Welcome to blueSTEAM Ahead!

INTRODUCTION

Welcome to ***blueSTEAM Ahead!***, an education initiative from Blue Robotics that brings real-world ocean and aquatic science exploration into classrooms through hands-on experiences with cutting-edge marine technology. Whether your students are piloting an ROV, deploying sensors, or analyzing field data, our goal is to support the next generation of explorers, scientists, and engineers by making ocean technology accessible, educational, and fun.

The materials in this curriculum are designed to be modular and adaptable — supporting a variety of learning environments, age levels, and research opportunities. They encourage student-led inquiry, real data collection, and engagement with environmental challenges in local waters.

We're building a community of educators who are using Blue Robotics technology to deepen science learning and create meaningful experiences for their students. If you'd like to stay connected, receive new resources, and be the first to hear about upcoming opportunities, we invite you to sign up for our *BlueSTEAM Ahead!* teacher updates.

→ **Sign up for updates here!**

Thank you for being part of this movement to bring marine technology into classrooms — and for inspiring students to explore the underwater world.

—The Blue Robotics Education Team

OUTLINE

BlueROV2 CURRICULUM OUTLINE

CURRICULUM SECTION	ACTIVITY OBJECTIVE	RESOURCES	DETAILS
PRE-LESSON	Teachers will select which aquatic research technology they will use with their class.	Decision tree to help classes make their technology selection: **Teacher Guide for Selecting Vessel and Technology**	This guide provides a brief overview of some Blue Robotics technology that is available to BlueSTEAM Ahead classes, including the BlueROV2, BlueBoat, and options for other kits.. The guide will help you as the teacher to select which technology is right for your class. This curriculum is geared towards a selection of the BlueROV2.
UNIT 1: Introduction to ROVs and Applied Aquatic Science Research	Classes will be introduced to ROVs and their application to marine and aquatic research.	Hyperdoc lesson plan: **UNIT 1: Introduction to ROVs and Applied Marine Science Research** **UNIT 1: Activity - Calculating Fish Diversity Using ROV Footage**	This in-class lesson includes an introduction to ROVs and other technology as tools to learn about aquatic environments and an activity for students to calculate fish species diversity using underwater footage collected by and a BlueROV2. This lesson is modular and the lesson sections may be divided between multiple class sessions. The Engage, Explore, Apply, and Reflect sections may be conducted during class time or as homework assignments. The Explain and Share sections are designed to be conducted in-class.

UNIT 2: Developing a Research Project Using ROV Technology	Teachers will select which level of inquiry is appropriate for their class research questions and projects.	Teachers' guide for selecting level of inquiry: **UNIT 2: Teacher Guide for Selecting the Level of Inquiry for Your Class Research Project**	This guide will help you as the teacher to decide what level of inquiry is appropriate for your class as you embark on your BlueSTEAM Ahead research projects. You may choose to have students work in small groups to do research projects, in which case different groups might use different levels of inquiry. Or you may decide to do multiple projects as a class, in which case you could use different levels of inquiry throughout the project progression. For example you might use a project with confirmation or structured inquiry to introduce research and then move on to guided or open inquiry projects where students have more creative license.
	Teachers or the class will select or generate the research questions and projects.	Example research projects and questions: **UNIT 2: Example Research Questions and Projects**	Depending on the type of inquiry your class will be using you and your class will use the resources provided to develop your research questions and projects. Again, you may have multiple groups of students working at different levels of inquiry or you may opt to have your class complete an example research project first and then design and complete their own research project. For guided, structured, and confirmation inquiry, you as the teacher will select from a set of research questions.
		Guide to generating research question: **UNIT 2: Guide to Developing a Research Question**	For open inquiry, classes will be guided through a set of steps for generating a research question.
		Guide to generating research project: **UNIT 2: Guide to Designing a Research Project**	For guided and open inquiry, students will be guided through a set of steps for generating a comprehensive plan for their research project.
UNIT 3: Class Research Project	Classes will test drive their ROV and practice data collection.	Support guide for ROV test drives and field excursions	This guide includes links to the BlueROV2 technical manuals plus tips and troubleshooting for flying the ROV.

		UNIT 3: Technical Guides, Tips and Tricks	
	Classes will execute their research projects and data analysis.	UNIT 3: Research Project 1 - Comparing Species Diversity in Two Areas UNIT 3: Research Project 2 - Benthic Macroinvertebrate Diversity and Microplastic Abundance in Aquatic Sediment Samples UNIT 3: Research Project 3 - Testing the Chemistry and Properties of Seawater	For classes that are using guided, structured, and confirmation inquiry, these are the detailed example research projects that they may choose from. These project descriptions include background information, protocol for collecting data, and data analysis.
UNIT 4: Research Reporting	Students will write a research report.	Guide to writing a research report UNIT 4: Guide to Writing a Research Report	This guide provides instructions for students to write a research report with an emphasis on putting class research into context of historical/existent applied science and research.

PRE-LESSON

CURRICULUM SECTION:

PRE-LESSON

ACTIVITY OBJECTIVE:

Teachers will select which aquatic research technology they will use with their class.

RESOURCES:

Decision tree to help classes make their technology selection:
Teacher Guide for Selecting Vessel and Technology

DETAILS:

This guide provides a brief overview of some Blue Robotics technology that is available to BlueSTEAM Ahead classes, including the BlueROV and, BlueBoat.

The guide will help you as the teacher to select which technology is right for your class.

This curriculum is geared towards a selection of the BlueROV2.

Teacher Guide for Selecting Vessel and Technology

Use this guide to help determine which Blue Robotics vessel and technology will be right for your class's BlueSTEAM Ahead! Project. Below are a few questions to help guide you in your choice.

What vessels and technology are available from Blue Robotics?

The BlueROV2 is a remotely operated vehicle that can fly underwater up to 300 meters deep, collecting video footage and other data, while tethered to a controller at the surface. For more information, visit the Blue Robotics BlueROV2 product page. BlueROV2 product page.

The BlueBoat is an uncrewed surface vessel that can be programmed or remotely controlled to cruise along the surface while collecting data with sonar or other sensors. For more information, visit the Blue Robotics BlueBoat product page. BlueBoat product page.

What is your budget?

The BlueROV2 starts at $4,250, and it comes with lights, a built- in camera, temperature gauge, and depth sensor. A sediment sample collector and an echosounder may also be purchased from Blue Robotics and added to the ROV. Additional water sensors may be purchased and installed on the BlueROV2 and your class will need to build the sensor housing using a kit.

The BlueBoat starts at $4,400. It comes with autonomous navigation capabilities, so you can plan and pre-program its routes. It is also a great platform for mounting sonars, including the echosounder, and other sensors. Similar to the BlueROV2, water sensors can be added with the construction of a housing.

SeaMATE offers a variety of beginner underwater robotics kits (starting at $220), building guides, and instructional materials aligned with standards, and other products that support the teaching, designing, and building of ROVs.

[[coming soon… info on GoSense]]

Where will your class research project take place and what type of data will be relevant and interesting?

Consider whether your class will be conducting their research in the ocean or in freshwater, nearshore or offshore, and what type of data they might collect in the research environment that is available to them. Also consider how your class will access their research area, whether from a boat, the shore, or a pier. For example, if your class will be able to take a boat ride out on the ocean to an area with a rocky reef you might use the BlueROV2 to collect video footage of the fish diversity there; if your class will visit a lake and conduct research from the shore you might use the BlueBoat with an echosounder to create a bathymetric map; and if your class will be accessing water from a pier you could lower a water sensor kit with a tether to create a depth profile of the water quality. NOTE: If you are interested in using a BlueROV2 or a BlueBoat, you should plan to conduct a test drive in a pool before deploying the vessels in the open water.

Continued engagement through student competitions

There exists many opportunities for students to take their learning to the next level through underwater robotics competition participation. These organizations provide pathways of hands-on educational experiences that empower students to find innovative solutions to global challenges.

- RoboSub
- RoboBoat
- MATE ROV Competition
- SeaPerch Challenge

Further reading: Which Underwater Robotics Competition is Right For You?

UNIT 1

CURRICULUM SECTION:

UNIT 1: Introduction to ROVs and Applied Aquatic Science Research

ACTIVITY OBJECTIVE:

Classes will be introduced to ROVs and their application to marine and aquatic research.

RESOURCES:

Hyperdoc lesson plan:
UNIT 1: Introduction to ROVs and Applied Marine Science Research

UNIT 1: Activity - Calculating Fish Diversity Using ROV Footage

DETAILS:

This in-class lesson includes an introduction to ROVs and other technology as tools to learn about aquatic environments and an activity for students to calculate fish species diversity using underwater footage collected by and a BlueROV2.

This lesson is modular and the lesson sections may be divided between multiple class sessions. The Engage, Explore, Apply, and Reflect sections may be conducted during class time or as homework assignments. The Explain and Share sections are designed to be conducted in-class.

Intro to ROVs and Applied Marine Science Research

UNIT 1: Introduction to ROVs and Applied Marine Science Research

In this unit, students will be introduced to remotely operated vehicles (ROVs) and some applications of ROV technology in marine research.

ENGAGE

These two videos were taken near Santa Cruz Island, which is part of Channel Island National Park off the coast of Southern California. Both videos were shot on the same day, August 5, 2024. As a class, watch each video and have students record their initial observations in a notebook or document.

What do you notice in each video? What do you wonder?

Kelp Forest, Santa Cruz Island, August 5, 2024.mp4

Urchin Barren, Santa Cruz Island, August 05, 2024.mp4

Have students share some of their initial observations of phenomena and their inquiries after watching the videos.

Ask your students a few questions to gauge their familiarity and understanding of ROVs and how they are applied to marine research. Students should record their answers in their notebooks or documents:

- How was this video footage taken?
- What is an ROV?
- What are ROVs used for?

Students will revisit and revise their responses to these questions, and add more questions and responses, as they move through this unit.

EXPLORE

Students will dive deeper into the question “What are ROVs used for?” as they;

1. explore the ROV Applied Research resource hub,
2. and explore example research projects that are designed to be conducted by classes using the BlueROV2.

EXPLAIN

Review the following presentation together as a class. While the presentation is being conducted, students should revisit and revise their answers to the following questions, from the “Engage” section about ROVs:

- What is an ROV?
- What are ROVs used for?

Students should also add a response to the question:

- How are ROVs used in marine research?

Copy of Unit 1: Introduction to ROVs

APPLY

In the following activity, students will practice applying ROV technology to marine research. They will identify fish species, record abundance, and calculate species diversity using real video footage taken from a BlueROV2. This activity may be completed in class or as a homework assignment.

UNIT 1: Activity - Calculating Fish Diversity Using ROV Footage

SHARE

After completing the Activity: Calculating Fish Species Diversity Using ROV Footage, have students share their results and discuss their reflections.

REFLECT

Students should, again, revisit and revise their responses to the following questions from previous sections using what they have learned throughout this unit:

- What is an ROV?
- How are ROVs used in marine research?

Students should also answer this additional question, which they will revisit in Unit 2.

- What research questions would you like to explore, using an ROV as a tool?

As a class, discuss the answers to these questions, and ask students to reflect on how their responses have developed throughout Unit 1. How has your class's understanding of ROVs and their application to marine research grown?

NGSS CONNECTIONS

Performance Expectations

HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Science and Engineering Practices

Using Mathematics and Computational Thinking.

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience
PS4.C: Information Technologies and Instrumentation

Crosscutting Concepts

Scale, Proportion, and Quantity

OCEAN LITERACY PRINCIPLES CONNECTIONS

Ocean Literacy Principle #1: Earth has one big ocean with many features.
Ocean Literacy Principle #5: The ocean supports a great diversity of life and ecosystems.
Ocean Literacy Principle #7: The ocean is largely unexplored.

Activity - Calculating Fish Diversity Using ROV

ACTIVITY: Calculating Fish Diversity Using ROV Footage

Introduction:

In this activity, you will practice applying ROV technology to marine research. You will identify types of fish, record abundance, and calculate taxonomic diversity using real video footage taken from a BlueROV2. The video footage was taken near Santa Cruz Island, which is part of Channel Island National Park off the coast of Southern California. Both videos were shot on the same day, August 5, 2024.

How is diversity researched and calculated?

In order to understand how taxonomic diversity is researched and calculated, it's important to understand a few key ecological concepts. Abundance is the total number of organisms in an area. Species richness is the number of different species in an area. Species evenness is a measurement of how common or rare a species is, relative to other species in an area. Species diversity can be calculated using the numbers and relative abundances of species within an area. Put another way, species diversity combines the species richness in an area with the evenness of their abundance. Richness and diversity in an ecosystem can also be calculated without identifying organisms down to the species level, as long as you are able to identify and group all of the organisms in an ecosystem into a consistent taxonomic group (e.g. phylum).

There are several formulas that ecologists commonly use to calculate diversity. The Simpson Diversity Index formula is:

$D=1-(\Sigma n(n-1)/N(N-1))$ where n is the total number of organisms of a particular species and N is the total number of organisms of all species.

