastics and pathogens.
- explains how these contaminants are removed by seagrasses from the surrounding water.
- introduces the notion of concentration and explains that a higher amount of a substance in a sample volume is equal to higher concentration (e.g., 4 μg Pb in 1 litre of seawater is more concentrated than 1 μg Pb in 1 litre of seawater).
- asks “Do you expect to find higher concentration of trace metals in seawater around a seagrass meadow or in a bare sediment, and why?”
- asks “Do you expect to find more contaminants around a seagrass meadow or in a bare sediment, and why?”

PHASE 2: EXPLORATION

Let's analyse seawater samples!

- Students become familiar with the printed images in Figs. 2, 3 and 4.
- Students associate the symbols to the respective trace metals.

If computers are available:

- Students become familiar with the excel file and the data.

PHASE 3: EXPLANATION

The teacher describes the objective of the exercise and:

- explains that less contaminants are expected in seawater surrounding a dense seagrass meadow compared to a fragmented meadow or a bare sediment area.
- asks students to place the images of the contaminants in the appropriate amount inside the sampling flasks.

If computers are available:

- Teacher asks students to associate the amounts of contaminants with the respective sampling location.

Teacher's notes: It is noteworthy to mention that the retention of contaminants by seagrass meadow potentially affects the trophic chain, namely trophic transfer of attached micro-plastics through grazing (connection with lesson plans: Seagrasses provide food for other organisms and Trophic interactions with other marine ecosystems, Thematic module 4: Seagrasses support a great diversity of life).

PHASE 4: ELABORATION

Let's look at a water sample!

Working in small groups, the students:

- cut the printed symbols of contaminants in Fig. 3.
- cut the printed flasks in Fig. 4.
- place inside the flasks as many symbols as they find appropriate to each scenario (dense meadow, fragmented meadow and bare sediment).

If computers are available, students:

- move the set of data to the appropriate place in the excel sheet.

Teacher's notes: Students must place the set of data relative to the higher concentrations of contaminants in the cells designated for the bare sediment, and the lower concentration of contaminants in the cells designated for the dense meadow.

PHASE 5: EVALUATION

Observational checklist

- Engagement: student's interest and attention during activities.

Target questioning

Teacher asks:

- Why does the seawater sample surrounding the dense seagrass meadow has less contaminants?
- Why does the seawater sample surrounding the unvegetated area has more contaminants?
- Is the presence of seagrass meadows important for the purification of the seawater? Why?

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
    - Engagement: student's interest and attention during activities.
2. **Summative Assessment (End of Lesson)**

    Targeted questioning
    - Scientific understanding: students correctly answered the questions.

SUCCESS CRITERIA (Student-Facing)

Share these with students at the end of the lesson:

○ I can tell that seagrass meadows improve seawater quality

○ I can tell seagrass meadows retain contaminants within the seagrass leaves, rhizomes and roots

○ I can tell that contaminants are lower in the seawater surrounding dense seagrass meadow

LESSON PLAN 4. SEAGRASSES CAPTURE AND STORE CARBON

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson focuses on the important role of seagrass meadows, along with mangroves and salt marshes, in capturing and storing atmospheric carbon dioxide. These ecosystems are significant carbon sinks because they store more carbon than they release. For this reason, they are vital for climate change mitigation and ocean acidification buffering. Because they store carbon in the sea, they are called blue carbon ecosystems.

In this lesson, students will learn that seagrass meadows remove carbon dioxide from the seawater through photosynthesis to build their vegetative structures, e.g. roots, rhizomes and leaves (see Fig. 5.1 of the SEAQUEST Curriculum for Teachers). Being perennial, seagrasses store carbon for long periods in these structures. Students will also learn that when seagrass plants and associated organisms die and decay, the carbon in their structures becomes trapped and buried in the sediment.

Through the exercise of building a blue carbon model for coastal ecosystems in tropical and temperate regions, represented in Figs. 1a and b, students will become familiar with the concept of carbon storage and the difference between carbon dioxide (CO_2), the carbon captured as a gas through photosynthesis, as well as released through respiration, and organic carbon (C), the carbon from the tissue breakdown of seagrasses and other organisms that is stored in sediments.

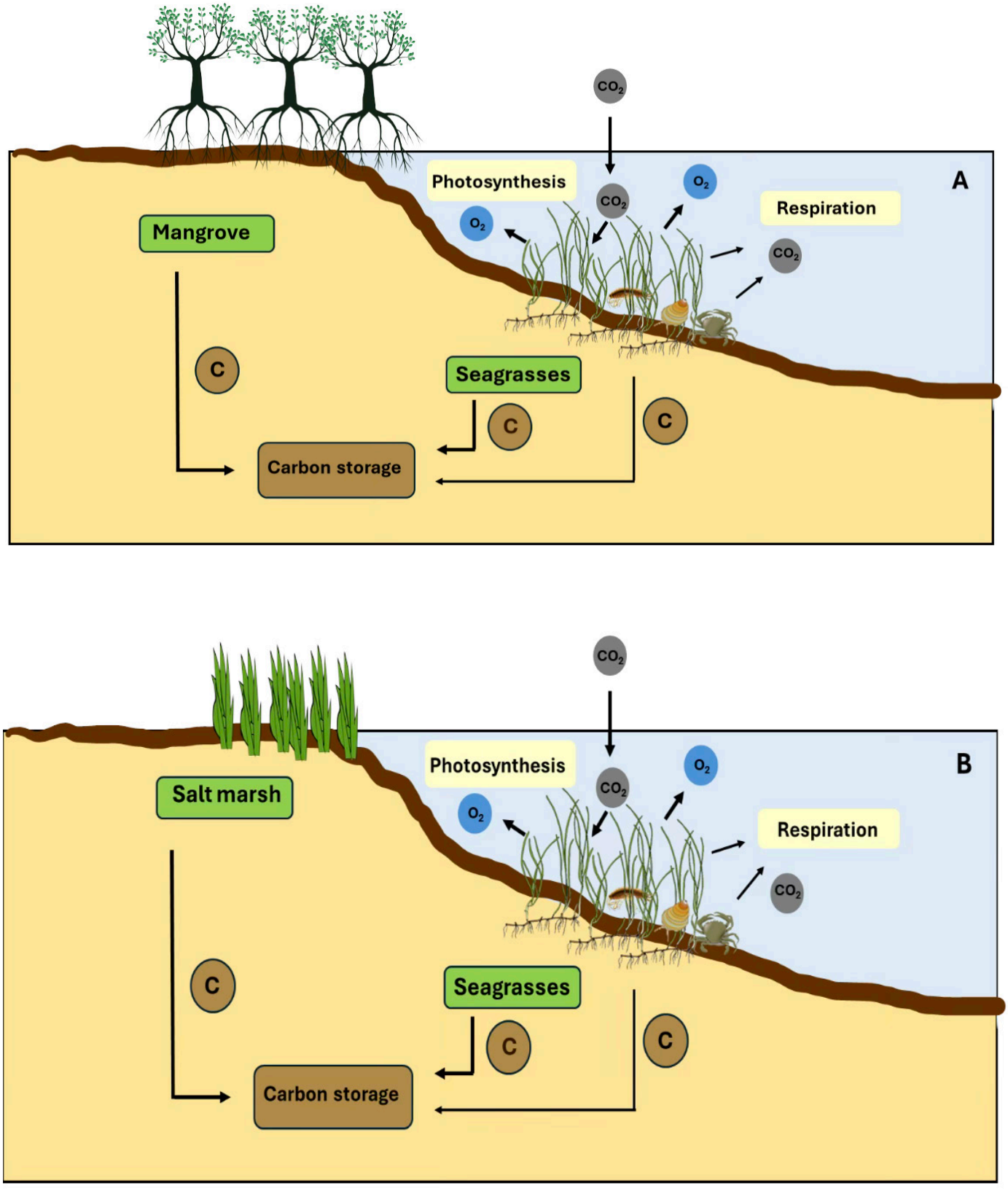


Figure 1. Schematic illustration of the carbon fluxes in (A) tropical and (B) temperate blue carbon ecosystems, with emphasis on seagrass meadows.