The Simpson Diversity Index will produce a number between 0 and 1, where 1 represents infinite diversity and 0, no diversity.

The Shannon Diversity Index formula is:

$H = - \Sigma(Pi) \times Ln(Pi)$ where Pi is the proportion of individuals in each taxonomic group to the total number of individuals.

With the Shannon Diversity Index, higher H values reflect more diverse ecosystems, and values typically fall between the ranges of 1.5 and 3.5.

Abundance data can be collected through direct methods, or in situ data collection, such as conducting surveys of organisms along transect lines, or it can be collected with remote sensing methods such as satellite imagery. Traditional methods of taxonomic identification and classification are conducted by comparing the physical characteristics of observed organisms to those of known species that may be listed in a taxonomic resource. You may be familiar with this method if you've ever identified a plant or animal using a field guide or an application like iNaturalist.

Instructions:

- Review the 1 minute clips of the kelp forest and urchin barren from Santa Cruz Island (slide 1 of each presentation):
  - Kelp Forest, Santa Cruz Island, Aug 5, 2024
  - Urchin Barren, Santa Cruz Island, Aug 5, 2024
- Record the predominant substrate type in each clip.
- For each clip, screenshots were taken every 5 seconds, at 13 intervals. Each interval provides a snapshot of the ecosystem and the types of fish that are present (slides 2-14 of each presentation) .
- Identify the fish by species or other taxonomic group at each interval using CA Department of Fish and Wildlife's Species identification resource: CA Marine Species Portal or a similar resource
- Record the abundance of the species at each interval
- Calculate the diversity using the Simpson Diversity Index (D) or the Shannon Diversity Index (H)
- For or the abundance of each species, use an average of the abundance across all 13 intervals
  - Species abundance (average) = Σ(species abundance per interval)/13
- This spreadsheet has examples of both diversity indexes using sample data. You can copy these spreadsheets and use the formulas for your own calculations:

Diversity Index Examples

Results:

Compare the abundance, richness, and diversity between the kelp forest and the urchin barren. Which area had greater abundance? Which area had greater richness? Which had greater diversity?

Reflections:

Why do you think there are differences between the abundance, richness, and diversity between the kelp forest and the urchin barren?

Glossary of terms and phrases

- ROV Technology: ROV stands for Remotely Operated Vehicle. It is an underwater robot controlled from the surface, used for exploration, research, and underwater tasks.
- Marine Research: Scientific investigations focused on understanding the ocean, its inhabitants, and the processes that occur within it.
- Abundance: The number of individuals of a particular species or group in a given area.
- Species Richness: The number of different species present in a particular area.
- Species Evenness: How evenly individuals are distributed among the different species in an area.
- Taxonomic Diversity: A measure of biodiversity that considers both the number of species (richness) and their relative abundance (evenness).
- Taxonomic Group: A group of organisms classified together based on shared characteristics, such as kingdom, phylum, class, order, family, genus, and species.
- Simpson Diversity Index: A mathematical formula used to calculate biodiversity, taking into account species richness and evenness.
- Shannon Diversity Index: Another mathematical formula used to quantify species diversity in a community, considering species richness and the proportion of each species.
- Direct Methods (In situ Data Collection): Collecting data directly from the environment where the organisms live, like observing and counting them in their habitat.
- Remote Sensing Methods: Gathering data from a distance without physical contact, often using technology like satellites or aerial photography.
- Taxonomic Identification and Classification: The process of identifying and grouping organisms based on their shared characteristics, using resources like field guides.
- Predominant Substrate Type: The most common type of material covering the seafloor in a given area, such as sand, rock, or mud.
- Kelp Forest: An underwater ecosystem dominated by large brown algae called kelp, providing habitat for a variety of marine life.
- Urchin Barren: An area where sea urchins have overgrazed kelp forests, resulting in a barren landscape with low biodiversity.
- Interval: A specific point in time or space used for sampling or data collection. In the context of the ROV footage, screenshots were taken at regular intervals.

NGSS Connections:

Performance Expectations

HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Science and Engineering Practices

Using Mathematics and Computational Thinking.

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Crosscutting Concepts

Scale, Proportion, and Quantity

Ocean Literacy Principles Connections:

Ocean Literacy Principle #5: The ocean supports a great diversity of life and ecosystems.
Ocean Literacy Principle #7: The ocean is largely unexplored.

UNIT 2

CURRICULUM SECTION:

UNIT 2: Developing a Research Project Using ROV Technology

ACTIVITY OBJECTIVE: PART 1

Teachers will select which level of inquiry is appropriate for their class research questions and projects.

RESOURCES: PART 1

Teachers' guide for selecting level of inquiry:
UNIT 2: Teacher Guide for Selecting the Level of Inquiry for Your Class Research Project

DETAILS: PART 1

This guide will help you as the teacher to decide what level of inquiry is appropriate for your class as you embark on your BlueSTEAM Ahead research projects. You may choose to have students work in small groups to do research projects, in which case different groups might use different levels of inquiry. Or you may decide to do multiple projects as a class, in which case you could use different levels of inquiry throughout the project progression. For example you might use a project with confirmation or structured inquiry to introduce research and then move on to guided or open inquiry projects where students have more creative license.

ACTIVITY OBJECTIVE: PART 2

Teachers or the class will select or generate the research questions and projects.

RESOURCES: PART 2A

Example research projects and questions:
UNIT 2: Example Research Questions and Projects

DETAILS: PART 2A

Depending on the type of inquiry your class will be using you and your class will use the resources provided to develop your research questions and projects.

Again, you may have multiple groups of students working at different levels of inquiry or you may opt to have your class complete an example research project first and then design and complete their own research project.

For guided, structured, and confirmation inquiry, you as the teacher will select from a set of research questions.

RESOURCES: PART 2B

Guide to generating research question:
UNIT 2: Guide to Developing a Research Question

DETAILS: PART 2B

For open inquiry, classes will be guided through a set of steps for generating a research question.

RESOURCES: PART 2C

Guide to generating research project:
UNIT 2: Guide to Designing a Research Project

DETAILS: PART 2C

For guided and open inquiry, students will be guided through a set of steps for generating a comprehensive plan for their research project.

Teacher Guide for Research Project

UNIT 2: teacher guide for selecting the level of inquiry for your class research project

Introduction:

In Unit 2, your class will develop a research project that uses the BlueROV as a tool. Skills in this unit will build the background information about ROVs and their applications to marine research from Unit 1. Depending on the level of inquiry that you decide to engage in with your class, you or your students will select or generate a research question and research project. Your class's level of inquiry will depend on a few factors including your class's available time for the research project and your students' capacity for independence, creativity, and challenge. Use the descriptions and time estimates below to determine which level of inquiry is appropriate for your class.

Resources:

Depending upon which level of inquiry you select, the following resources will be available to you, the teacher, or to your students to aid in the process of developing a class research project:

- Example Research Projects (including example research questions)
- Guide to Generating Research Questions
- Guide to Generating Research Projects
- Pre-designed Research Projects
    - Comparing species diversity in two areas
    - Benthic macroinvertebrate density and microplastic abundance in aquatic sediment samples
    - Testing the chemistry and properties of seawater

Open Inquiry

Students will generate a novel question and a research study.
Duration: 3 months - 1 year

This is the most advanced level of inquiry and the most time intensive. This level of inquiry may be appropriate for classes that have enough time and advanced skills to undertake the creative challenge, and reward, of developing and designing a unique research project. Classes may develop and conduct their Open Inquiry research projects over the course of a few months, at minimum, and up to an entire school year.

For this level of inquiry, students will be asked to consider the area (marine protected area, national marine sanctuary, etc.) and ecosystem (kelp forest, rocky reef, etc.) where they will fly their ROV. They should also consider which sensors they will have access to on their ROV. With these considerations in mind, they will review the Example Research Projects and conduct their own literature reviews to find studies that have been carried out in similar ecosystems and using equipment similar to what they have access to. Then, using the guide to Generating Research Questions, students will develop their own research question and then they will design the study that they will conduct using the Guide to Generating Research Projects.

Guided Inquiry

Teachers will select or generate a research question and students will design the study.
Duration: 2 months - 1 year

This level of inquiry may be appropriate for classes that are advanced enough to take on the creative process of designing a research project with some guidance. A project with this level of inquiry may be completed in as little as two months and could be extended over the course of an entire year.

For this level of inquiry, you, the teacher, will review Example Research Projects, taking into consideration the area (marine protected area, national marine sanctuary, etc.) and ecosystem (kelp forest, rocky reef, etc.) where your class will fly their ROV and which sensors your class will have access to. The Example Research Projects will include example research questions, which you can select from, or you may use the guide to Generating Research Questions, to develop a unique research question for your class. Then, given their research question, your students will design the study that they will conduct using the Guide to Generating Research Projects.

Structured Inquiry

Teachers will select or generate the research question and study.
Duration: 1 month - 1 year

This level of inquiry is appropriate for a class that needs a high level of structure around their research project, but that may have the option to conduct a longer research project. A project with this level of inquiry may be completed in as little as one month or may be extended over the course of an entire year.

For this level of inquiry, you, the teacher, will review Example Research Projects, taking into consideration the area (marine protected area, national marine sanctuary, etc.) and ecosystem (kelp forest, rocky reef, etc.) where your class will fly their ROV and which sensors your class will have access to. The Example Research Projects will include example research questions, which you can select from, or you may use the guide to Generating Research Questions, to develop a unique research question for your class. Then, using the Guide to Generating Research Projects, you will design a study that your class will conduct.

Confirmation Inquiry

The class will conduct observations using a pre-designed research question and study.
Duration: 1 month

This level of inquiry is appropriate for classes that require a high level of structure to conduct their research project and that may be constrained for time. A project using this level of inquiry may be conducted over the course of a month, with a minimum of one class session to prepare, one field excursion to fly the ROV, and a follow up class session to analyze and summarize data.

You, the teacher, will select from the following Pre-designed Research Projects for your class to undertake:

- Comparing species diversity in two areas
- Benthic macroinvertebrate density and microplastic abundance in aquatic sediment samples
- Testing the chemistry and properties of seawater

Example Research Questions and Projects

Example Research Project 1 - Comparing Species Diversity in Two Aquatic areas

Project Overview

Student researchers will investigate the species diversity of a selected research area, using the camera on their ROV to capture underwater video footage for analysis.

Research Questions

What is the species diversity in our class's selected research area?

Full Research Project Description

UNIT 3: Research Project 1 - Comparing Species Diversity in Two Areas

Access, Equipment, and Materials Needed

- ROV (Remotely Operated Vehicle) with a camera to capture underwater video footage for analysis.
- Access to an aquatic research area, ideally with diverse habitats.
- Maps and satellite imagery (e.g., Google Earth) for research area exploration.
- Handheld GPS device or mapping app to mark and navigate to transect locations.
- Computer with video editing software to review, label, and analyze the video footage.
- Species identification resources, like the CA Department of Fish and Wildlife's Species Identification Resource: CA Marine Species Portal or a similar resource.
- Spreadsheet software (e.g., Google Sheets) to record data and calculate diversity indices.

Example Research Project 2 - Benthic Macroinvertebrate Diversity and Microplastic Abundance in Aquatic Sediment Samples

Project Overview

Student researchers will collect benthic sediment samples using the sediment grabber on their ROV and they will analyze those samples for abundance and diversity of benthic invertebrates and the presence and quantity of microplastics.

Research Questions

What is the diversity of benthic macroinvertebrates in our class's research area? Are microplastics present in the sediment samples collected at our class's research area, and if so, what is the quantity of microplastics? Is there a relationship between the presence and quantity of microplastics and the diversity of benthic macroinvertebrates in our class's research area?

Full Research Project Description

UNIT 3: Research Project 2 - Benthic Macroinvertebrate Diversity and Microplastic Abundance in Aquatic Sediment Samples

Access, Equipment, and Materials Needed

- ROV (Remotely Operated Vehicle) equipped with a sediment grabber to collect sediment samples.
- Access to an aquatic research area with suitable sediment for sampling.
- Covered storage containers (e.g., 100 ml wide-mouth Nalgene bottles) to store sediment samples.
- Cooler with ice to store samples before processing.
- 1 mm mesh sieve to separate macroinvertebrates from sediment.
- Collection containers for sediment and water passing through the sieve.
- Containers with 70% ethanol solution to preserve macroinvertebrates.
- Tools for sorting macroinvertebrates, like forceps and trays.
- Macroinvertebrate identification resources (see suggestions in the sources).
- Materials for microplastic processing:
    - 2000 ml beaker to hold sediment and $ZnCl_2$ solution.
    - $ZnCl_2$ (Zinc Chloride) to create a solution with a density of 1.5 g/cm3.