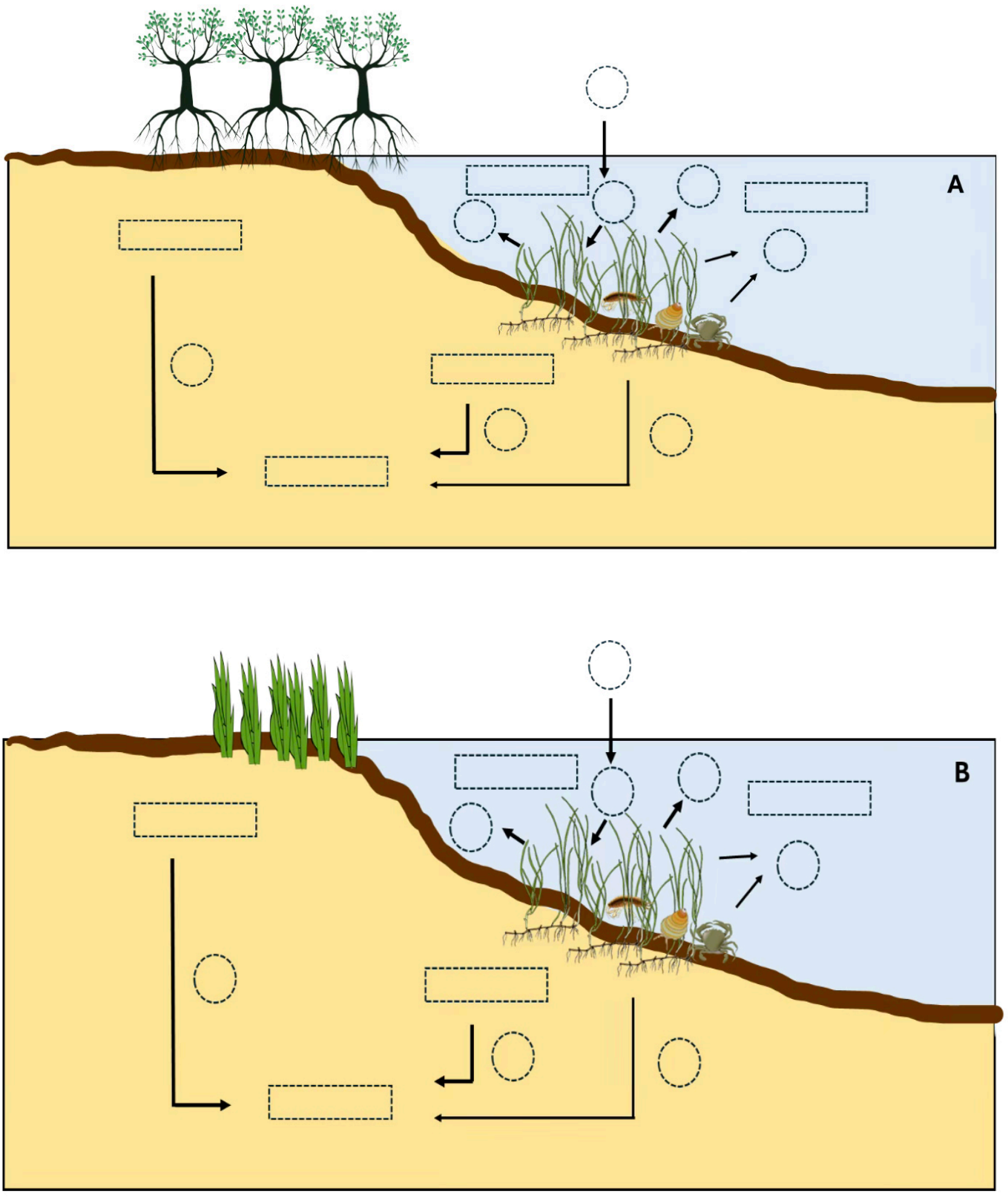


Figure 2. Printable images to be completed using the images provided in Fig. 3.

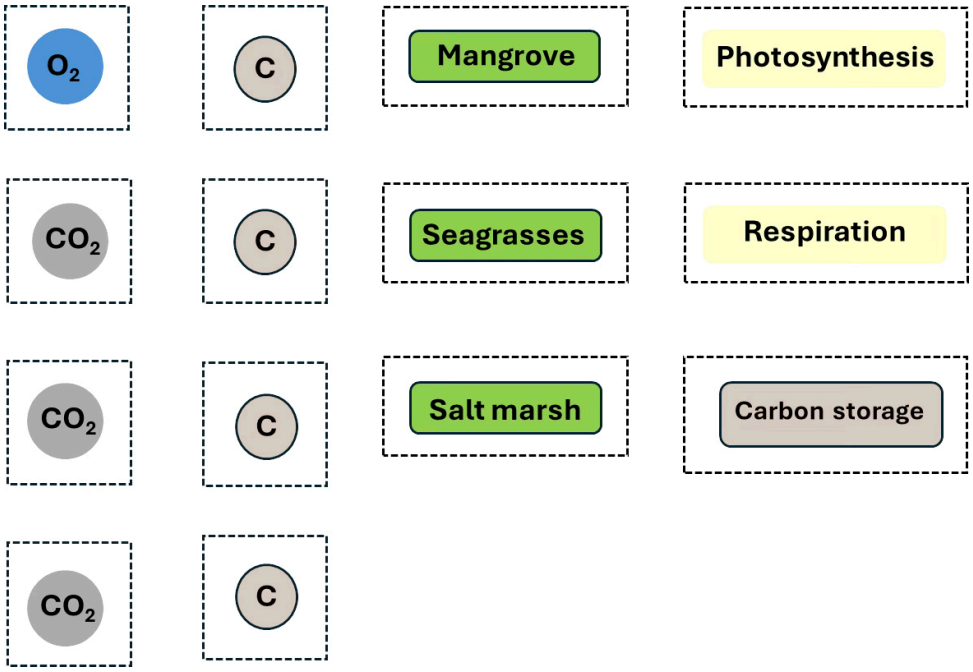


Figure 3. Printable images to be placed in the correct locations in Figs. 2A and B.

LESSON OBJECTIVES

Knowledge Objectives

- Define blue carbon.
- Identify blue carbon ecosystems.
- Describe the process of carbon capture and storage in blue carbon ecosystems.

Skills Objectives

- Create visual representations of blue carbon ecosystems.
- Transfer knowledge into visual representations.

Attitudes and Values Objectives

- Value seagrass meadows as crucial for carbon capture and storage.

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Understand the importance of blue carbon ecosystems for climate change mitigation.
- Understand the role of seagrass meadows for buffering ocean acidification.

Environmental Literacy Competencies:

- Recognize the importance of protecting blue carbon ecosystems.
- Identify consequences of seagrass loss for carbon capture and storage.

Social and Civic Competencies:

- Raise concerns about the conservation of seagrass meadows.
- Engage in collective conservation actions.

MATERIALS AND RESOURCES

Required Materials

- Printed images of Figs. 2 and 3.
- Scissors.

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

What is blue carbon?

Using Fig. 1, the teacher explains:

- the importance of coastal ecosystems for the capture and storage of carbon, with emphasis on seagrass meadows.
- the teacher explains the main processes through which seagrass plants sequester and store carbon.
- highlight that the amount of carbon stored is higher than the carbon released (e.g. through respiration).

Teacher Notes: The notion that the amount of carbon stored is higher than the carbon released is represented by the difference in boldness of the arrows.

PHASE 2: EXPLORATION

Let's look at blue carbon ecosystems!

- Students become familiar with Fig. 1.
- Students become familiar with the printed images in Figs. 2 and 3.
- Students ask questions.

PHASE 3: EXPLANATION

Understanding blue carbon ecosystems

Teacher explains:

- that mangroves, salt marshes and seagrass meadows are vital for carbon capture and storage.
- that carbon is captured by seagrasses through photosynthesis (connection with lesson plan: Seagrasses are important primary producers, Thematic module 4: Seagrasses support a great diversity of life).
- that carbon is stored in sediments after plant and other organism decay.
- the objective of the exercise (i.e., to place the images in Fig. 3 in the correct locations in Fig. 2) (Fig. 1 is not shown).

PHASE 4: ELABORATION

Let's build a blue carbon model!

Working in small groups, the students:

- cut the printed images in Fig. 3.
- create a blue carbon model, using the images provided and placing them in the appropriate locations in Fig. 2.
- restructure the model after removing seagrasses.

PHASE 5: EVALUATION

Exit ticket with quiz (e.g., digital quiz can be done using Google Forms)

Students complete a quick exit ticket with four questions:

- Are mangroves and seagrasses blue carbon ecosystems? (YES/NO)
- Does photosynthesis capture carbon from the seawater? (YES/NO)
- Are C and CO_2 the same thing? (YES/NO)
- If we remove seagrasses, the carbon storage increases? (YES/NO)

ASSESSMENT

Formative Assessment (During Lesson):

1. **Observation Checklist:**
   - Engagement: student's interest and attention during activities.
2. **Summative Assessment (End of Lesson)**

   Targeted questioning/Quiz
   - Scientific understanding: students correctly answered the questions.

SUCCESS CRITERIA (Student-Facing)

Share these with students at the end of the lesson:

○ I can tell that mangroves, salt marshes and seagrasses are blue carbon ecosystems

○ I can tell that blue carbon ecosystems remove more carbon than they release

○ I can tell that carbon is stored in the sediments of blue carbon ecosystems

B6.

THEMATIC MODULE 6: SEAGRASSES AND HUMANS ARE INEXTRICABLY INTERCONNECTED

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LESSON PLAN 1. SEAGRASSES AS COASTAL BODYGUARDS

DURATION: 45 MINUTES

LESSON OVERVIEW

In this lesson, we discover how seagrass meadows help shield coastal communities from erosion, coastal flooding, and storm surge (see Fig. 1). Students perform an outdoor hands-on storm simulation to see how seagrasses reduce wave energy and stabilise sediments. At the end of the lesson, students will understand how seagrass meadows protect the coasts and associate this protective function with human safety, homes, jobs, and climate resilience. This lesson complements the module's central theme that seagrasses are directly related to human well-being and coastal survival.

Following the structure and pedagogical approach of this lesson plan, teachers can also develop additional lesson plans focusing on the other ecosystem services and values of seagrass meadows, as presented in the SEAQUEST Curriculum for Teachers.