    - Stir stick or magnetic stirring bar and plate to mix the sediment and ZnCl2 solution.
    - Spoon to collect plastic materials from the solution surface.
    - Petri dishes to store collected microplastics.
    - Microscope to examine and quantify microplastics.
- Optional materials for microplastic analysis:
    - Drying oven and scale to determine the dry weight of microplastics.
    - Laboratory coats, microfiber cloths, and covers to prevent contamination.
- Spreadsheet software (e.g., Google Sheets) to record data, calculate diversity indices, and quantify microplastics.

Example Research Project 3 - Testing the Chemistry and Properties of Seawater

Project Overview

Student researchers will test water quality in marine environments by collecting in situ data using sensors on their ROV and, optionally, by collecting water samples for analysis back in the classroom. This project can be performed using the sensors that are built into the BlueROV2 (temperature and depth), with additional sensors (electrical Conductivity, pH, dissolved oxygen, oxidation reduction potential) and/or with an additional water sample collection kit. The additional sensor kit and water sample collection kit will need to be purchased, built, and added to the ROV by your class or by a partnering robotics club or class.

Research Questions

What are the physical and chemical properties of the water in our class's selected research area (or areas) and how do these properties change with depth?

Full Research Project Description

UNIT 3: Research Project 3 - Testing the Chemistry and Properties of Seawater

Access, Equipment, and Materials Needed

- ROV (Remotely Operated Vehicle) with built-in temperature and depth sensors.
- Access to an aquatic research area for water property measurements.
- Optional: Additional sensor kit for measuring parameters like electrical conductivity, pH, dissolved oxygen, turbidity, and oxidation-reduction potential.
- Optional: Water sample collection kit to collect water samples at various depths.

- Optional: Chemical testing kits to analyze water samples in the classroom.
- Spreadsheet or graphing software (e.g., Google Sheets, R) to input, plot, and analyze data.

Guide to Developing a Research Question

UNIT 2: Guide to Creating Research Questions

Step 2: Identify and Research a Research Topic

- Choose a research topic that interests your class. Topics could include, but are not limited to:
    - Impact of Plastic Pollution on Aquatic Life
    - Climate Change and Ocean Acidification
    - Water Quality Assessment in Local Water Bodies
    - Effects of Nutrient Runoff on Algal Blooms
    - Aquatic Ecosystems and Biodiversity
    - Seafloor Mapping
- Conduct background research on your topic
    - Start off by identifying the general research area that your specific topic is part of. For example, if you are interested in Ocean Acidification, do background reading about marine biogeochemistry research. If you are interested in ecosystems and biodiversity, do background reading about marine ecology research. Learning about your general research area will give you information about different research fields and you might learn about new research topics that are interesting to you. Other general research areas include:
        - Marine/Aquatic Biology
        - Conservation
        - Human Impacts on the Marine/Aquatic Environment
        - Hydrography
    - Next, dig deeper and find scientific articles, textbooks, and trustworthy online resources (e.g. university and government websites) about the specific topic that you'd like to research. Use these resources to get a deeper understanding of that topic and current issues and research within that topic.
    - Keep a list of researchers and research institutions that are investigating your specific topic area. They might serve as mentors for your project!

- Identify issues that need further investigation within your specific topic area. For example, if you are interested in ocean acidification, has anyone collected pH data in the specific spots where your class can fly their ROV?

Step 3: Draft Your Research Question

- Using the research that you've done in Steps 1 and 2, draft several open-ended questions about your specific focus area. For example, if you are focusing on studying pH levels off of your local ocean pier, you could ask "how does the distance from the shore relate to seawater's pH level?"
    - NOTE: an open ended research question requires exploration, and cannot be answered with a simple "yes" or "no"
    - For example, instead of asking "can kelp grow in cold water?" you could ask "how does water temperature affect the density of a kelp forest?"
- Make sure that your question is specific and measurable so that you can investigate it through observations
    - For example, instead of asking "how does ocean water change over the course of a month?" you could ask "how does the surface temperature of the water off the Santa Cruz pier change during weekly low tide events over the course of one month?"

Step 4: Review, revise and refine your question

- Seek feedback from your teacher, your classmates and research professionals to get insights and suggestions on your research question
    - Now is the time to go back to the list of researchers who are working on your specific topic area from Step 2. Reach out to researchers to get feedback on your research question! You can usually find a researchers' email address through the website of the university or research institution where they work. Don't be discouraged if you don't hear back right away.
- Re-assess the feasibility of investigating your research question with the resources that you have access to. Double check that you have what you need (time, materials, etc.) to conduct research on your question. Consider:
    - Does your class have access to a boat or pier to deploy the ROV in the ocean?
    - How much time will you have to conduct your study? How frequently will you be able to deploy the ROV?
    - What are the limits on the ROV? How deep can it dive? Are there places (like dense kelp forests) where it cannot go?
    - Do you need to get permits to take the ROV into the area that you are interested in studying?
    - What types of sensor and additional equipment will your class ROV be equipped with?
- Revise your research question as necessary based on feedback and feasibility

Examples Research Questions and Projects

[Unit 2: Example Research Questions and Projects]

Glossary of Terms and Phrases

- **Marine Biogeochemistry**: The study of the chemical, physical, geological, and biological processes that control the cycles of matter and energy in the ocean.
- **Marine Biology**: The study of marine organisms, their behaviors, interactions, and the environments they inhabit.
- **Marine Ecology**: The study of the relationships between marine organisms and their environment, including interactions within and between species and their physical surroundings.
- **Conservation**: The protection and management of natural resources, including marine ecosystems and species.
- **Human Impacts on the Marine Environment**: The effects of human activities on the ocean, such as pollution, overfishing, climate change, and habitat destruction.
- **Hydrography**: The science that deals with measuring and describing the physical features of bodies of water, such as oceans, rivers, and lakes.
- **Background Research**: Gathering information and knowledge from existing sources (e.g., scientific articles, books, websites) to understand a topic before starting a research project.
- **Ocean Acidification**: The ongoing decrease in the pH of the ocean primarily caused by the absorption of carbon dioxide from the atmosphere.
- **Kelp Forest Ecosystems**: Underwater ecosystems dominated by kelp, providing habitat for a diverse array of marine life.
- **Rocky Reef Ecosystems**: Marine environments characterized by rocky substrates, which support a variety of attached organisms like algae, invertebrates, and fish.
- **Literature Reviews**: A comprehensive summary and analysis of existing research on a particular topic.
- **Open-Ended Research Question**: A question that cannot be answered with a simple "yes" or "no" and requires exploration and investigation.
- **Measurable**: Able to be quantified or observed using specific methods and tools.
- Feasibility: The practicality or possibility of carrying out a research project given the available resources and constraints.
- **Marine Protected Area**: A designated area in the ocean where human activities are restricted to protect marine ecosystems and biodiversity.
- **National Marine Sanctuary**: A special area within U.S. waters that protects significant marine resources, including habitats, wildlife, and cultural heritage.

NGSS Connections

Science and Engineering Practices:

Asking Questions

Planning and Carrying Out Investigations

Ocean Literacy Principles Connections

Ocean Literacy Principle #7: The ocean is largely unexplored.

Guide to Designing a Research Project

UNIT 2: Guide to designing a research project

Step 1. Develop a hypothesis

Based on the research question that you developed, formulate a testable hypothesis. Make sure your hypothesis is testable by considering what equipment and methods you will need to use in order to collect the data required to prove or disprove your hypothesis. Your hypothesis should be an educated guess about how your research question might be answered by the data that you collect. You should be able to explain your reasoning for making your hypothesis. For example, if your research question is “How does the taxonomic diversity of fish vary between a kelp forest and a sandy bottom ecosystem?” your hypothesis could be “There will be higher taxonomic diversity of fish in or near a kelp forest ecosystem than there will be in or near a sandy bottom ecosystem.” because in your background research you found several articles describing how kelp forests provide habitat for fish.

Step 2. Identify your variables

As you are planning your field-research procedures, identify the independent and dependent variables. For example if your hypothesis is “There will be higher taxonomic diversity of fish in or near a kelp forest ecosystem than there will be in or near a sandy bottom ecosystem”, the independent variable is the type of ecosystem in your surveys (kelp forest vs. sandy bottom) and the dependent variable is the taxonomic diversity of fish. Identify possible confounding variables and try to control for these variables as much as possible. Using our example hypothesis, the time of year could be a confounding variable that might affect the diversity of fish so you should conduct your field research in both the kelp forest and the sandy bottom ecosystems during the same season.

Step 3. Plan your methodology

Outline the details of how you will conduct your research. Consider:

- What data will need to be gathered? Include details about where you will conduct your research and what type of data you will be collecting in order to investigate your hypothesis.
- What data collection methods will you use? Will you be making observations, collecting samples, using sensors? Describe your data collection methods and all of the steps that you will follow in your research.
- What materials will you need? List everything that you will need to conduct your research including equipment (e.g. ROV and controller) and supplies (e.g. clipboards and pencils).
- How will you record your data and measurements? Some data will be stored on a hard drive and uploaded back in the classroom (e.g. video footage) and some data will need to be recorded on a datasheet (e.g. GPS coordinates and air temperature) during your field work. Include these details in your methodology.

Step 4. Consider environmental impacts and regulations

As you are planning and executing your research project, make sure that your project won't cause harm to aquatic life or habitats by minimizing your disturbance to ecosystems. Follow local regulations for conducting research and obtain permits when necessary.

Glossary of terms and phrases

- **Hypothesis**: A testable statement that proposes an explanation for a phenomenon or a relationship between variables.
- **Independent Variable**: The variable that is manipulated or changed by the researcher in an experiment to observe its effect on the dependent variable.
- **Dependent Variable**: The variable that is measured or observed in an experiment to see how it responds to changes in the independent variable.
- **Confounding Variables**: Factors that can influence the results of an experiment but are not the variables being studied. Controlling for these variables is important for ensuring that the results are accurate.
- **Field-Research Procedures**: The steps and methods used to collect data in a natural setting, outside of a laboratory environment.
- **Methodology**: A detailed description of the research methods and procedures used in a study.
- **Datasheet**: A structured form used to record data and observations during field research.
- **GPS Coordinates**: GPS stands for Global Positioning System. Numerical coordinates that represent a specific location on Earth, often used in field research to mark study sites.
- **Environmental Impacts**: The effects of research activities on the natural environment.
- **Regulations**: Rules and guidelines established by governing bodies to protect the environment and ensure responsible research practices.
- **Permits**: Official authorizations granted by regulatory agencies to conduct research activities in specific areas or with certain species.

NGSS Connections

Science and Engineering Practices:

Planning and Carrying Out Investigations

Ocean Literacy Principles Connections

Ocean Literacy Principle #7: The ocean is largely unexplored.

UNIT 3

CURRICULUM SECTION:

UNIT 3: Class Research Project

ACTIVITY OBJECTIVE: PART 1

Classes will test drive their ROV and practice data collection.

RESOURCES: PART 1

Support guide for ROV test drives and field excursions

UNIT 3: Technical Guides, Tips and Tricks

DETAILS: PART 1

This guide includes links to the BlueROV2 technical manuals plus tips and troubleshooting for flying the ROV.

ACTIVITY OBJECTIVE: PART 2

Classes will execute their research projects and data analysis.

RESOURCES: PART 2

UNIT 3: Research Project 1 - Comparing Species Diversity in Two Areas

UNIT 3: Research Project 2 - Benthic Macroinvertebrate Diversity and Microplastic Abundance in Aquatic Sediment Samples

UNIT 3: Research Project 3 - Testing the Chemistry and Properties of Seawater

DETAILS: PART 2

For classes that are using guided, structured, and confirmation inquiry, these are the detailed example research projects that they may choose from. These project descriptions include background information, protocol for collecting data, and data analysis.

Technical Guides, Tips and Tricks

Operating your BlueROV2

The following will serve as guidelines, tips and tricks for operating your BlueROV2. If you are assembling your ROV and setting up the software for the first time, please refer to the BlueROV2 Assembly and Software Setup below.

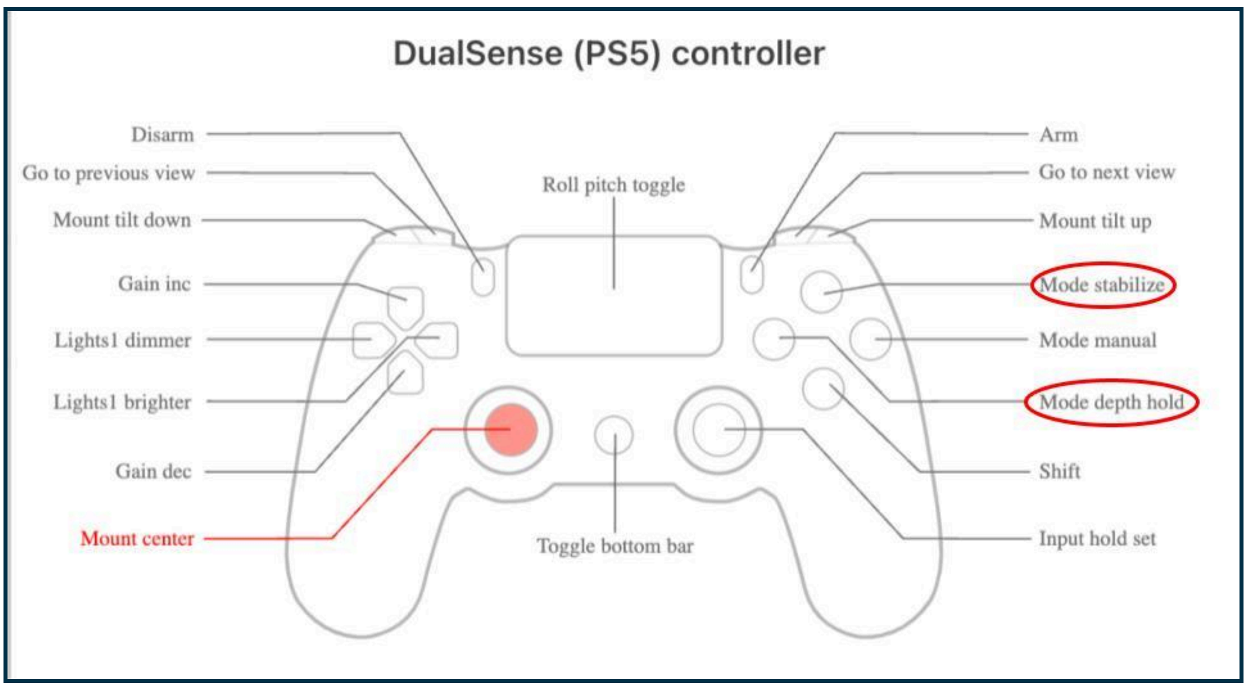
BlueROV2 Operations Guide

- BlueROV2 Operation Guide

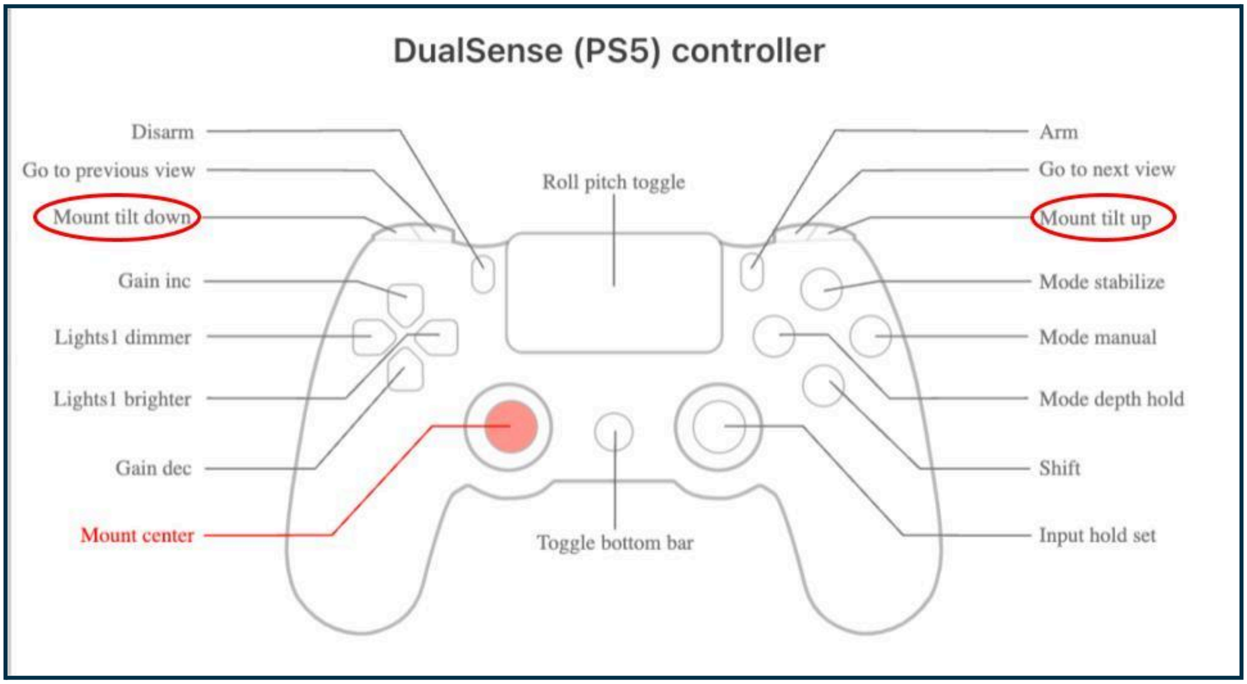
Practice flying the BlueROV2:

Practice flying your ROV in a pool before taking it into open water. Use all of the following tips while practicing:

- Start on low power (25%)
- Use "Stabilize" (Y) or "Depth Hold" (X) autopilot mode for improved control.



- Practice using all of the controls (gripper, camera angle, etc.)



- Practice staying off the bottom!
  - Use the visual display on the ground control station software to navigate above the bottom of the pool
- If you have installed a Ping2 Sonar, practice using the Ping-Viewer interface to see the depth of the ROV and to view the bottom
- If you have installed a sediment sample collector, practice retrieving objects and collecting samples
  - Try adjusting the ROV’s pitch angle downward while in Depth Hold mode (X)
  - Open and close the gripper (NOTE: you will configure which button controls the gripper when you set it up)
  - The virtual horizon widget displays the vehicle's pitch and roll as though on the gauge in a plane:

- Practice using sonar in the pool (if applicable)
    - Ping2 Sonar Altimeter and Echosounder, for elevation readings and bottom avoidance
    - Ping360 Scanning Imaging Sonar, for navigation, object location, and obstacle avoidance
- Practice using the compass to navigate
    - Establish headings for deployment and return home
    - The compass widget displays the vehicle's orientation as though looking at a compass in your hand:

- Follow your tether home
    - Tilt the camera upward until the tether is in view and then fly the ROV along in the direction of the tether

Tips and tricks for flying in the open water:

When it comes time to fly your ROV in the open water, use methods that you practiced in your pool and follow these tips:

- Stay off the bottom
- Follow your tether home
- Use Stable mode (Y) or Depth Hold mode (X)
- Use the compass to navigate

Collecting and uploading data:

- For video footage, don't forget to turn on the record button!
- [see Cockpit screenshot]
- Uploading video footage:
- [see Cockpit screenshot]
- Collecting temperature and depth data
- This automatically records in the vehicle log
- Retrieving temperature and depth data vehicle log

- To collect sediment samples, the pitch angle of the BlueROV2 or follow the Newton Gripper user guide to mount the gripper at a downward angle beneath the ROV

BlueROV2 Assembly and Software Setup:

- BlueROV2 Assembly
- BlueROV2 Software Setup
- BlueROV2 Cockpit Software (new!)

Optional additional builds

- Building housing and collecting data with additional sensors:
    - H20 Testing for the World: Low-Cost Submersible Water Test Kit
- Building housing and collecting water samples:
    - Coming soon!
- Instructions for adding and using a stereo camera for photogrammetry:
    - Coming soon!

Research Project 1

UNIT 3: Research Project 1- Comparing Biodiversity in Two Areas

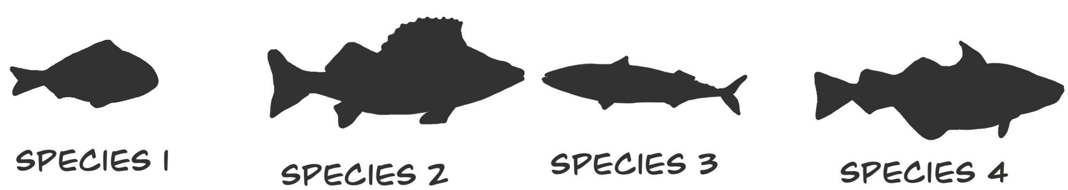
Background

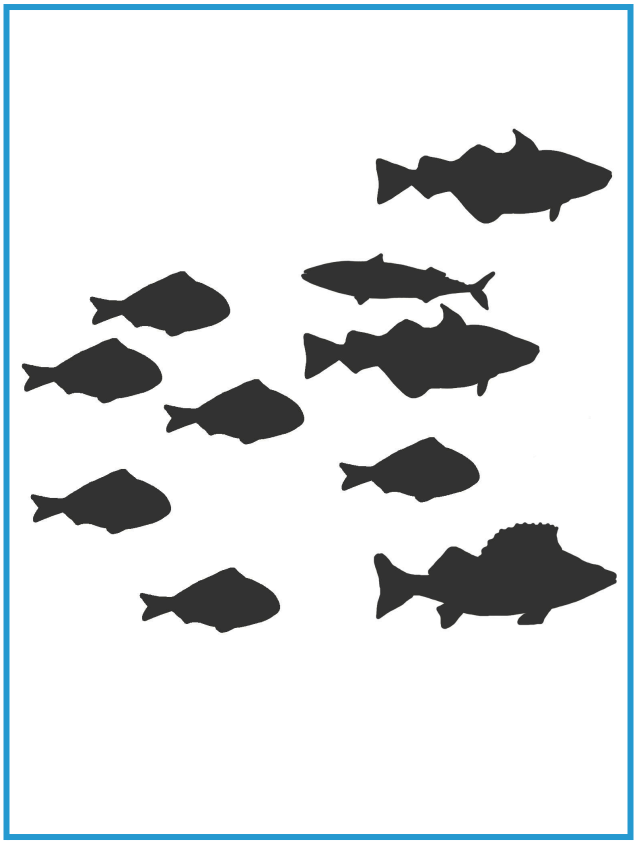
What is species or taxonomic diversity?

Species or taxonomic diversity is a metric that is used to understand the biodiversity of an ecosystem. It is one of the fundamental measurements in ecology. Ecologists research the interactions between living organisms and their environments. They may explore patterns of taxonomic diversity over space and time, and they may use observed patterns of taxonomic diversity in nature to test out ideas about ecological processes.

How is diversity researched and calculated?

In order to understand how taxonomic diversity is researched and calculated, it's important to understand a few key ecological concepts. **Abundance** is the total number of organisms in an area. **Species richness** is the number of different species in an area. **Species evenness** is a measurement of how common or rare a species is, relative to other species in an area. Species diversity can be calculated using the numbers and relative abundances of species within an area. Put another way, species diversity combines the species richness in an area with the evenness of their abundance. Richness and diversity in an ecosystem can also be calculated without identifying organisms down to the species level, as long as you are able to identify and group all of the organisms in an ecosystem into a consistent taxonomic group (e.g. phylum).





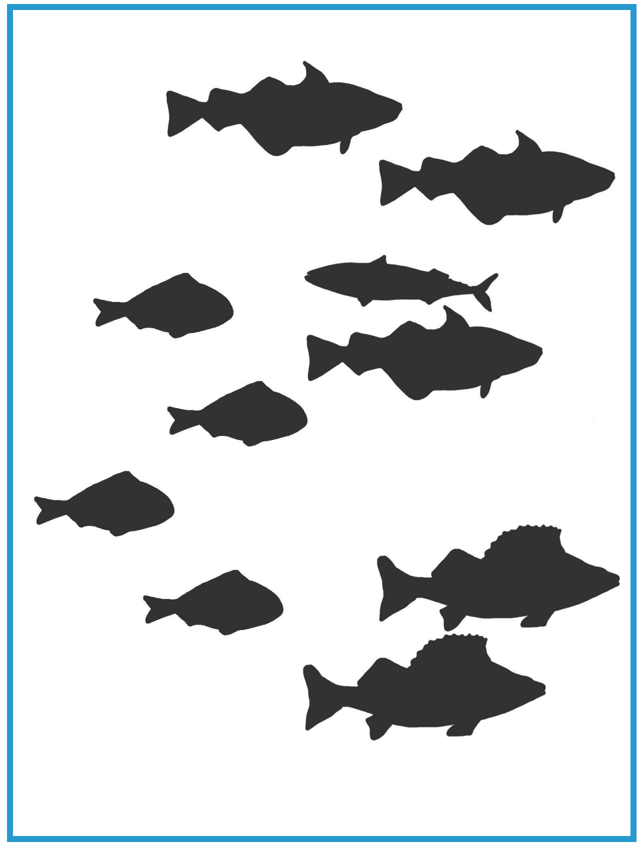


Figure 1. Abundance = 10, Richness = 4, Evenness = species 1 (60%), species 2 (10%), species 3 (10%), species 4 (20%)	*Figure 2. Abundance = 10, Richness = 4, Evenness = species 1 (40%), species 2 (20%), species 3 (10%), species 4 (30%)*

There are several formulas that ecologists commonly used to calculate diversity. The Simpson Diversity Index formula is:

$D=1-(\Sigma n(n-1)/N(N-1))$ where n is the total number of organisms of a particular species and N is the total number of organisms of all species.

The Simpson Diversity Index will produce a number between 0 and 1, where 1 represents infinite diversity and 0, no diversity.