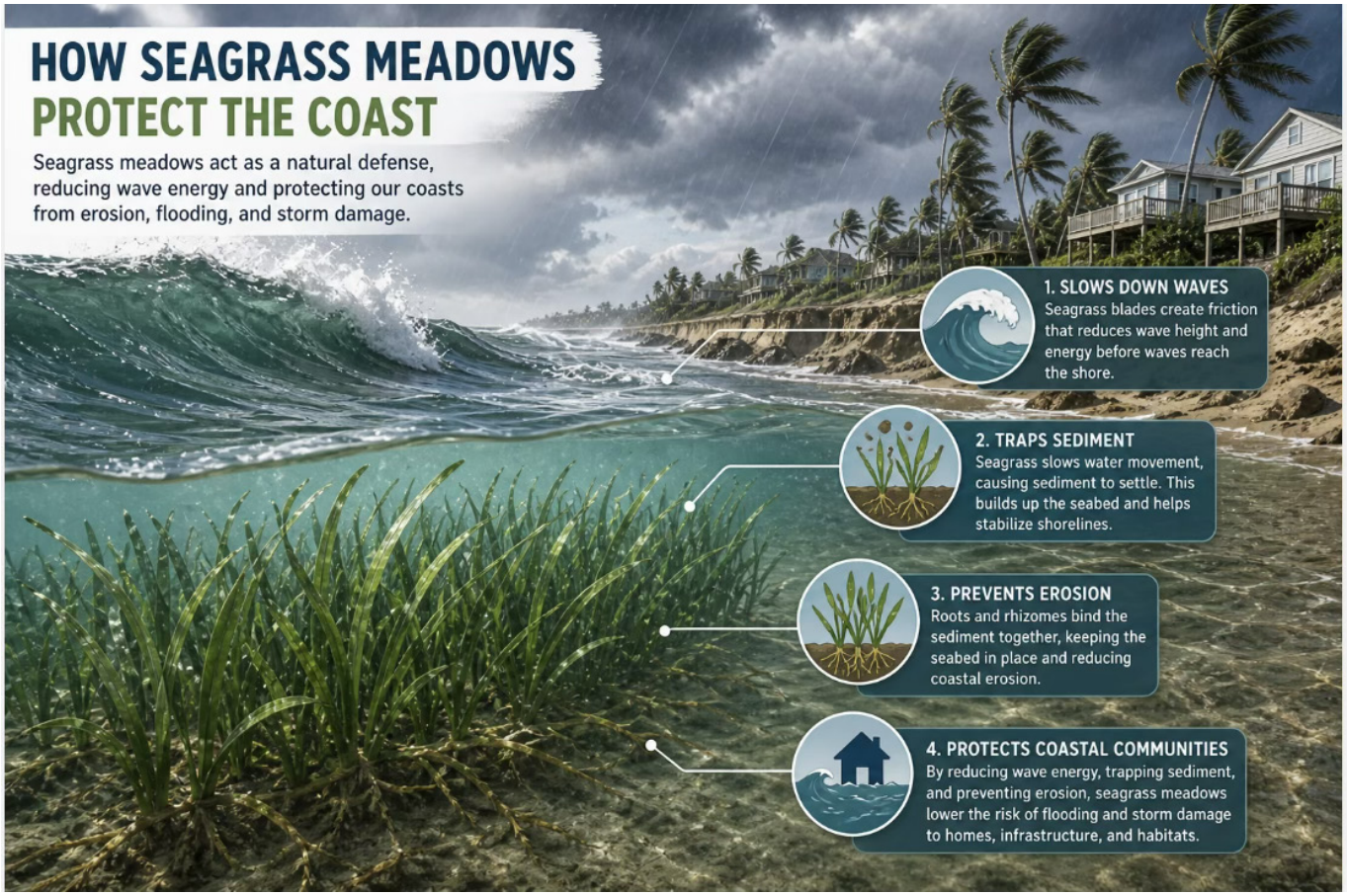

Figure 1. Illustration of mechanisms showing how seagrass meadows protect the coasts from erosion, flooding, and storm damage. This image has been generated using Artificial Intelligence.

LESSON OBJECTIVES

Knowledge Objectives

- Define coastal erosion and storm surge
- Recognize how seagrasses protect coastlines
- Explain why seagrass loss increases coastal risk to humans

Skills Objectives

- Compare erosion in protected vs. unprotected coast models
- Analyse results from a storm simulation investigation
- Design a simple coastal protection solution

Attitudes and Values Objectives

- Appreciate the protective role of seagrasses for communities
- Value natural ecosystems as climate defenders
- Demonstrate responsibility towards coastal conservation

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Conducting a simple scientific investigation
- Observing and recording results
- Drawing conclusions from evidence

Environmental Literacy Competencies:

- Understanding ecosystem services
- Recognizing human–nature interdependence
- Identifying consequences of environmental degradation

Digital Competences

- Using a tablet or device to record experimental results (photo/video) (optional)
- Interpreting a short digital animation of storm surge (optional)

Social and Civic Competencies:

- Collaborating in group investigations
- Participating in structured discussion
- Recognizing Community Responsibility in Environmental Management

MATERIALS AND RESOURCES

Required Materials

- Two shallow trays per group (to stimulate coastline with and without seagrass meadows)
- Sand or soil to represent coastline
- Cups or bottles to pour water (to simulate waves)
- Small grass, raffia, string, or natural plant material (to simulate seagrass)
- Measuring tape or ruler (to measure coastal erosion)
- Observation worksheet (Print Appendix)

Optional / Enhanced Materials

- One-minute video showing storm surge impacts: https://www.youtube.com/watch?v=an5uDl2ftb8
- Printed images of coastal flooding: Find relevant images through Google search or use Figure 2.

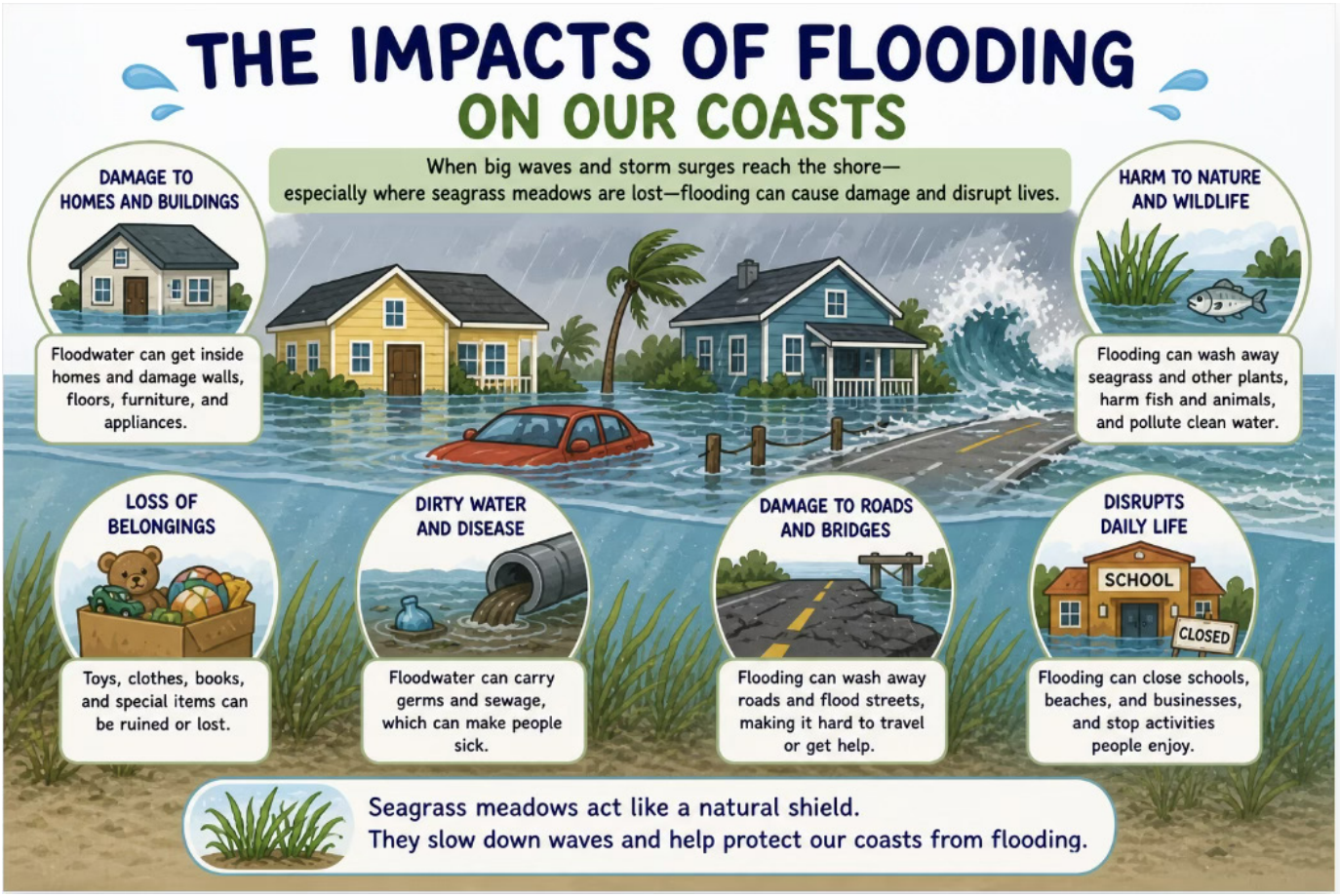

Figure 2. Optional material showing impacts of storm surges and flooding on coastal areas. This image has been generated using Artificial Intelligence.

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity Name / Title: **Who Protects the Coast?**

Activity Description:

1. Show students Figure 2 or a real (perhaps local) image of coastal flooding after a storm.
2. Ask students what might protect houses near the sea.
3. Write suggestions on board (sea walls, rocks, plants, sand dunes).
4. Introduce the idea that underwater plants – seagrasses – also protect coastlines.

Guiding Questions / Prompts:

- What happens during a strong storm near the sea?
- Why do some beaches disappear after storms?
- Can plants really stop water?

Teacher Notes:

Encourage curiosity. Do not explain fully yet – allow students to hypothesise. Look for the following points:

- What happens in a heavy storm near the sea?

  Strong storms have high-speed winds, low air pressure, and large waves. Such forces can

create a storm surge, where water levels rise temporarily and push water onto land. Waves become stronger and more frequent leading to more sand and water movement along the coast. This can cause flooding, damage to buildings and major changes to the shoreline quickly.

- Why do some beaches vanish after a storm?
  When big waves and fast moving water remove sand from the shore and transport it offshore or along the coast, beaches "disappear." When there is nothing to hold the sand in place, erosion occurs rapidly. The process is far more severe where there are no natural barriers such as seagrass, dunes or offshore rocks, or where these have been degraded.

- Can plants actually hold water?
  Seagrasses, for instance, don't stop water entirely, but they do slow the water down and take some of the energy out of it. Seagrass leaves act as a barrier to reduce the energy of the waves and the roots hold the sand in place. This combination helps protect coastlines from erosion, and dampen the force of powerful waves and storm surges. Ask students to think of seagrass as a 'natural shield' rather than a solid wall.

PHASE 2: EXPLORATION

Activity Name / Title: **Storm Simulation Investigation**

Activity Description:

1. Divide students into small groups.
2. Each group prepares two trays containing water ('sea') and sand/soil ('coast') at one side of the tray (Figure 3). Try to make the width of the 'coast' on both trays as similar as possible.
   - Tray A: Sand/Soil only (bare coast) at the edge of the tray.
   - Tray B: Sand/Soil as above, but with "seagrass" inserted into the sand
3. Students measure the width of the 'coast' and mark the sand line on their recording sheet (recording sheet can be found in Appendix).
4. Simulate waves by pouring equal amounts of water onto both trays.
5. Repeat 3–4 "wave rounds" if needed.
6. Students measure erosion (how much sand moved) and the new width of the 'coast'.

Guiding Questions / Prompts:

- Which tray lost more sand?
- What did the "seagrass" do to the water movement?
- What might happen to houses built near Tray A?

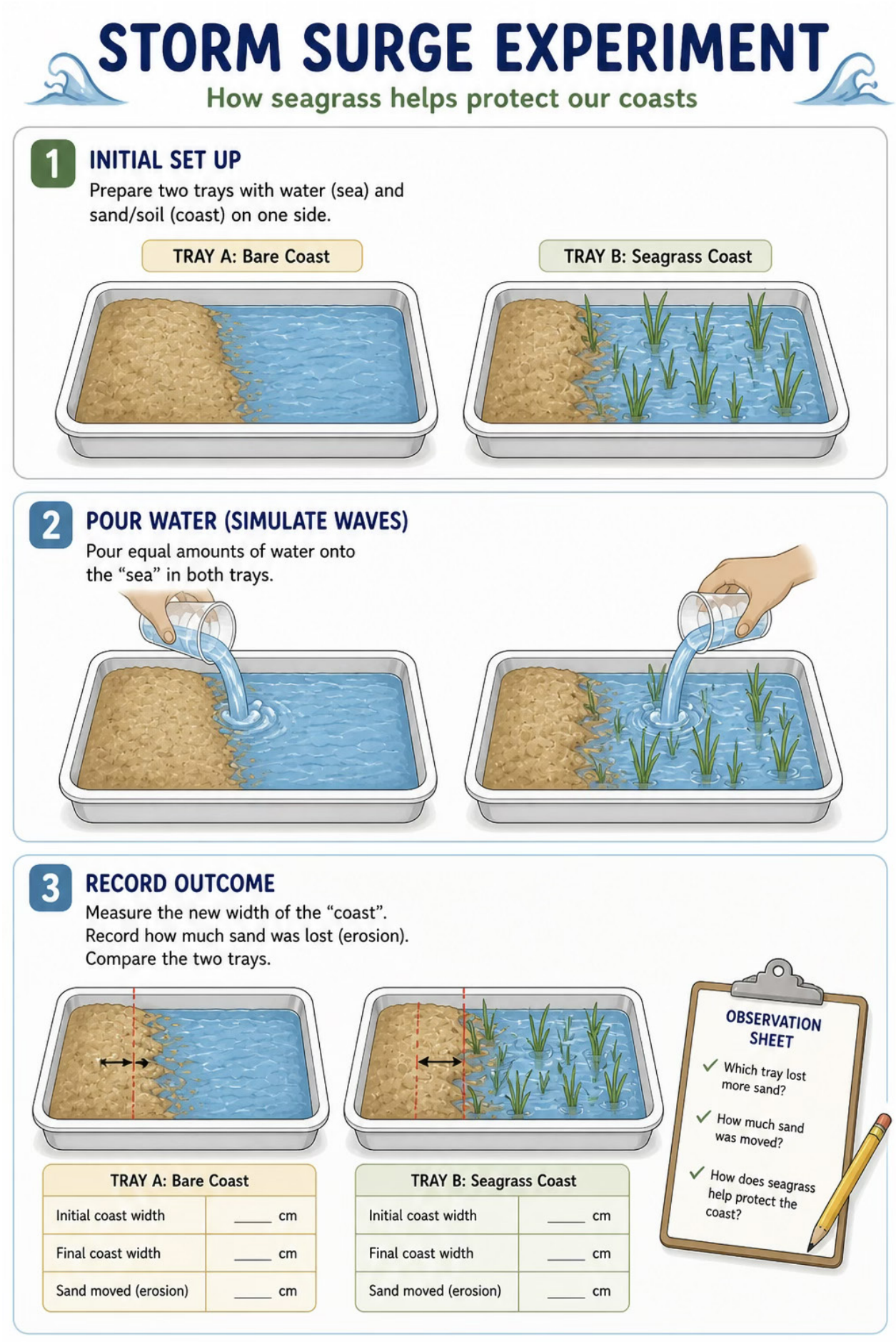

Figure 3. Step-by-step procedure for an experiment investigating how healthy seagrass meadows reduce coastal erosion and the impacts of storm surges. This image has been generated using Artificial Intelligence.

Teacher Notes:

Regarding the experiment:

- Ensure equal water amounts for fair testing.
- Encourage careful measurement.
- Allow students to repeat if results seem inconsistent.

Regarding the theory:

- Which tray lost the most sand?
  Students should notice that the tray without seagrass (Tray A) tends to lose more sand. That is because there is nothing to hold back the sediment or to reduce the force of the waves.

- How did the "seagrass" affect the water motion?
  The "seagrass" is intended to slow the water down and reduce wave energy. Students can observe smaller splashes and cleaner water. This models how real seagrass meadows reduce wave energy and stabilise sediment.

- What could happen to houses near Tray A?
  Get students to recognize that the unprotected coastlines (tray B) are more vulnerable. There is no natural barrier to reduce the impact of waves, so houses near these areas are vulnerable to more erosion, flooding and storm damage.

PHASE 3: EXPLANATION

Activity Name / Title: **Seagrasses as Natural Barriers**

Activity Description:

Teacher explains:

- Seagrass leaves slow down waves.
- Roots hold sediment in place.
- Meadows reduce wave energy before it reaches shore.
- Loss of seagrass increases coastal erosion.

Reinforce key vocabulary:

Erosion, storm surge, sediment, protection

Guiding Questions / Prompts:

- Why did Tray B stay more stable?
- How is this similar to real coastlines?
- How does this protect people?

Teacher Notes:

Tray B is more stable because the "seagrass" helps to reduce the effect of the waves on the sand. The water is slowed in passing through the seagrass and less sand is lifted and taken away. The roots (or a simulated equivalent) also tend to anchor the sediment and make it less prone to easy displacement. Imagine real shorelines, where seagrass beds serve as natural buffers, binding and trapping sediment and dissipating wave energy before it hits the shore. This protection is important for people as it reduces coastal erosion and flooding risk, helping to protect homes, roads and other infrastructure in coastal communities, particularly during storms and rising sea levels. This links explicitly to human communities in various ways, such as homes, tourism, and fishing industries.

PHASE 4: ELABORATION

Activity Name / Title: **Design a Safer Coast**

Activity Description:

Students design a coastal protection plan (diagram on paper) that includes:

- Seagrasses
- Other natural features (mangroves, dunes, reefs)
- Responsible human behaviour

Groups draw a labelled diagram.

Optional discussion topic: Students compare natural solutions with concrete sea walls.

Guiding Questions / Prompts:

- Why might natural solutions be better than concrete walls?
- What happens if we remove seagrasses?
- Who should protect these ecosystems?

PHASE 5: EVALUATION

Activity Name / Title: **Explain It Like a Scientist**

Activity Description:

Students write 5 sentences explaining how seagrasses protect humans.

Guiding Questions / Prompts:

- What evidence do you have from today's experiment?
- What would happen if seagrasses disappeared?

Teacher Notes:

Encourage students to refer directly to what they saw in the trays (evidence from the experiment): the tray with seagrass lost less sand and there was less visible movement of sediment which demonstrates that seagrass reduces wave energy and erosion. They should link this to real world impacts, such as how stable coastlines help protect homes, roads and coastal communities from damage from storms and flooding.

Have students also think about what would happen if seagrasses disappeared.

ASSESSMENT

1. **Formative Assessment (During Lesson):**

- Observation of group collaboration
- Listening to predictions before experiment
- Questioning during data collection

2. **Summative Assessment (End of Lesson)**

Assessment Type: Exit ticket

Students answer one of the options:

- 3 things you learned today
- 2 ways seagrass protects coasts
- 1 question you still have

Evidence captured:

- Understanding of protection mechanism
- Correct vocabulary
- Clear connection to human well-being

SUCCESS CRITERIA

○ I can define coastal erosion and storm surge

○ I can explain how seagrasses protect coastlines

○ I can compare erosion in two different models

○ I can describe why protecting seagrasses protects people

Appendix
Coastal Erosion Experiment Recording Sheet

Name: _____ Date: _____Group Members: _____

Aim:

To investigate how seagrass affects coastal erosion during wave action.

Prediction (Hypothesis)

What do you think will happen to the sand in each tray?

Tray with seagrass: _____

Tray without seagrass: _____

Results

Observation	Tray WITH Seagrass	Tray WITHOUT Seagrass
Starting coast width (cm)		
Ending coast width (cm)		
Water clarity (clear/cloudy)		
Wave strength (same for both?)		

Observations (what you saw)

Describe what happened during the experiment:

_____ _____

_____ _____ _____

Conclusion: What did you find out about seagrass and erosion?

_____ _____

_____ _____

Explanation: Why did this happen? (Think about waves, roots, and sand movement)

_____ _____

_____ _____

Reflection: Was your prediction correct? What would you change next time?

_____ _____

_____ _____ _____

LESSON PLAN 2. FROM LAND TO SEA – HOW NUTRIENT EXCESS AFFECTS SEAGRASSES

DURATION: 45 MINUTES

LESSON OVERVIEW

Seagrass meadows are frequently in a bad state due to poor water quality, primarily excess nutrients from sewage, agriculture and livestock. Fertilizers from farming, livestock farming waste and human sewage enter the sea through surface run-off and point sources, bringing excess nutrients into the sea (Figure 1).

Nutrient excess in seagrass meadows can trigger rapid explosions of epiphytes (e.g. microalgae and macroalgae growing on seagrass leaves), macroalgae (seaweeds), and phytoplankton (algal blooms). As macroalgae and microalgae grow, they block the sunlight that seagrass needs for photosynthesis.

If nutrient pollution becomes too high, the system shifts from a seagrass-dominated state to an algae-dominated state. When the seagrass is out-competed, it dies (Figure 1).