The Shannon Diversity Index formula is:

$H = - \Sigma(Pi) \times Ln(Pi)$ where Pi is the proportion of individuals in each taxonomic group to the total number of individuals.

With the Shannon Diversity Index, higher H values reflect more diverse ecosystems, and values typically fall between the ranges of 1.5 and 3.5.

Abundance data can be collected through direct methods, or in situ data collection, such as conducting surveys of organisms along transect lines, or it can be collected with remote sensing methods such as satellite imagery. Traditional methods of taxonomic identification and classification are conducted by comparing the physical characteristics of observed organisms to those of known species that may be listed in a taxonomic resource. You may be familiar with this method if you've ever identified a plant or animal using a field guide or an application like iNaturalist.

What methods are used to conduct taxonomic diversity studies using an ROV?

A transect survey is a method that ecologists use to quantify organisms and to understand their distribution. There are many different types of transect surveys, and their use depends on the research subject and the ecosystem. A transect is simply a line in an area of study, which can be made by a tape measure, a string, or even designated by GPS points on a map. In ecology, researchers may count and identify organisms and substrates along a transect line in an area of study. Counts may be conducted at regular intervals or randomly along the transect. They may be conducted at specific points along the transect or within two-dimensional or three-dimensional bands around the transect. For the sake of this research project, we will focus on one transect method that is commonly used in fish surveys called a strip transect.

Strip transect

In the strip transect method, organisms are counted at regular intervals within a two dimensional band along the transect.

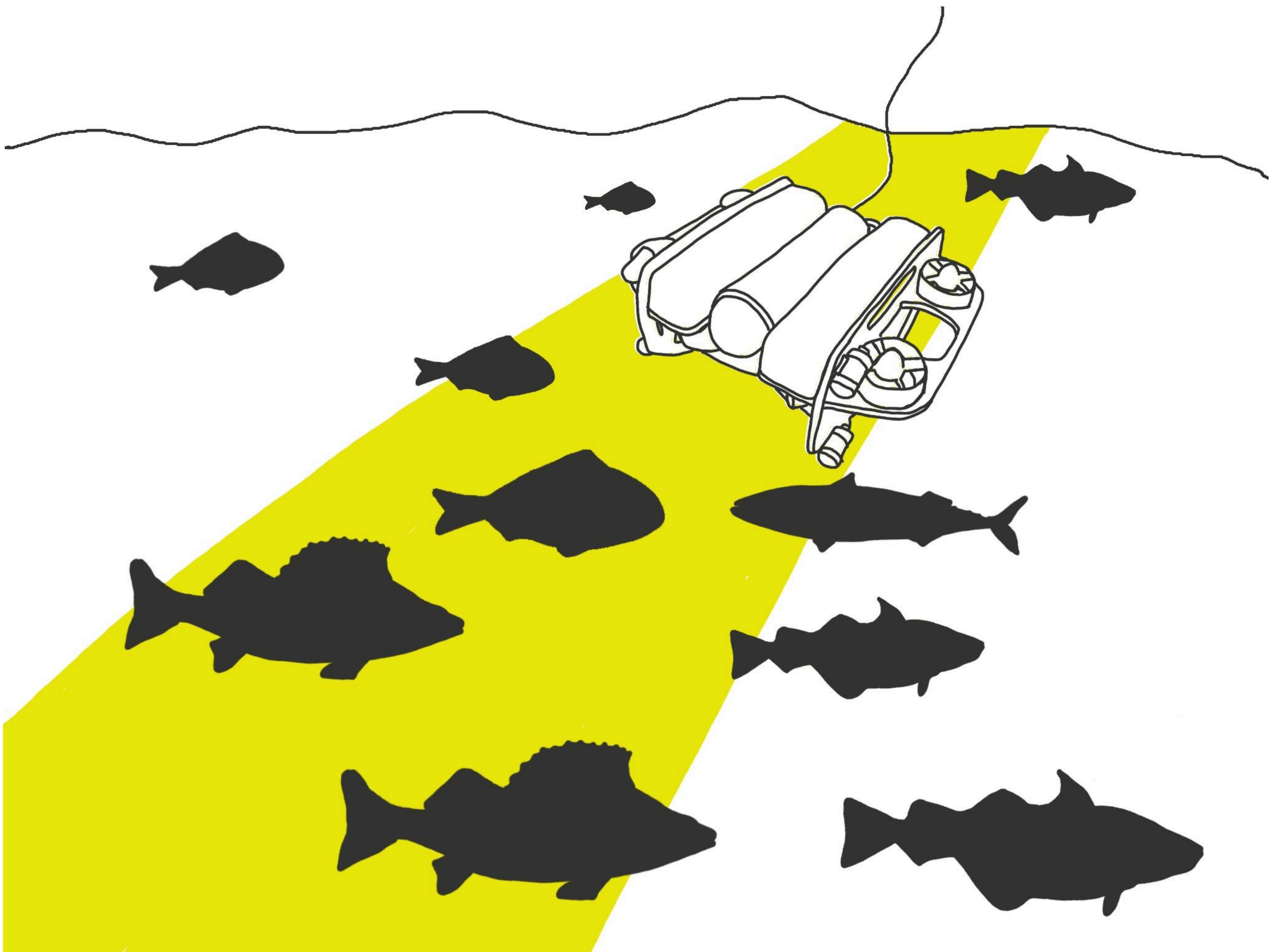


Figure 3. Flying the ROV in a straight path creates a strip transect. The fish and other animals that pass in front of the ROV will be recorded and later counted.

Project Overview

In this project, student researchers will investigate the diversity of a selected research area, using the camera on their ROV to capture underwater video footage for analysis.

Research Questions

What is the taxonomic diversity in our class's selected research area?

Optional additional research questions:

How does the diversity vary between two (or more) of our class's selected research areas?
How does the diversity vary at different times of the year at our class's selected research area?

Protocol and Instructions

1. Planning your research
   - Select a general research area where you will conduct your diversity survey.
     - NOTE: Your research area will be determined by where your class will have access to fly your ROV during your field trip.
   - Conduct some exploration of the research area before your field trip including:
     - Reviewing maps and satellite imagery (e.g. GoogleEarth)
     - Talking to local experts, including marine/aquatic resource managers, scuba divers, and kayak guide companies, about areas that will provide ideal habitat and survey conditions
     - If possible, conducting exploratory ROV flights within your selected area before conducting your surveys to familiarize yourself with the substrate (e.g. rocky or sandy) and any potential obstacles (e.g. dense kelp forests)
   - Designate survey area(s) within your research area
     - Define at least one survey area where you will fly your ROV along transects
     - Each survey area should have similar physical characteristics (e.g. kelp forest, rocky reef, sandy bottom)
   - Map out your transects within the survey area(s)
     - Include at least three strip transects within each survey area.
     - Identify and mark on a map approximately where your strip transects will begin and end and note the GPS coordinates for the start and finish
       - NOTE: These coordinates will just serve as guidelines for your transects, keeping in mind that you may need to modify your plan and conduct your surveys in a different area if you encounter obstacles during your ROV flight.
     - NOTE: You will be flying your ROV along the transects at an average speed of 0.5 meters per second, so you may determine the maximum length of your transects based on the total amount of flight time you will have. For example, if you will have 1 hour to fly your ROV, you could conduct three 600-meter transects in one area, you could conduct three 300-meter transects in two different areas, three 150-meter transects in three different areas, etc.
2. Conducting your research:
   - Conduct your surveys following these strip transect instructions:
     - Get as close as possible to your GPS start-point using a handheld GPS device or a mapping app
     - Turn on the ROV camera, temperature, and depth sensors before launching the ROV
     - Fly the ROV in the direction of your GPS end-point in as straight a line as possible, maintaining a speed close to 0.5 meters per second (try to keep the speed between 0.25m/s and 0.75m/s). Use these tips:
       - Lock in the inputs to control the forward thrust level
       - Set the ROV in stable mode (Y)

- Repeat these steps for each transect in each of your survey areas.
- Note the time and actual GPS points when/where you start and end each transect

Data Analysis

Reviewing and Labeling the Data

Instructions for getting the video footage off of the device

You will be analyzing data (counting and identifying species) at regular intervals along your transect using the footage. There are many ways to mark intervals in your video footage, and the following is one suggestion for how to do this.

- Review the video footage and label the footage from each transect using a clear naming convention (e.g. survey area 1_transect 1 or SA1_T1). Repeat this for each transect at each survey area.
- Note the start time and end time of each transect in the video clips (not counting the time it takes to get the ROV in position to start the transect or to return to the surface). Take the total duration of the transect clip and divide it by 10. This will give you the time intervals for analyzing your video footage.
    - Example: The video clip for transect 1 at survey area 1 was 15 minutes long. 15 minutes /10 intervals = 1.5 minutes / interval. The video clip for transect 2 at survey area 1 was 20 minutes long. 20 minute/10 intervals = 2 minutes / interval

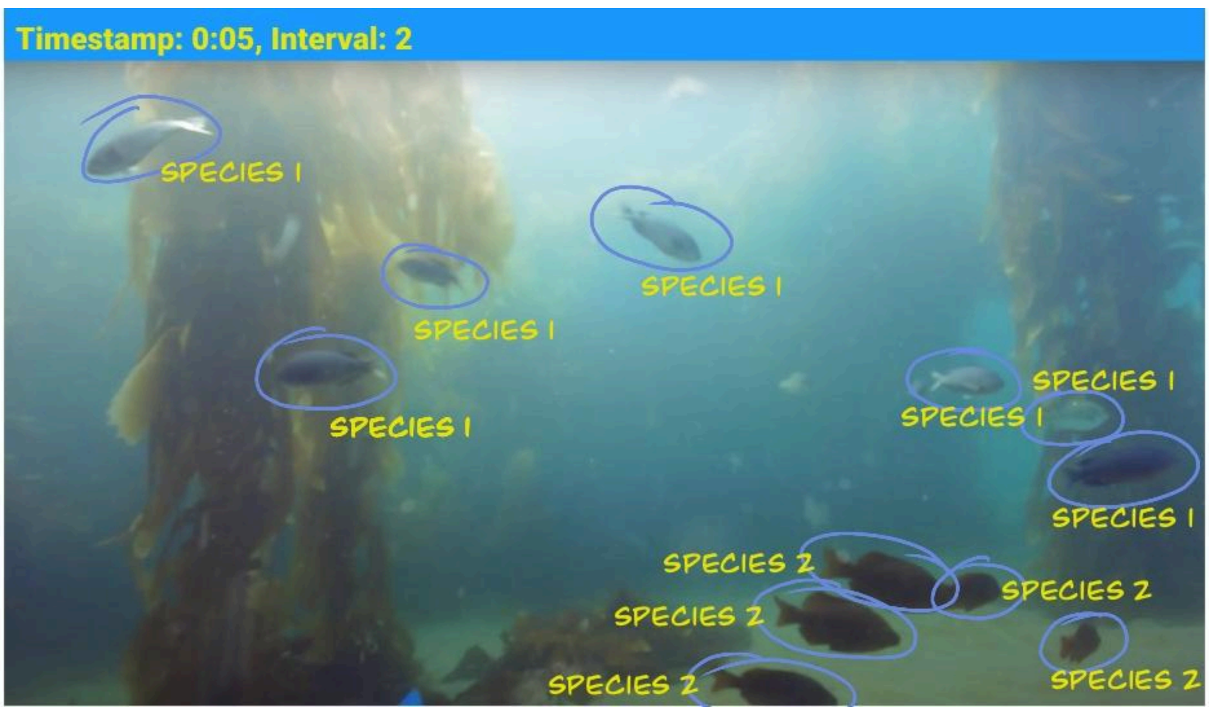
Transect 1			Transect 2	
Interval	Minute marker (mm:ss)		Interval	Minute marker (mm:ss)
1	01:30		1	02:00
2	03:00		2	04:00
3	04:30		3	06:00
4	06:00		4	08:00
5	07:30		5	10:00
6	09:00		6	12:00
7	08:30		7	14:00
8	10:00		8	16:00
9	12:30		9	18:00

10	15:00		10	20:00

- Play the video clips again with the player in full-screen. This time, pause the video at these regular intervals and take a screenshot of the video player. So, you will end up with 10 screenshots for each transect.
- Make sure to label each screenshot using a clear naming convention, (e.g. survey area 1_transect 1_interval1 or SA1_T1_I1). Repeat this for each transect at each survey area.