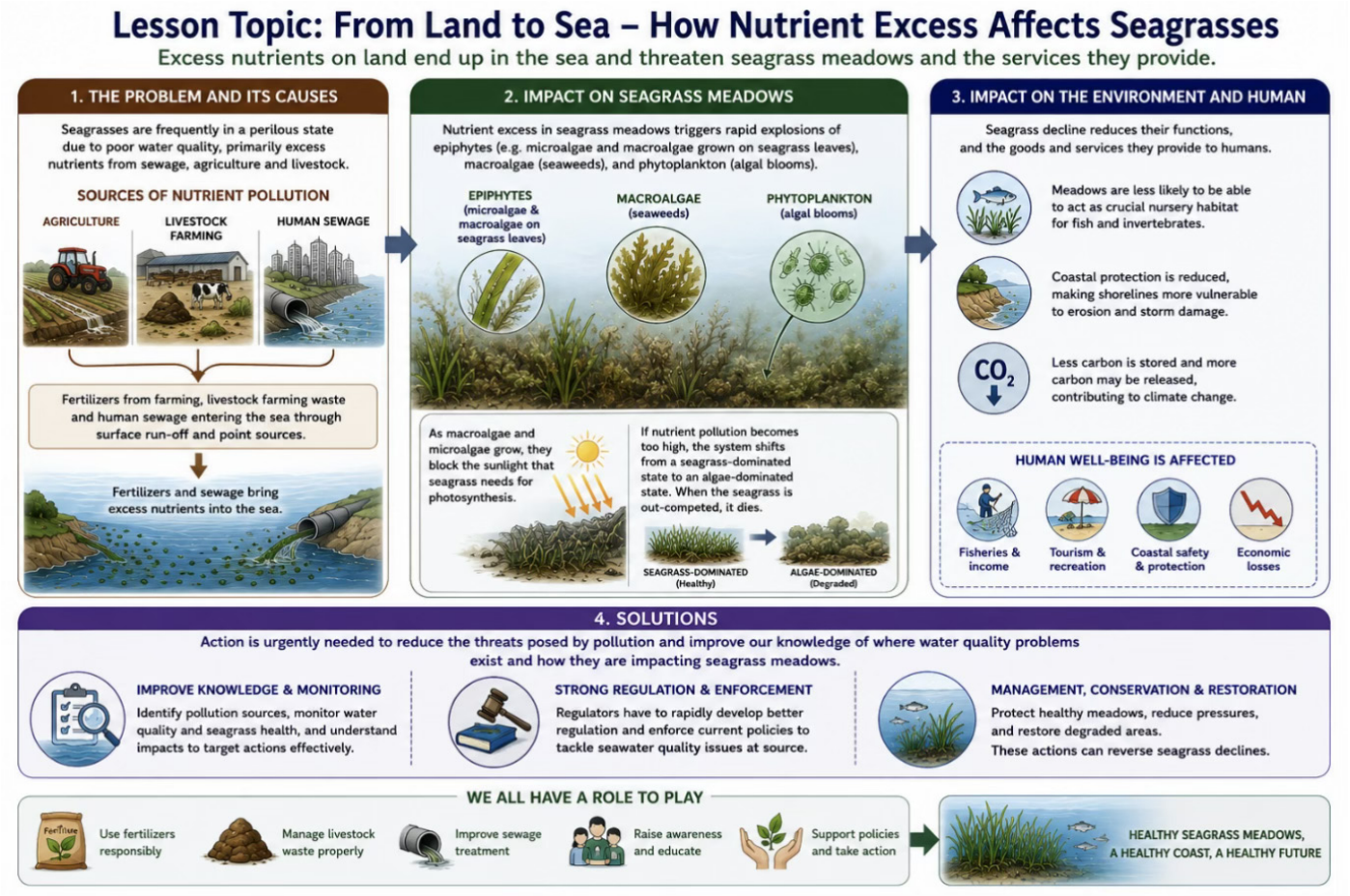

Figure 1. Schematic presentation of nutrient excess input in seagrass meadows: The problem and its causes, the impact on seagrass meadows and humans, solutions. This image has been generated using Artificial Intelligence.

Seagrass decline reduces the functions and the goods and services seagrasses provide to humans – for example, meadows become less able to act as crucial nursery habitat and to mitigate coastal erosion.

Thereby,

Action is urgently needed to reduce threats from pollution and to improve knowledge of where water-quality problems exist and how they impact seagrass meadows.

Regulators must rapidly develop better regulation and enforce current policies to tackle seawater-quality issues at source.

In this context, we must keep in mind that management, conservation, and restoration can reverse the decline of seagrass meadows.

In this lesson students will investigate eutrophication – a state of excessive algal and plant growth caused by nutrients, predominantly nitrogen and phosphorus, in the water – and its devastating impact on seagrass meadows. In a hands-on runoff simulation, students will see how pollution travels and affects underwater plants. In addition, through a hands-on core experiment (exploring how turbid water blocks light) and a dedicated eutrophication activity (observing algal growth driven by fertiliser addition), students will connect

everyday human activities on land to the health of marine ecosystems, and discuss practical solutions for reducing nutrient pollution.

Following the structure and pedagogical approach of this lesson plan, teachers can also develop additional lesson plans focusing on other major threats to seagrass meadows described in the SEAQUEST Curriculum for Teachers, such as coastal development, dredging, anchoring and boating activities, destructive fishing practices, and climate-based threats (Fig. 1).

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Define eutrophication and explain how excess nutrients enter the sea from land
- Identify the main sources of nutrient pollution (fertilisers, livestock waste, human sewage)
- Describe the chain of effects that nutrient excess has on seagrass meadows
- Explain how light blockage caused by algal growth leads to seagrass decline
- Recognise the wider environmental and human consequences of losing seagrass meadows

Skills Objectives

By the end of this lesson, students will be able to:

- Conduct simple experiments and record observations accurately
- Compare experimental conditions (clean vs nutrient-enriched water) and draw conclusions
- Use scientific vocabulary (eutrophication, epiphytes, photosynthesis, nutrients, run-off) appropriately

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Show curiosity about the connections between land-based activities and marine ecosystems
- Demonstrate responsibility by proposing concrete actions to reduce nutrient pollution

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Conducting a controlled experimental investigation
- Observing cause-and-effect relationships
- Recording and interpreting simple data

Environmental Literacy Competencies:

- Recognising land–sea ecological connections
- Understanding human-induced environmental change
- Identifying prevention and mitigation measures

Social and Civic Competencies:

- Collaborating in group investigations
- Discussing shared environmental responsibility
- Participating in solution-focused dialogue

MATERIALS AND RESOURCES

Required Materials

- Large trays or shallow containers
- Soil or sand, small stones, leaves, grass clippings
- Food colouring (to represent pollution)
- Small pieces of paper (to represent litter)
- Watering cans/bottled water with holes on the lid to stimulate rainfall
- Transparent cups or jars (to collect runoff)
- Observation worksheet (Print Appendix)
- Flashlight to observe water clarity
- 3 plastic water bottles
- Seawater from a local coastal area or lagoon water from a local coastal lagoon
- Tap water
- Liquid fertilizer containing nitrogen or phosphorus (available from agricultural supply stores)

Optional / Enhanced Materials

- Images of eutrophication in coastal waters, e.g.: https://link.springer.com/chapter/10.1007/978-3-031-10127-4_4#Fig4
- 2 minute video showing storm-water runoff: https://www.youtube.com/watch?v=GrBEEji-jxaY
- 2 minute video showing agricultural runoff: https://www.youtube.com/watch?v=noIsLL-SpXeg
- 1 minute video showing coastal eutrophication: https://www.facebook.com/IocUnesco/videos/coastal-eutrophication-eutrophication-the-over-enrichment-of-nutrients-into-coas/2613661302256999/
- Photos of seagrass meadows
- Chalk for drawing runoff pathways outdoors

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity Name / Title: **Where Does Rainwater Go?**

Activity Description:

This outdoor activity is designed to help students observe water movement through their immediate environment to introduce the concept of terrestrial runoff. Ask students to consider what happens to rainwater when it falls. Encourage students to suggest ideas such as soaking into the ground or flowing across surfaces. Take students outside, and group them in small groups to explore the school grounds. Have them look for features such as slopes, drains, soil or grass areas, and paved surfaces, and think about how each of these might affect the movement of water.

Next, do a simple demonstration by pouring a small, controlled amount of water on different surfaces, such as pavement, rubble and vegetated soil. Students should look at how fast the water is moving, where it is going, whether it goes down or runs off and if there is any dirt or trash in it.

After the observation, lead a discussion. Ask the students where the water went, what path it took and what it carried with it. Explain that water runs from drains into streams, rivers and ultimately the ocean, and help them to link this to the broader system. Then add in the term terrestrial runoff – water running over the land bringing stuff with it to the streams and the sea.

Guiding Questions / Prompts:

- Where does rainwater go after it falls?
- How fast does water move on vegetated land versus concrete?
- Does it stay here, or does it travel?
- What might it carry with it?
- What do you think happens to underwater plants due to this water?
- Introduce the key term: eutrophication – write it on the board and invite students to guess its meaning.

Teacher Notes:

Rainwater does not just stay where it falls. Some of it soaks into the ground, especially in soil or grassy areas, but a large amount flows over surfaces like roads and pavements. This flowing water is called surface or terrestrial runoff, and it usually moves downhill, following slopes into drains, gutters, streams, and rivers, eventually reaching the sea. As it moves, it can carry many things with it, such as soil, litter, fertilisers, and pesticides. These materials can end up in rivers and the ocean, where they may harm ecosystems like seagrass meadows.

Emphasise that rainwater travels, sometimes over long distances, connecting land to waterways and coastal environments. Encourage students to think locally first before connecting globally.

PHASE 2: EXPLORATION

Activity Name / Title: **Runoff in Action – Pollution Journey**

Activity Description:

1. Divide students into groups.
2. Each group creates a "mini landscape" in a tray:
    - Soil (farmland)
    - Rocks (urban areas)
    - Leaves (natural vegetation)
3. Add "pollutants":
    - Food colouring (fertiliser/chemicals)
    - Paper bits (litter)
4. Tilt the tray slightly to create slope.
5. Simulate rainfall using watering can.
6. Collect runoff in a transparent jar.
7. Shine flashlight to observe light penetration and pollution

Students observe and record (recording sheet in Appendix):

- Water clarity
- Movement speed
- Amount of "pollution" carried

Guiding Questions / Prompts:

- What happened when the rain started?
- Did more polluted runoff come from vegetated or bare areas?
- How clean or dirty is the collected water?
- How does dirty water affect seagrass, fish, and people (fishermen, beach-goers...)?

Teacher Notes:

When the "rain" begins have students watch how water begins to flow downhill across the tray picking up and carrying material as it flows. Ask them to explain how flow speed and direction varies on different surfaces (soil, rocks, leaves). Try to help them understand that smoother, harder surfaces (like rocks/urban areas) are going to have faster runoff, while soil and vegetation may slow the water down a little, but can still release sediment and pollutants.

Ask students to compare and contrast where most pollution came from. They should notice that bare or loose soil makes cloudy water (sediment) and that areas with added "pollutants" (food colouring, paper) clearly demonstrate how contaminants are transported. Emphasise the idea of suspension of sediment, where fine particles remain in the water, making it appear muddy.

Have students describe the appearance of the collected water—clean or dirty—and relate that to real-world water quality. Then link to impacts: cloudy or polluted water means less light gets through to seagrass and this affects its ability to photosynthesise and survive. Pollutants can harm fish and marine life. Poor water quality can impact on people by reducing fish stocks, affecting livelihoods such as fishing and making beaches less safe or enjoyable.

Remind students to pour water evenly across groups to make the comparison fair and observations more reliable.

PHASE 3: EXPLANATION

Activity Name / Title: **Eutrophication Activity – Fertiliser in the Sea**

Objective: Students observe experimentally what happens when nutrients enter an aquatic system, investigating the effects of fertilizer on the growth of phytoplankton! Conduct a two-week experiment by following the instructions below.

Activity description

- Fill two of the water bottles halfway with seawater or coastal lagoon water.
- Fill the third bottle to the same level with tap water.
- Label the three bottles with the initials L (Lagoon), L+ (Lagoon with added fertilizer), and T (Tap water).
- Place the three bottles side by side in a location exposed to sunlight.
- In the table below, record the appearance of the water in all three bottles before beginning the experiment.
- After the initial recording, add two teaspoons of liquid fertilizer to bottle L+.
- Every day for 15 days, record your observations about the water in the table.

ANSWER THE QUESTIONS:

- Why do we use tap water?
- Why do we use three bottles?
- What kinds of organisms are present in the water?
- How is the water in bottle L+ affected by the addition of fertilizer? What does this indicate?
- Where does the fertiliser come from in real life? How does it reach the sea?
- What can farmers, governments and we ourselves do to reduce nutrient run-off?

Day and Time	Bottle L	Bottle L+	Bottle T	Observations

Teacher explains:

- Runoff carries nutrients and pollutants into coastal waters.
- Too many nutrients cause rapid explosions of epiphytes, macroalgae, and phytoplankton (algal blooms)
- Algae block sunlight and dead and decomposing algae consume oxygen in water.
- Seagrasses need sunlight to photosynthesise.
- Reduced light leads to seagrass decline.

Explain that globally, about 20% of the global seagrass area has been lost since the late 19th century due to human and natural pressures. Deterioration of seawater quality due to industrial and agricultural runoff and disposal of insufficiently treated wastewater and sewage are one of the main contributors to this decline.

Guiding Questions / Prompts:

- Why do seagrasses need clear water?
- What might happen if algae cover the water over a seagrass meadow?
- How are we connected to this process?

Teacher Notes:

Keep explanation age-appropriate and visual.

Explain to students that seagrasses require clear water to thrive because they rely on sunlight to photosynthesise and produce their own energy. If the water is cloudy or blocked less light can reach the plants. This makes it harder for the plants to grow and survive. This can be reinforced by a simple diagram of sunlight passing through clear water and sunlight blocked by murky water.

When you mention algae, mention that if it grows too much and covers the water over a seagrass

meadow or seagrass leaves, it acts like a "shade" and blocks the sunlight from reaching the plants underneath. This can eventually weaken or kill seagrass. Utilise visuals and analogies that resonate, like attempting to cultivate a plant in the dark.

To address human connection, help students realise that land-based activities such as discharge of insufficiently treated sewage and wastewater, and excessive use and runoff of fertilisers can wash into the sea and cause explosions of epiphytes, macroalgae, and phytoplankton. Remind that people are part of this system and our actions can hurt or help protect seagrass ecosystems.

PHASE 4: ELABORATION

Activity Name / Title: **Build a Cleaner Landscape**

Activity Description:

The teacher demonstrates or leads students to redesign their tray landscape to reduce runoff pollution by adding:

- Natural barriers (more vegetation, grass/raffia/or a sponge to represent wetlands etc.)
- Slower water pathways (e.g. leaving rocky areas before water)

Repeat rainfall test and compare results.

Students evaluate improvement.

Guiding Questions / Prompts:

- What changes reduced pollution?
- How can plants help stop runoff?
- What real-life solutions can communities use?

Teacher Notes:

In this phase, guide students to think like problem-solvers as they redesign their landscape to reduce pollution. Encourage them to include in "natural barriers" such as vegetation (leaves, raffia, sponge as wetlands) and to slow down water pathways by changing the layout (e.g. putting rocks or plants in the flow path). Have them repeat the rainfall test, encouraging them to watch closely for differences in the speed of the water, the clarity, and the amount of "pollution" that makes it into the collection jar.

During the discussion, students discover which changes were most effective. They should realise that more plants or barriers mean more water slowed down so it can soak in, and more sediment and pollutants caught before they move on. Emphasise that plants act as natural filters, reducing runoff and improving water quality.

When discussing real life, encourage students to propose solutions such as planting vegetation, protecting wetlands, creating green spaces, and reducing pollution at the source. Emphasise that vegetation and wetlands can trap pollutants, reduce nutrient runoff, and improve water quality before it reaches rivers and the sea. Note that these are nature-based solutions communities can use to protect waterways and coastal ecosystems.

Encourage experimenting and engineering thinking throughout – there is no one "right" way to design something and improvement comes from testing and adapting ideas.

Connect the activity to real-life solutions such as protecting and restoring wetlands, planting vegetation along waterways, improving wastewater treatment, and reducing fertiliser use. Reinforce that good land management can help prevent coastal eutrophication and protect seagrass meadows.

PHASE 5: EVALUATION

Activity Name / Title: **The Journey of a Raindrop**

Activity Description: Storytelling

Students tell a short story from the perspective of a raindrop traveling to a seagrass meadow.

Guiding Questions / Prompts:

- What did we discover about runoff?
- How can humans reduce harmful runoff?

Teacher Notes:

This storytelling activity allows students to demonstrate their understanding in a creative way. Guide them to describe the journey of a raindrop step by step–from where it falls (e.g. city, farm, or natural land), how it moves (runoff, drains, rivers), what it picks up along the way (e.g. fertilisers, sediment), and what happens when it reaches the sea and a seagrass meadow.

Encourage students to include clear cause-and-effect links, such as how human activities (e.g. fertiliser use) lead to polluted runoff, and how this affects water quality and seagrass health. They should also show awareness of solutions, for example how adding plants or reducing pollution can change the raindrop's journey and reduce harm.

When assessing, look for logical sequence (clear beginning → journey → outcome), understanding of runoff and pollution movement, connection between land activities and marine impact, inclusion of solutions or positive actions.

ASSESSMENT

1. **Formative Assessment (During Lesson):**

- Observation during experiment setup
- Monitoring predictions vs results
- Group discussions
- Think-pair-share reflections

2. **Summative Assessment (End of Lesson)**

Assessment Type:

1. Role play

   Students do a theatrical representation of the story of a raindrop activity done in the previous step.

   Evidence captured:

   - Understanding of runoff pathway
   - Identification of pollution sources
   - Clear connection to seagrass health

   Evidence captured:

   - Understanding of protection mechanism
   - Correct vocabulary
   - Clear connection to human well-being

2. Students complete a short exit ticket with three components:

    - **Draw & label**: Create a flow diagram showing the eutrophication chain (fertiliser → run-off → sea → algal growth → light blocked → seagrass death).
    - **Explain**: Write one sentence explaining why turbid water is harmful to seagrasses.
    - **Act**: Name one thing you could do – or ask adults to do – to help reduce nutrient pollution.

SUCCESS CRITERIA (Student-Facing)

Share these with students at the end of the lesson:

❍ I can define terrestrial runoff

❍ I can explain how pollution from land reaches the sea

❍ I can describe how runoff affects seagrasses

❍ I can define eutrophication

❍ I can suggest ways to reduce harmful runoff

Appendix

Runoff Experiment Recording Sheet

Name: _____ Date: _____Group Members: _____

Our Mini Landscape

Tick what you used:

❍ Soil (farmland)

❍ Rocks (urban area)

❍ Leaves (plants)

What did we add as "pollution"?

❍ Food colouring

❍ Paper bits

Other: _____

Observations

1. **Water clarity** (circle one):

Clear / Slightly cloudy / Very cloudy / Dirty

2. **How fast did the water move?** (circle one):

Slow / Medium / Fast

3. **How much "pollution" was carried?** (circle one):

None / A little / Some / A lot

What did you see? (Write or draw your observations)

Light Test (flashlight)

Could light pass through the water easily?

Yes / A little / No

What does this mean?

Conclusion: What did you learn about runoff and pollution?

Think about it: Where could this polluted water go in real life?

LESSON PLAN 3. WE ARE SEAGRASS GUARDIANS

DURATION: 45 MINUTES

LESSON OVERVIEW

This lesson empowers students to take responsibility for protecting seagrass ecosystems. Students will reflect on what they learned and create a small awareness or action project, using previous lessons on coastal protection, run-off, biodiversity and conservation. They will develop messages that promote sustainable behaviour and environmental responsibility through collaborative outdoor activities. The lesson ends the unit on a note of hope, agency and stewardship.

Following the structure and pedagogical approach of this lesson plan, teachers can also develop additional awareness-raising and action-oriented lesson plans inspired by the activities and themes presented in the SEAQUEST Curriculum for Teachers. These may include student campaigns, beach and coastal conservation actions and school-community collaborations, that encourage active participation in the protection and restoration of seagrass ecosystems.