Calculating Species Diversity

- Identify the fish species at each interval using CA Department of Fish and Wildlife's [Species identification resource: CA Marine Species Portal]() or a similar resource. You may also decide to identify other organisms along your transect (e.g. seaweeds, invertebrates) Keep in mind, if you cannot confidently identify the organisms to the species level, that is fine. You may identify them down to a different taxonomic level (e.g. genus) or you could create your own categories (e.g. fish species 1, fish species 2). The important thing is to categorize organisms consistently throughout your analysis.
- Record the abundance of the species or taxonomic groups at each interval



- Calculate the diversity using the Simpson Diversity Index (D) or the Shannon Diversity Index (H)
- For or the abundance of each species, use an average of the abundance across all 10 intervals
    - Species abundance (average) = Σ(species abundance per interval)/10
- This spreadsheet has examples of both diversity indexes using sample data. You can copy these spreadsheets and use the formulas for your own calculations:

Diversity Index Examples

Glossary of terms and phrases

- **Biodiversity** - The variety of life in a particular habitat or ecosystem.
- **Species or taxonomic diversity** - Refers to the variety of different species and their classifications within an ecosystem.
- **Ecology** - The branch of biology that studies the interactions between organisms and their environment.
- **Abundance** - The total number of organisms present in a particular area.
- **Species richness** - The number of different species present in a particular area.
- **Species evenness** - A measure of how evenly individuals are distributed among the different species in an area.
- **Taxonomic group** - A group of organisms classified together based on shared characteristics (e.g., phylum, class).
- **Simpson Diversity Index** - A mathematical formula used to measure biodiversity within a community.
- **Shannon Diversity Index** - Another mathematical formula used to quantify the diversity in a community.
- **In situ data collection** - Research conducted in the natural environment rather than in a laboratory.
- **Transect survey** - A method for studying the distribution of organisms by counting them along a predetermined line.
- **Strip transect** - A specific type of transect survey where organisms are counted within a defined width along the line.
- **ROV (Remotely Operated Vehicle)** - An unmanned vehicle operated from a distance, often used for underwater exploration.
- **Substrate** - The surface or material on or from which an organism lives, grows, or obtains its nourishment.
- **GPS (Global Positioning System)** - A satellite-based navigation system used to determine precise location on Earth.

NGSS Connections

Performance Expectations

HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Science and Engineering Practices

Asking Questions and Defining Problems
Using Mathematics and Computational Thinking.
Planning and Carrying Out Investigations
Developing & Using Models

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Crosscutting Concepts

Scale, Proportion, and Quantity

Ocean Literacy Principles Connections

Ocean Literacy Principle #5: The ocean supports a great diversity of life and ecosystems.
Ocean Literacy Principle #7: The ocean is largely unexplored.

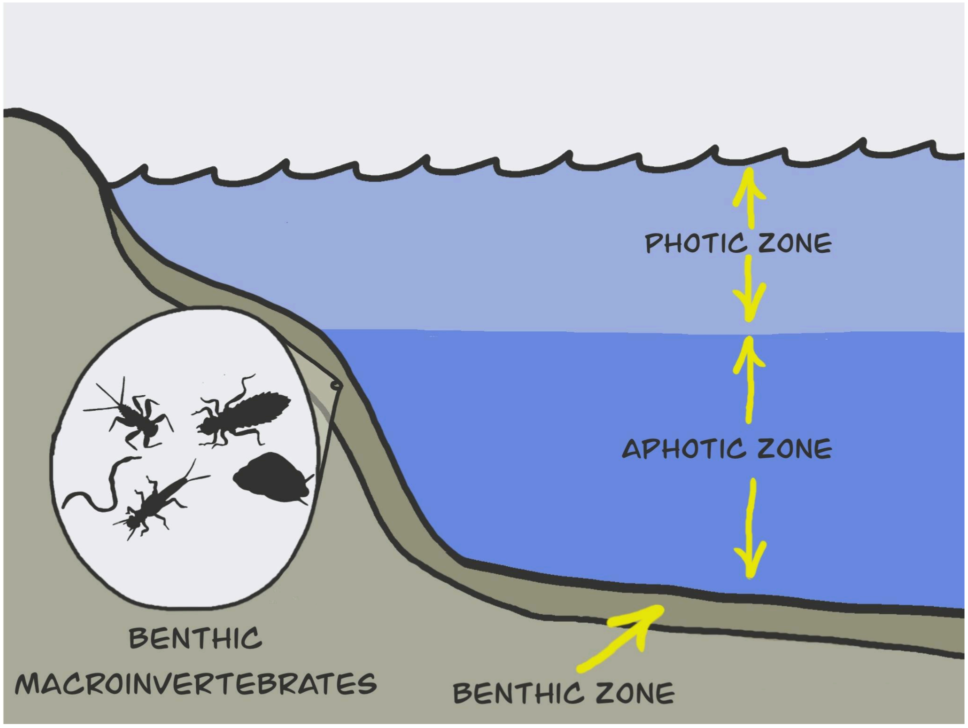
Research Project 2

UNIT 3: Research Project 2 - Benthic Macroinvertebrate Diversity and Microplastic Abundance in Aquatic Sediment Samples

Background

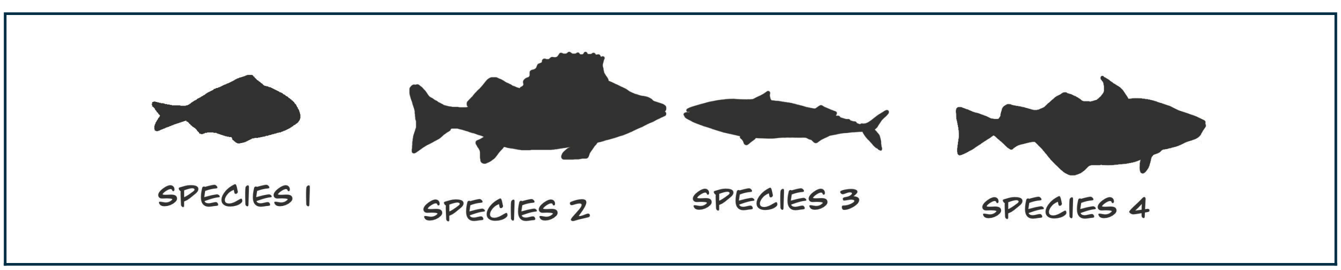
What are benthic macroinvertebrates?

Benthic invertebrates are spineless animals that are found living in the lowest ecological layer of a body of water, the benthic zone. Benthic invertebrates may be found burrowed in sediments or attached to substrate in the benthic zone. The term macroinvertebrates refers to those that can be seen without a microscope. In general, diversity in benthic invertebrate communities is an indication of aquatic ecosystem health.



How is diversity researched and calculated?

In order to understand how taxonomic diversity is researched and calculated, it's important to understand a few key ecological concepts. **Abundance** is the total number of organisms in an area. **Species richness** is the number of different species in an area. **Species evenness** is a measurement of how common or rare a species is, relative to other species in an area. Species diversity can be calculated using the numbers and relative abundances of species within an area. Put another way, species diversity combines the species richness in an area with the evenness of their abundance. Richness and diversity in an ecosystem can also be calculated without identifying organisms down to the species level, as long as you are able to identify and group all of the organisms in an ecosystem into a consistent taxonomic group (e.g. phylum).



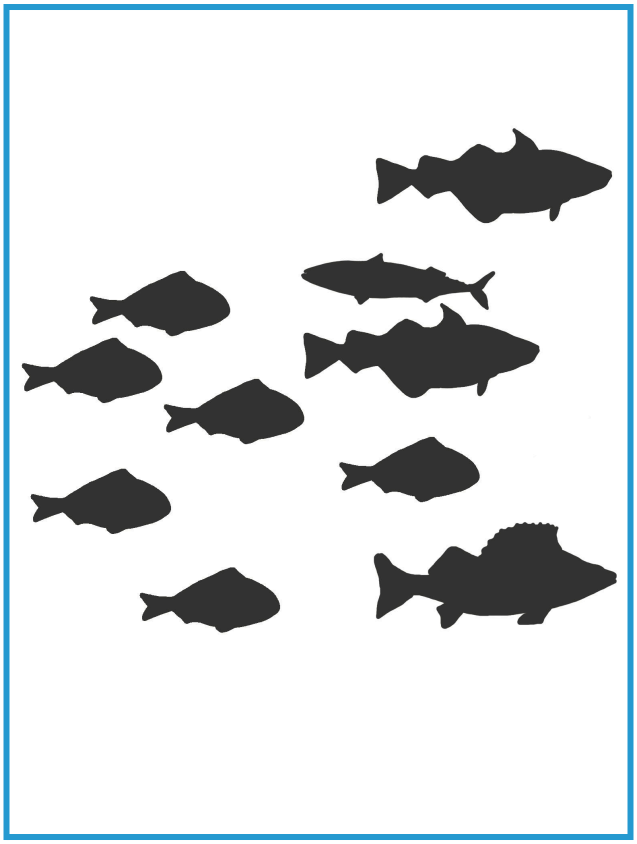


Figure 1. Abundance = 10, Richness = 4, Evenness = species 1 (60%), species 2 (10%), species 3 (10%), species 4 (20%)

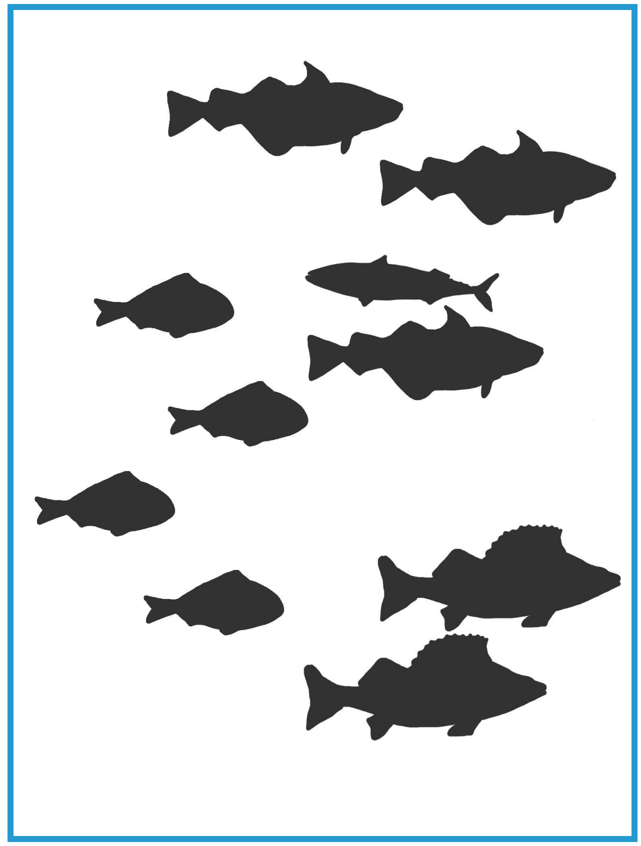


Figure 2. Abundance = 10, Richness = 4, Evenness = species 1 (40%), species 2 (20%), species 3 (10%), species 4 (30%)

There are several formulas that ecologists commonly use to calculate diversity. The Simpson Diversity Index formula is:

$D=1-(\Sigma n(n-1)/N(N-1))$ where n is the total number of organisms of a particular species and N is the total number of organisms of all species.

The Simpson Diversity Index will produce a number between 0 and 1, where 1 represents infinite diversity and 0, no diversity.

The Shannon Diversity Index formula is:

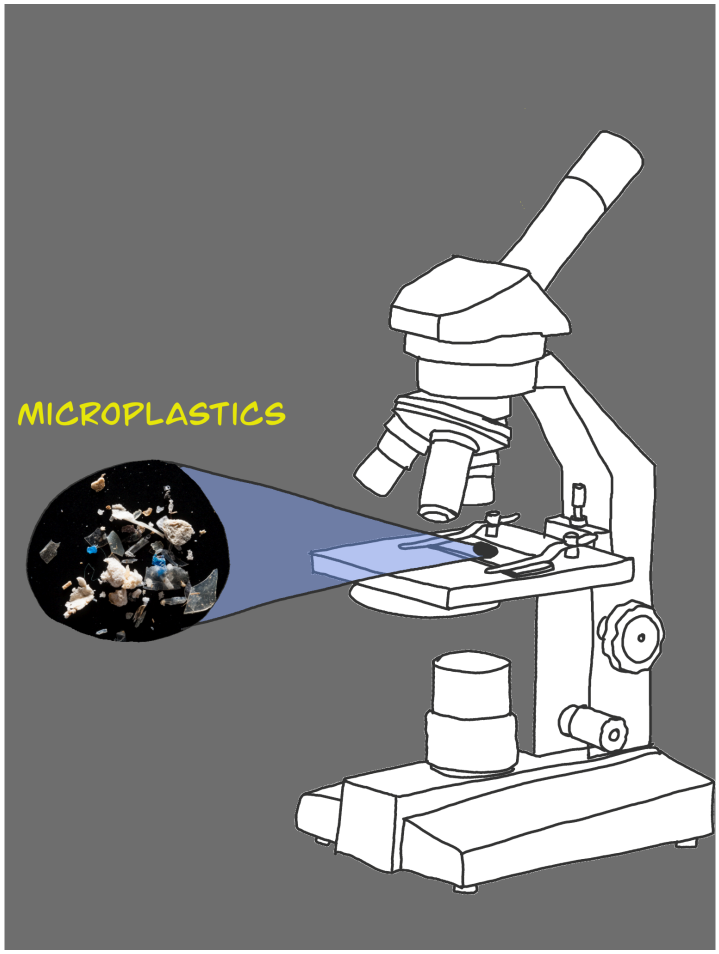
$H = - \Sigma(Pi) \times Ln(Pi)$ where Pi is the proportion of individuals in each taxonomic group to the total number of individuals.