LESSON OBJECTIVES

Knowledge Objectives

- Identify actions that help protect seagrasses
- Recognize that everyone shares responsibility for marine ecosystems

Skills Objectives

- Create an awareness message for a target audience
- Design a simple environmental action plan
- Communicate scientific ideas clearly and confidently

Attitudes and Values Objectives

- Demonstrate pride in protecting the environment
- Value teamwork in solving environmental problems
- Show commitment to responsible environmental behaviour

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Synthesizing scientific knowledge
- Communicating environmental concepts
- Applying science learning to real-world contexts

Environmental Literacy Competencies:

- Developing stewardship and responsibility
- Identifying sustainable behaviours
- Engaging in environmental problem-solving

Digital Competences

- Creating a short awareness video or digital poster (optional)

Social and Civic Competencies:

- Participating in democratic discussion
- Collaborating on shared goals
- Understanding collective and individual responsibility

MATERIALS AND RESOURCES

Required Materials

- Poster paper or cardboard
- Markers, paints, coloured pencils
- Sticky notes
- Large (preferably outdoor) space for display

Optional / Enhanced Materials

- Tablets/cameras for recording awareness messages. QR codes to videos can be printed and glued onto poster displays.
- Examples of environmental campaign posters (real examples or Figures 1 and 2) to provide ideas and inspiration.
- Images of seagrass meadows for inspiration



Figure 1. Examples of advocacy poster designs. This image has been generated using Artificial Intelligence.



Figure 2. Examples of advocacy poster designs. This image has been generated using Artificial Intelligence.

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity Name / Title: **What Have We Learned?**

Activity Description:

This opening activity gives students an opportunity to activate prior knowledge and to see how much they've learnt from the unit. It also creates a sense of collective achievement and sets a reflective mood for this lesson on action and responsibility.

1. Students sit in a circle outside in a quiet, open area to encourage engagement and eye contact.
2. The teacher introduces a soft ball as a 'talking object' to structure turns and to ensure one speaker at a time. "Seagrasses protect coastlines from erosion" is one example the teacher starts with and gently tosses the ball to a student.
3. Each student who receives the ball states one thing they have learned about seagrasses. Responses can be scientific facts, processes or human connections. If necessary, the teacher can offer guiding questions, such as "How do seagrasses help people?" or "What affects seagrass health?"
4. After sharing, the student passes the ball to another classmate. And so on, until most students have shared.
5. The teacher records key ideas on a large sheet or board where everyone can see them, under headings such as:
    - Coastal Defence
    - Biodiversity (nursery grounds)
    - Human Impacts and Runoff Pollution
    - Climate and carbon storage (if previously discussed)
    - Human responsibility and conservation
    - The teacher then provides a brief summary of the ideas and shows how interconnected they are and how they relate to real world environmental issues.

Message reinforcement:

"If we know something, we can protect it." Students need to know they can now make change happen with what they know, not just point out problems.

Guiding Questions / Prompts:

- Why are seagrasses important for people?
- What problems threaten them?
- Can people make a difference?

Teacher Notes:

This engagement phase is designed to reactivate prior learning, build confidence and create a shared foundation before students begin creating their final awareness or action projects. It supports reflection, reinforces science vocabulary and helps students to recognise the interconnected nature of human and ecosystem systems.

Look for mention of key topics:

- Seagrass protects coastlines by reducing wave energy and erosion
- Roots/rhizomes stabilise sediment and help hold the seabed together
- Seagrass provides habitats and nursery areas for marine life
- It supports food webs and biodiversity
- Runoff from land can pollute water and harm seagrass (e.g. nutrients, litter, sediment)
- Clear water is needed for photosynthesis and survival of seagrass
- Human activities can damage or protect seagrass ecosystems
- Seagrass helps with climate regulation (carbon storage)
- People depend on healthy coasts for safety, food, and livelihoods

PHASE 2: EXPLORATION

Activity Name / Title: **Seagrass Guardians Brainstorm**

Activity Description:

Students work in small groups to answer:

"How can we protect seagrasses from our school, home, or community?"

Groups brainstorm practical actions such as:

- Reducing litter
- Saving water
- Using fewer chemicals
- Teaching others

They organise ideas into:

- At Home
- At School
- In the Community

Guiding Questions / Prompts:

- What small actions can prevent terrestrial runoff?
- How can we raise awareness?
- Who needs to know about seagrasses?

Teacher Notes:

This activity takes learning from understanding seagrass ecosystems to applying knowledge through practical local action. Students are encouraged to realise environmental protection is not only something that happens in marine or scientific settings, but that it starts with everyday choices at home, in school and in the wider community. The emphasis is on stopping harm at the source – especially by reducing runoff pollution, litter and chemical use – major threats to the health of seagrass.

Encourage students to think practically and realistically and not to list idealised or unrealistic solutions. Ask them to link ideas to what they learnt about runoff (e.g. "How does this action stop pollution getting to the sea?"). Help groups to organise ideas clearly under the three categories: At Home, At School and In the Community.

Encourage students to take age-appropriate and feasible actions such as reducing litter, avoiding unnecessary chemicals, planting vegetation. If groups are stuck, use prompts such as: "What might we change in our daily routine?" or "How might we stop something from washing into drains?"

Emphasise that even small actions can reduce pollution and protect seagrass ecosystems and keep the focus on empowerment. Foster teamwork and make sure all students have something to add to their group.

PHASE 3: EXPLANATION

Activity Name / Title: **From Ideas to Campaign**

Activity description

Teacher explains that awareness helps communities change behaviour.

Students form groups and choose one of the following projects:

- Design a poster campaign
- Create a short "Protect Our Seagrasses" speech
- Record a 1-minute awareness video (if digital tools are available)
- Write a letter to families about clean water practices.

Explain that good communication includes:

- Clear message
- Facts
- Positive tone
- Call to action

Guiding Questions / Prompts:

- What is the most important message people should hear?
- How can we make our message clear and powerful?
- Why is positive language important?

Teacher Notes:

Explain to students that increasing awareness is an important way to protect seagrass ecosystems as it helps change people's behaviour in everyday life. Emphasise that scientific understanding is more powerful when it is clearly shared with others, and that even simple messages can have a real impact on communities. Help students refine their ideas and to ensure that their selected project (poster, speech, video, or letter) delivers one clear, focused message rather than multiple messages.

Challenge students to apply accurate scientific information from the unit: runoff, pollution, sediment, erosion, and the role of seagrass in coastal protection. Tell them: "Good communication

should be simple, factual and easy for others to understand". Ask them to think about who their audience is and what they want the audience to do with the message.

Emphasise the importance of maintaining a positive and solution-oriented tone. Students should not only analyse problems but demonstrate how small, practical steps can help protect seagrasses. Let them know that using clear language, strong scientific vocabulary and a strong call to action will make their message more impactful and meaningful.

PHASE 4: ELABORATION

Activity Name / Title: **Outdoor Seagrass Awareness Trail**

Activity Description:

1. Students set up their posters/speech text/letters around the school grounds.
2. Groups rotate and present their message.
3. Option: Invite another class to walk through the "Seagrass Awareness Trail".

Students explain:

- Why seagrasses matter
- What threatens them
- What people can do

Guiding Questions / Prompts:

- How did it feel to teach others?
- Which ideas were most convincing?
- What might happen if our community takes action?

Teacher Notes:

Give students time and space to display their posters, speeches or letters clearly around the school grounds. Facilitate the rotation so that each group can share its message and structured interaction with the others. If another class is invited, support the organisation of a "Seagrass Awareness Trail", ensuring smooth movement between stations and that all students are engaged and respectful. When students present, have them clearly explain why seagrasses are important, what threatens them, and what people can do to protect them, using the vocabulary from the unit as appropriate.

Build confidence in communicating. Highlight that students are acting as environmental educators, passing on important scientific ideas to their peers. After the presentations, use guiding questions to help the students reflect. Examples include: - How did it feel to teach others? - What ideas were most persuasive? - How might action by the community make a difference? Keep the mood positive and celebratory, recognising effort, creativity and team work.

PHASE 5: EVALUATION

Activity Name / Title: **My Seagrass Promise**

Activity Description:

Students write a personal commitment statement:

"I promise to help protect seagrasses by _____."

Students are asked to pick a real and specific action they can take based on what they have learned throughout the unit (e.g. reduce litter, use less plastic, spread awareness, or protect water quality). They can write their promise on a card and create a collective "Wall of Commitments" in their classroom. Students are then invited to share their promise with the group (voluntarily or in small circles) to strengthen accountability and shared responsibility.

Guiding Questions / Prompts:

- What is one thing you can do today to help protect seagrasses?
- What can you do every day to reduce pollution or have healthier seas?
- Why is every action, however small, important for the environment?
- How will your promise help people, animals or the environment?

Teacher Notes:

General statements. Help them tie their promise to ideas from the unit like reducing runoff pollution, protecting coastal habitats, or raising awareness. Create a sense of collective responsibility by displaying or discussing the work as a group, but still allow students that want to share, so that they feel comfortable.

Foster a supportive and reflective environment, helping students understand that individual actions add up to wider environmental change when everyone does their bit in a community. Remind that we don't want perfection, we want awareness and willingness to act. Finish the lesson on a positive and empowering note that students now have the knowledge and ability to be agents of positive change for seagrass ecosystems and coastal environments.

ASSESSMENT

1. **Formative Assessment (During Lesson):**

- Participation in brainstorming
- Collaboration during campaign creation
- Accuracy of information shared in presentations
- Quality of reasoning in discussions

2. **Summative Assessment (End of Lesson)**

Exit Ticket – Campaign Message (One Sentence)

Write one powerful sentence for a campaign to protect seagrass:

"_____"

(Your sentence should include why seagrasses matter and/or what people should do to protect them)

Teacher focus when assessing:

- Clear environmental message
- Includes seagrass importance or threat
- Suggests action or awareness
- Positive, persuasive tone

Evidence captured:

- Content accuracy
- Communication skills
- Application of learning

SUCCESS CRITERIA (Student-Facing)

Share these with students at the end of the lesson:

○ I can explain why seagrasses are important

○ I can describe ways humans affect seagrasses

○ I can suggest actions to protect seagrasses

○ I can create a message to encourage others to care

B7.

THEMATIC MODULE 7: SEAGRASSES ARE LARGELY UNEXPLORED

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LESSON PLAN 1. SEAGRASS SCIENCE TEAMS & OCEAN TECHNOLOGY

DURATION: 45 MINUTES

LESSON OVERVIEW

In this lesson, students discover how scientists use modern technologies – such as satellites, drones, and underwater vehicles – to study seagrass meadows. They learn that many different types of experts work together to understand and protect seagrasses. Through a role-play activity, students form interdisciplinary "Seagrass Research Teams" and work collaboratively to analyse a real monitoring challenge. This lesson concludes the module by conveying that protecting seagrasses requires technology, teamwork, and shared responsibility.

LESSON OBJECTIVES

Knowledge Objectives

By the end of this lesson, students will be able to:

- Identify examples of technologies used to study seagrasses (satellites, drones, sonar)
- Recognise that seagrass research involves collaboration between scientists from different disciplines
- Explain why interdisciplinary teamwork leads to better scientific understanding and more effective conservation

Skills Objectives

By the end of this lesson, students will be able to:

- Interpret simple visual data (maps or aerial images)
- Work collaboratively within assigned expert roles, contributing meaningfully to group decisions
- Present group findings clearly

Attitudes and Values Objectives

By the end of this lesson, students will be able to:

- Appreciate the importance of teamwork in science
- Develop respect for different roles and contributions
- Value technology as a tool for environmental protection

COMPETENCES ADDRESSED

Scientific Literacy Competencies:

- Understanding how scientific tools help to collect data
- Connecting evidence to conclusions
- Problem-solving through collaboration

Environmental Literacy Competencies:

- Recognizing how human activity affects seagrass ecosystems and the need for ongoing monitoring
- Understanding that conservation requires planning and research

Digital Competences

- Interpreting simple aerial images
- Building awareness of the range of digital and remote-sensing technologies available for seagrass monitoring

Social and Civic Competencies:

- Cooperative teamwork
- Role responsibility
- Respectful communication and shared decision-making

MATERIALS AND RESOURCES

Required Materials

- Printed aerial images of a seagrass meadow (before & after change) – See Figure 1
- Role cards (Biologist, Engineer, Data Scientist, Community Leader, Diver)
- Large poster paper
- Markers and pencils
- Simple fact cards describing each role

Optional / Enhanced Materials

- Short child-friendly video of underwater drones https://www.youtube.com/shorts/Wx-v2dwekeW8 (1 minute video)
- Tablets for zooming into digital maps or Google Earth to explore satellite views of coastal areas https://earth.google.com/web/search/seagrass/@35.08899515,32.30432273,-0.1883626a,916.33232415d,35y,0h,0t,0r/data=CiwiJgokCXSN6XeqjUFAEZ2qC1_djEFAGbWZZoGyJUBAIQE1opK8I0BAQgIIA-ToDCgEwQgIIAEoNCP_____wEQAA
- Example of a simplified sonar image to show how depth data is collected



Figure 1. Image showing distribution of a seagrass meadow at a coastal site, in current state and its projected state in 20 years into the future. This image has been generated using Artificial Intelligence

LESSON STRUCTURE & ACTIVITIES

PHASE 1: ENGAGEMENT

Activity: **How Do We See Underwater?**

- Display an aerial or satellite image of a coastline with seagrass areas clearly highlighted.
- **Ask**: *"How did scientists take this picture if seagrasses live underwater?"*
- Introduce simple, visual explanations of the key monitoring technologies (see Teacher Notes below).
- Explain that no single scientist can do everything alone – different experts work together in research teams.

Guiding Questions / Prompts

- Can we see seagrasses from space? How?
- What tools might help scientists study plants that live underwater?
- Why might one scientist not be enough to study a whole seagrass meadow?

Teacher Notes:

Introduce as many of the following technologies as is appropriate for your group, keeping explanations simple and visual. Use images or short video clips to show how the tools are used in real life. Avoid heavy technical language. The key concept is that tools help scientists collect information safely, accurately, and at scales that would be impossible to study by hand.

Mapping and monitoring seagrass meadows:

- **Satellites**: Detect seagrass distribution, density, and changes over time using spectral (light) signatures visible from orbit.
- **Drones**: Provide detailed aerial imagery of shallow coastal zones and are ideal for small-scale or follow-up studies.
- **Specialised Imaging**: Often aerial or drone-based hyper-spectral sensors that differentiate species based on precise light reflection and assess physiological health by analysing absorption features.

Underwater observation and monitoring:

- **Underwater cameras & GoPros**: Used for quick, non-destructive surveys to monitor biodiversity and identify disturbances.
- **SCUBA surveys & quadrat sampling**: Scientists dive to measure seagrass coverage, and shoot density directly, identify species composition directly, and to collect samples.
- **Acoustic Systems (Sonar)**: Creates high-resolution images of the sea bottom
- **ROVs (Remotely Operated Vehicles)**: Allow researchers to explore deeper or difficult-to-access areas safely, without needing to dive.

Water quality and environmental sensors:

- **Turbidity and light sensors**: Track how much sunlight reaches seagrass, which is essential for photosynthesis
- **Water quality probes**: Monitor key parameters including nutrients, dissolved oxygen, and pH, which indicate pollution or eutrophication.
- **Temperature & salinity loggers**: Record environmental changes that may affect seagrasses.
- **Laboratory analysis**: Used to examine seagrass samples (e.g. nutrient analysis, epiphyte load, contaminant detection, biomass and productivity, etc.)

PHASE 2: EXPLORATION

Activity: **Seagrass Research Teams**

- Divide students into small groups (ideally 5 students per group, one per role).
- Assign each student a role card and the corresponding fact sheet:
  - Biologist: Studies the plants, animals, and overall ecosystem structure, function and health
  - Engineer: Designs, deploys, and maintains monitoring tools such as drones and sensors
  - Data Scientist: Analyses satellite imagery, aerial photos, and field data to identify patterns and trends
  - Diver: Conducts direct underwater observations and collects physical samples
  - Community Leader: Represents local communities, communicates research findings, and contributes to decisions
- Provide each team with two printed images (Figure 1): a Year 1 seagrass distribution image and a Year 20 image showing visible decline.
- Each team discusses and records their answers on poster paper:
  - What has changed between Year 1 and Year 20?
  - What might have caused these changes?
  - What should the team do next? What does each expert recommend?

Guiding Questions / Prompts

- What differences can you see between the two images?
- What specific information does your role contribute to the team's understanding?
- How can your team combine your different perspectives to find a solution?

Guiding Questions / Prompts:

- What small actions can prevent terrestrial runoff?
- How can we raise awareness?
- Who needs to know about seagrasses?

Teacher Notes:

Encourage students to speak from their assigned expert perspective, rather than just offering personal opinions. Remind the class that every role is equally important. Circulate between groups to prompt quieter students and challenge groups that finish early with: "What would you need to know to be more certain of your conclusions?"

PHASE 3: EXPLANATION

Activity: **Why Teams Matter**

- Each group presents their poster to the class, explaining what they found and what they recommend.
- The teacher facilitates a brief class discussion, drawing out the key ideas:
    - Technology expands what scientists can observe and measure
    - Each expert brings a different type of knowledge and perspective
    - Working together produces more complete and reliable conclusions
- Connect back to the module's key principle: there is still a great deal to learn about seagrasses, which is why ongoing research and monitoring are so important.

Guiding Questions / Prompts

- Could one expert have solved this problem alone? Why or why not?
- How did technology make the team's work easier or more accurate?
- What might happen to a seagrass meadow if no one was monitoring it?

Teacher Notes:

Highlight the theme of shared responsibility: protecting an ecosystem is not the job of any single person or profession. Reinforce that the more we understand about seagrasses, the better equipped we are to protect them. If students have different conclusions in their groups, this is a good opportunity to discuss how scientists compare and evaluate evidence before reaching consensus.

PHASE 4: ELABORATION

Activity: **: Design a Future Tool**

- Students work individually to draw or design an imaginary "Future Seagrass Research Tool".
- They label their design with:
  - What it does
  - How it collects or transmits data
  - Who would use it (which expert role)
- Students share their inventions briefly with a partner or with the class.

Guiding Questions / Prompts

- What problem would your tool solve that current tools cannot?
- Would it fly, float, dive, or orbit in space? How would it work?
- How would it help scientists learn more about seagrasses?

Teacher Notes:

Encourage creativity and imaginative thinking, but gently prompt students to connect their ideas to genuine monitoring needs discussed earlier in the lesson. Accept all ideas– the goal is to consolidate learning through creative application, not to test technical accuracy.

PHASE 5: EVALUATION

Activity: **Science Team Reflection**

Activity Description:

Students complete a short individual reflection (written or drawn), recording:

- One technology scientists use to study seagrasses
- One expert role found in a seagrass research team
- One reason why teamwork is important in scientific research

Guiding Questions / Prompts

- What is the most important thing you learned about studying seagrasses today?
- Which expert role did you find most interesting, and why?
- Why is it important for scientists with different expertise to work together?

Teacher Notes:

As students complete their reflections, listen for evidence that they understand research as an ongoing, collaborative process. Some students may prefer to draw rather than write– both are equally valid forms of response. Collect reflections to use as a quick formative check on individual understanding.

ASSESSMENT

1. **Formative Assessment:**

- Teacher observation of student participation during the role-play and group discussions
- Quality and depth of contributions made within expert roles
- Observations during group presentations: accuracy of content, use of key vocabulary, and clarity of explanation

2. **Summative Assessment**

Assessment Type: Concept Drawing with Short Written Explanation

Students submit:

- A labelled drawing of their "Future Seagrass Research Tool" (from Phase 4)
- A short written response to the question: "Why do scientists use technology and teamwork to study seagrasses?"

Evidence captured:

- Understanding of the role of technology in seagrass monitoring
- Recognition of the value of interdisciplinary collaboration
- Appropriate use of key vocabulary: technology, monitor, research, data, collaboration, ecosystem
- Ability to connect scientific tools and teamwork to environmental protection outcomes

SUCCESS CRITERIA (Student-Facing)

Share the following checklist with students at the end of the lesson:

○ I can name at least one tool that scientists use to study seagrasses.

○ I can explain why seagrass research teams include experts with different skills.

○ I can describe how technology helps scientists protect marine ecosystems.

○ I can work collaboratively in a team to analyse a problem and suggest solutions.

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Seagrass-Watch

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