With the Shannon Diversity Index, higher H values reflect more diverse ecosystems, and values typically fall between the ranges of 1.5 and 3.5.

Abundance data can be collected through direct methods, or in situ data collection, such as conducting surveys of organisms along transect lines, or it can be collected with remote sensing methods such as satellite imagery. Traditional methods of taxonomic identification and classification are conducted by comparing the physical characteristics of observed organisms to those of known species that may be listed in a taxonomic resource. You may be familiar with this method if you've ever identified a plant or animal using a field guide or an application like iNaturalist.

What are microplastics?

Microplastics are small pieces of plastic, less than five millimeters in length. Microplastics may be pieces of broken down plastic products, microbeads that are manufactured and used in cosmetics, nurdles that are granules of plastic used to manufacture plastic products, or plastic fibers from synthetic clothing. Microplastics are found in every ecosystem on earth and they have been found in the digestive tract of many animals, as they can accumulate through feeding. The effects of microplastics on animals and ecosystem health is not fully understood and it is an important field of active research. Some invertebrates show decreased feeding and fertility when exposed to microplastics. Importantly microplastics can accumulate in the digestive tracts of animals that directly feed on aquatic invertebrates or eat other animals that feed on invertebrates. Fish, mammals, and birds can experience negative health effects such as altered feeding behavior and metabolism due to microplastic accumulation in their guts and tissues. Humans can also accumulate microplastics as they eat fish and other aquatic animals. The health effect of microplastics on humans is also not fully understood.



microplastics photo credit: Chesapeake Bay Program

Project Overview

Student researchers will collect benthic sediment samples using the sediment grabber on their ROV and they will analyze those samples for abundance and diversity of benthic invertebrates and the presence and quantity of microplastics.

Research Questions

What is the diversity of benthic macroinvertebrates in our class's research area? Are microplastics present in the sediment samples collected at our class's research area, and if so, what is the quantity of microplastics? Was there a relationship between the presence and quantity of microplastics and the diversity of benthic macroinvertebrates in our class's research area?

Protocol and Instructions

Collecting samples

Using the sediment grabber on your ROV, collect and retrieve sediment samples three times within your class's research area. The sediment grabber collects up to 300 ml per grab, so you will collect approximately 900 ml of sediment. You may compare multiple research areas, collecting three sediment samples in each area.

Macroinvertebrates: storage and processing

Transfer all three samples into a covered storage container (e.g. 100 ml wide mouth Nalgene bottle). Store the sample in a cooler with ice until you are ready for processing. Process the sample by transferring it to a 1 mm mesh sieve, placing a collection container beneath the sieve, and rinsing the sample with water collected from your research area. Particles and macroinvertebrates that are larger than 1 mm will be retained on the sieve. Collect the particles that pass through the sieve, as this will be analyzed later for microplastics. Transfer the macroinvertebrates from the sieve into a container with 70% ethanol solution for preservation. It is okay if some sediment particles also get transferred into the solution, these will be sorted out in the next step.

Macroinvertebrates: sorting and identification

The first step will be to conduct a rough sort of the sample. Separate the macroinvertebrates from sediment and other debris that got caught in the sieve. Add the sediment and debris to the sample that was retained for microplastic analysis. Sort the macroinvertebrates into taxonomic groups at least by phylum (annelids, echinoderms, molluscs, etc.). Your class may decide to sort the specimens to a lower taxonomic level (e.g. genus), but keep in mind that it can be challenging to get down to species level identification with aquatic invertebrates. You can conduct the diversity analysis in the next step using any taxonomic level, as long as you are consistent.

Resources for macroinvertebrate identification:

- *The Light and Smith Manual Intertidal Invertebrates from Central California to Oregon: Even though this is a guide to intertidal invertebrates, it is a good place to start for benthic invertebrate identification*
- *iNaturalist: upload a photo and the location of your sample to crowdsource identification*
- *Southern California Association of Marine Invertebrate Taxonomists (SCAMIT): take a picture and email it to the to ask for identification Contact information can be found here: https://www.scamit.org/contact*

Microplastics: processing and measuring

Prepare 700 ml of $ZnCl_2$ solution at 1.5 g cm^3 concentration. After allowing the sediment and particles that were filtered through the 1 mm sieve and separated from the macroinvertebrates to settle in their container, skim any remaining water from the top using a cup. Take care not to stir up the sediment; leave some water in the container if necessary. Transfer the remaining sediment into a 2000 ml beaker. Add 700 mL of $ZnCl_2$ solution to the sediment. Thoroughly stir the sediment using a stir stick or magnetic stirring bar and plate. Ensure that all clumps are broken up and that air bubbles escape. Allow the mixture to settle again. As the sediment settles back to the bottom of the solution, plastic materials will float to the top. Collect the plastic materials from the top of the solution using a spoon. Place the collected material into a petri dish (or multiple dishes) and cover immediately to prevent any contamination from fibers or dust that might be in the air. Examine your samples under a microscope and look for particles with a synthetic appearance (i.e. lacking cell structure, unnatural appearance in shape, color or texture).

Data Analysis

Calculating macroinvertebrate diversity:

Calculate the macroinvertebrate diversity in your sample using the Simpson Diversity Index (D) or the Shannon Diversity Index (H).

This spreadsheet has examples of both diversity indexes using sample data. You can copy these spreadsheets and use the formulas for your own calculations:

Diversity Index Examples

Calculating microplastic abundance:

Quantify the microplastics in each sample by counting the individual particles. Optionally, you can categorize the microplastics by shape (fragment, fiber or nurdle), color and size of each particle, for a more detailed description of your sample. As an alternative to counting the individual microplastic particles, if your class has access to a drying oven, you may quantify the microplastics by taking their dry weight. Note: prevent contamination from microplastics that may be in your classroom environment by washing and drying all equipment and wiping them down with a microfiber cloth, wearing laboratory coats when handling samples and keeping samples covered.

Glossary of terms and phrases

- **Benthic Zone**: The ecological region at the lowest level of a body of water, including the sediment surface and some sub-surface layers.
- **Sediment**: Material that settles to the bottom of a liquid, often composed of organic matter, minerals, and rock fragments.
- **Substrate**: The surface on or from which an organism lives and obtains nourishment.
- **Microbeads**: Tiny plastic beads, often smaller than 1 millimeter, used in personal care products like exfoliants and cleansers. They are a significant source of microplastic pollution.

- **Nurdles**: Small plastic pellets that serve as raw material for manufacturing plastic products. They are a source of microplastic pollution when they are accidentally released into the environment.
- **Synthetic Fibers**: Man-made fibers, often derived from petroleum, used in textiles and clothing. They are a common type of microplastic pollution, released during washing and wear.
- **Sediment Grabber**: A device used to collect samples of sediment from the bottom of a body of water.
- **Ethanol Solution**: A mixture of ethanol (alcohol) and water, commonly used for preserving biological specimens.
- **Sieve**: A mesh or perforated device used to separate particles of different sizes.
- **Phylum**: A major taxonomic group ranking above class and below kingdom. Organisms within the same phylum share a common body plan and evolutionary history.
- **Annelids**: Segmented worms, including earthworms, leeches, and marine worms.
- **Echinoderms**: Marine animals with radial symmetry, including starfish, sea urchins, and sea cucumbers.
- **Molluscs**: A diverse group of invertebrates with a soft body, often enclosed in a shell. They include snails, clams, oysters, and squid.
- **Intertidal Invertebrates**: Animals without backbones that live in the intertidal zone, the area between high and low tide marks.
- **Southern California Association of Marine Invertebrate Taxonomists (SCAMIT)**: An organization that promotes the study of marine invertebrates in Southern California.
- **ZnCl2 Solution**: A solution of zinc chloride, a chemical compound used to separate microplastics from sediment samples based on density.
- **Magnetic Stirring Bar**: A small, magnetic bar placed in a beaker or flask and used with a magnetic stirrer to mix liquids.
- **Petri Dish**: A shallow, cylindrical dish with a lid, commonly used in laboratories for culturing microorganisms or examining small specimens.
- **Microscope**: An instrument that uses lenses to magnify small objects, allowing for detailed observation.
- **Drying Oven**: An oven used to dry materials at a controlled temperature.
- **Dry Weight**: The weight of a sample after all the moisture has been removed, often used to quantify the solid component of a sample.
- **Microfiber Cloth**: A cloth made from very fine synthetic fibers, often used for cleaning delicate surfaces.

NGSS Connections

Performance Expectations

HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Science and Engineering Practices

Asking Questions and Defining Problems
Using Mathematics and Computational Thinking.
Planning and Carrying Out Investigations

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience
LS4.D: Biodiversity and Humans

Crosscutting Concepts

Scale, Proportion, and Quantity
Stability and Change

Ocean Literacy Principles Connections

Ocean Literacy Principle #5: The ocean supports a great diversity of life and ecosystems.
Ocean Literacy Principle #6: The ocean and humans are inextricably interconnected.
Ocean Literacy Principle #7: The ocean is largely unexplored.

Research Project 3

UNIT 3: Research Project 3 - Testing the Chemistry and Properties of Seawater

Background

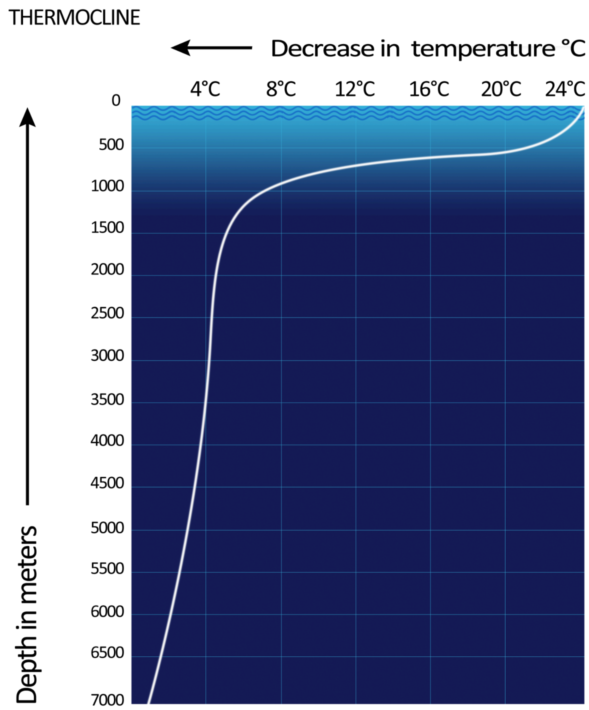
What is marine chemistry?

Marine chemistry is the study of the chemical properties and composition of seawater and marine environments. Seawater chemistry is influenced by geological processes, like plate tectonics and seafloor spreading, biological processes, like carbon and nutrient cycling, and physical processes, like ocean currents.

Marine chemistry research can be used to understand and model how the physical and geological processes in the ocean affect seawater properties, the effects of pollution in marine environments, and the impacts of chemical processes on marine organisms.
What are some important physical properties of seawater and how are they measured?
Depth is an important metric to record when collecting data in a marine environment because many environmental factors change with depth, including temperature, conductivity, and the availability of light and nutrients. Many of these factors are interdependent and they impact the marine life that are found at different depths.

The depth of the ROV is calculated as the water pressure exerted on the depth/pressure sensor changes. Pressure increases with depth. For example, at the surface of the ocean the air that surrounds us exerts 1.013529 Bar of pressure. For every 10.06 meters (33 feet) that the ROV descends in the ocean, the pressure increases by 1.01325 Bar (1 atmosphere). Pressure is commonly measured with the units Bar or Standard atmosphere.

Temperature, measured in degrees celsius (C), is another important metric to record when collecting data in the marine environment. Temperature is highly variable in the ocean, but there are certain observable patterns. Sea surface temperatures range from about -2 to 30 degrees C, with the warmest water found nearest the equator and the coldest water closest to the poles.



Praveenron, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

Temperature changes with depth in seawater, forming ocean layers. The uppermost layer of the ocean is known as the epipelagic zone or the "sunlight zone". As the name suggests, the surface water here is warmed by sunlight and it is mixed by wind and wave action. The bottom of the epipelagic zone is the beginning of the **thermocline**. This is the transition layer between the warm mixed layer and the cooler water below. The thermocline is indicated when temperature measurements start to drop rapidly as a function of depth. The depth of the thermocline can vary by season and from year to year. The thermocline indicates the beginning of the mesopelagic zone, also known as the "twilight zone" because some sunlight can still reach it. Beneath the mesopelagic zone is the bathypelagic zone, the coldest, darkest, and deepest layer of the ocean.

What are some important chemical properties of seawater and how are they measured?

Electrical conductivity is a measurement of how well a solution conducts electricity. Conductivity is measured in siemens per meter (S/m). Changes in seawater conductivity can affect communication and navigation in the ocean.

Conductivity is directly related to salinity, or the concentration of salts in seawater. By measuring the conductivity of seawater, the salinity can be derived from the temperature and pressure of the water. Temperature and salinity of the seawater can be used to calculate the density of the water, and depth can be determined from the density.

Ocean scientists often measure conductivity and temperature at different depths using a package of sensors called a CTD, which stands for conductivity, temperature and depth. This provides basic oceanographic measurements that are used to describe the water column.

pH is the measurement of the concentration of hydrogen ions in a solution, which tells us how acidic or alkaline a solution is. pH is measured on a logarithmic scale from 0-14. A pH of 7 is neutral (neither acidic nor alkaline), a pH higher than 7 is alkaline, and a pH lower than 7 is acidic.

The average pH of ocean water is 8.1. Seawater's pH has a direct effect on ocean life. For example, shell-forming animals need carbonate ions to grow their calcium carbonate shells. Carbonate ions react with free hydrogen ions in seawater. So, when there are more hydrogen ions present in seawater (lower pH) there is less material available for these animals to build shells.

Dissolved oxygen is the amount of oxygen that is present in water. Oxygen is introduced into water by aquatic plants through photosynthesis and from the atmosphere. Oxygen is used in respiration by marine animals. Dissolved oxygen is usually measured in mg/L or % saturation (DO%).

Dissolved oxygen levels in the ocean vary depending on the temperature and salinity of the water. The colder the water, the more dissolved oxygen it can hold. The higher the water's salinity, which is measured as electrical conductivity, the less dissolved oxygen it can hold. Oxygen levels will also go through natural seasonal variation. Hypoxic (or low oxygen) conditions can be caused by stratification in the water column and nutrient runoff (or eutrophication).

Turbidity is the measurement of cloudiness in water due to suspended particles. Turbidity sensors are used to detect how much a light beam scatters in water. Turbidity is generally reported in Nephelometric Turbidity Units (NTU).

Ocean turbidity in seawater can be caused by sediment, plankton, or pollution. In the ocean, turbidity has a direct effect on the amount of sunlight that is available to marine organisms. Suspended particles in the water can also clog animals' gills and impact suspension feeders.

Oxidation Reduction Potential is a measurement of the net balance of redox reactions in a solution. In general, samples with a net balance of oxidized substances, e.g. dissolved oxygen and nitrate, will have a positive ORP, and sample environments with a net balance of reduced substances, e.g. organic carbon and ammonia, will have a negative ORP.

In marine environments, ORP can indicate conditions that are, oxic (dissolved oxygen is available for respiration), anoxic (dissolved oxygen is not available, but nitrate (NO3) and nitrite

(NO2) are available for respiration), and anaerobic (neither dissolved oxygen nor nitrate are available and respiration is not supported).

Additional seawater testing procedures can be used to analyze water samples for the presence and concentration of pollutants such as oils, pesticides, and plastics, and bacteria such as fecal coliforms and enterococci. Some seawater tests (e.g. nitrates) may be performed by your class using test kits and others (e.g. bacterial analysis) may be performed by a professional laboratory. Seawater testing can provide important water quality information used to:

- monitor the health of marine ecosystems, which can be indicated by changing levels of nutrients and pollution,
- monitor the impacts of human activities on marine ecosystems,
- determine sources of pollutants,
- and help inform management decisions like beach closures.

Project Overview

Student researchers will test water quality in marine environments by collecting in situ data using sensors on their ROV and, optionally, by collecting water samples for analysis back in the classroom. This project can be performed using the sensors that are built into the BlueROV2 (temperature and depth), with additional sensors (electrical Conductivity, pH, dissolved oxygen, turbidity, oxidation reduction potential) and/or with an additional water sample collection kit. The additional sensor kit and water sample collection kit will need to be purchased, built, and added to the ROV by your class or by a partnering robotics club or class.

Research Questions

What are the physical and chemical properties of the seawater in our class's selected research area (or areas) and how do these properties change with depth?

Protocol and Instructions

Using built in sensors:

Create a temperature depth profile of your research area by flying your ROV vertically from the surface down and back up again while recording temperature and depth using the ROV's built in sensors. Replicate the temperature depth profile at least three times in your research area. Your class also has the option to compare multiple research areas, conducting at least three temperature depth profiles per area.

Using additional sensors:

Your class will have the option to select two or more additional parameters that you would like to test. This will require building a sensor housing kit, which will be added to your ROV. You will be able to collect data with these additional sensors as you create your temperature and depth profiles.

Using water sample collection kit:

Your class will have the option to build and add a water sample collection kit to your ROV. Using this kit, you will be able to collect at least 4 water samples per dive. These samples may be collected at different depths as you create your temperature depth profiles. Samples may then be analyzed using chemical testing kits in your classroom or they may be sent to a laboratory for analysis.

Data Analysis

There are a number of methods for displaying and analyzing seawater property data, depending on which data you collect. For example, to create a temperature depth profile graph, you will need to input your raw data and plot your data using a spreadsheet (e.g. Google Sheets) or a graphing software (e.g. R). Here is a temperature depth profile graph using sample data:

Temperature Depth Profile Sample

In this sample data set, the depth measurements are negative numbers. This generates a graph that can be read logically, with the shallowest depth at the top and deepest at the bottom of the Y-axis.

Glossary of terms and phrases

- **Marine Chemistry** : The study of the chemical composition, properties, and reactions of seawater.
- **Plate Tectonics**: The theory that Earth's outer layer is made up of plates that move and interact, causing earthquakes, volcanoes, and mountain formation.
- **Seafloor Spreading**: The process by which new oceanic crust is formed at mid-ocean ridges as magma rises from the mantle and solidifies.
- **Carbon and Nutrient Cycling**: The movement and transformation of carbon and essential nutrients (e.g., nitrogen, phosphorus) through biological and physical processes in the ocean.
- **Ocean Currents**: Continuous, directed movements of seawater driven by wind, temperature, salinity differences, and Earth's rotation.
- **Pollution**: The introduction of harmful substances or contaminants into the environment, including the ocean.
- **Bathymetry**: The measurement of the depth of water in oceans, seas, or lakes.
- **Water Pressure**: The force exerted by water on a surface due to its weight. Water pressure increases with depth.
- **Depth/Pressure Sensor**: A device that measures the pressure exerted by water, which can be used to determine depth.

- **Bar**: A unit of pressure equal to 100,000 pascals, approximately equal to the average atmospheric pressure at sea level.
- **Standard Atmosphere**: A unit of pressure equal to 101,325 pascals, defined as the average atmospheric pressure at sea level.
- **Equator**: The imaginary line that circles Earth at 0 degrees latitude, dividing the planet into the Northern and Southern Hemispheres.
- **Poles**: The points on Earth's surface where the axis of rotation intersects.
- **Epipelagic Zone (Sunlight Zone)**: The uppermost layer of the ocean, where sunlight penetrates and supports photosynthesis.
- **Thermocline**: The transition layer between the warm, mixed surface waters and the colder, deeper waters of the ocean, characterized by a rapid decrease in temperature with depth.
- **Mesopelagic Zone (Twilight Zone)**: The layer of the ocean below the epipelagic zone, where some sunlight reaches but not enough for photosynthesis.
- **Bathypelagic Zone**: The deepest layer of the ocean, characterized by darkness, cold temperatures, and high pressure.
- **Salinity**: The concentration of dissolved salts in seawater.
- **Density**: The mass per unit volume of a substance. Seawater density is influenced by temperature and salinity.
- **Water Column**: The vertical profile of water from the surface to the bottom of a body of water.
- **CTD (Conductivity, Temperature, Depth)**: A package of sensors used to measure conductivity, temperature, and depth in the ocean.
- **Alkaline**: Having a pH greater than 7, also referred to as basic.
- **Acidic**: Having a pH less than 7.
- **Carbonate Ions**: Ions formed from carbonic acid, important for the formation of calcium carbonate shells and skeletons in marine organisms.
- **Calcium Carbonate**: A chemical compound commonly found in the shells and skeletons of marine organisms.
- **Photosynthesis**: The process by which plants and some other organisms use sunlight to synthesize foods with glucose from carbon dioxide and water.
- **Respiration**: The process by which organisms break down glucose to release energy.
- **Seasonal Variation**: Changes in environmental conditions or biological processes that occur over the course of a year.
- **Hypoxic Conditions**: Low oxygen conditions in a body of water, often harmful to aquatic life.
- **Stratification**: The layering of water in a body of water due to differences in temperature or salinity.
- **Nutrient Runoff (Eutrophication)**: The excessive flow of nutrients (e.g., nitrogen, phosphorus) from land into water bodies, often leading to algal blooms and oxygen depletion.

- **Plankton**: Small organisms that drift in water, including phytoplankton (plant-like) and zooplankton (animal-like).
- **Suspension Feeders**: Animals that filter food particles from the water.
- **Redox Reactions**: Chemical reactions involving the transfer of electrons between substances.
- **Oxic Conditions**: Conditions where dissolved oxygen is present and available for respiration.
- **Anoxic Conditions**: Conditions where dissolved oxygen is absent but nitrate or nitrite is available for respiration.
- **Anaerobic Conditions**: Conditions where neither dissolved oxygen nor nitrate is available, and respiration cannot be supported.
- **Fecal Coliforms**: A group of bacteria found in the intestines of warm-blooded animals, their presence in water indicates fecal contamination.
- **Enterococci**: A group of bacteria found in the intestines of humans and animals, often used as indicators of fecal contamination in water.
- **Beach Closures**: The temporary closure of beaches to swimming or other recreational activities due to water quality concerns, often caused by pollution.
- **Temperature Depth Profile**: A graph or chart that shows how temperature changes with depth in a body of water.
- **Vertically**: In a straight up-and-down direction.
- **Replicate**: To repeat an experiment or measurement to ensure accuracy and reliability.
- **Sensor Housing Kit**: A protective enclosure for sensors that are deployed in the water.
- **Water Sample Collection Kit**: Equipment used to collect water samples from different depths.
- **Spreadsheet (e.g., Google Sheets)**: A computer program that organizes data in rows and columns, allowing for calculations and data analysis.
- **Graphing Software (e.g., R)**: A computer program designed for creating graphs and charts from data.

NGSS Connections

Performance Expectations:

HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

Science and Engineering Practices

Asking Questions and Defining Problems
Using Mathematics and Computational Thinking.
Planning and Carrying Out Investigations
Developing and Using Models

Disciplinary Core Idea

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
ESS2.C: The Roles of Water in Earth's Surface Processes
ESS2.A: Earth Materials and Systems

Crosscutting Concepts

Energy and Matter
Systems and Systems Models
Patterns

Ocean Literacy Principles Connections

Ocean Literacy Principle #1: Earth has one big ocean with many features.
Ocean Literacy Principle #7: The ocean is largely unexplored.

UNIT 4

CURRICULUM SECTION:

UNIT 4: Research Reporting

ACTIVITY OBJECTIVE:

Students will write a research report.

RESOURCES:

Guide to writing a research report:
UNIT 4: Guide to Writing a Research Report

DETAILS:

This guide provides instructions for students to write a research report with an emphasis on putting class research into context of historical/existent applied science and research.

Guide to Writing a Research Report

UNIT 4: Guide to writing a research report

Writing Style Suggestions

Below are some general suggestions for the writing style that should be used in a research report:

- Formal Tone: Use a professional tone, avoiding slang and casual language. This helps convey seriousness and credibility.
- Objective Language: Focus on facts and evidence rather than personal opinions. Use third-person perspective to maintain objectivity.
- Clarity and Simplicity: Write in straightforward language. Avoid overly complex sentences and jargon unless it's necessary for the topic and well-defined.
- Structured Organization: Follow a clear structure in your report (outlined below) Use headings and subheadings for clarity.
- Evidence-Based: Support claims with research and citations from credible sources. This demonstrates thoroughness and reinforces arguments.
- Consistent Formatting: Adhere to a specific style guide (e.g. APA, Chicago, or CSE) for citations and references. Consistency is key for professionalism.
- Active Voice: Use active voice where possible to make writing more engaging. For example, "The researcher conducted the experiment" is clearer than "The experiment was conducted by the researcher."
- Revision and Editing: Proofread your own work and have your peers and teacher review your report to eliminate errors and improve clarity.

Title Page

The first page of your research report should include a title, your name and the names of any collaborators, and the date that you completed or submitted your report. Your title should be concise and descriptive, with specific information about your research topic. In general, a research paper title should be 5-15 words long. Here is an example research project title: “Using an ROV to analyze fish abundance in marine protected areas near Santa Cruz Island”.

Abstract

The first section of your report should be a brief summary including the background, purpose, methods, results, and conclusions. The abstract gives readers a quick overview of your work, and it should be 150-250 words long. You can write your abstract last, after you've written all of the other sections in your report, by summarizing each section of your report in 1-3 sentences.

Introduction

The introduction will provide your reader with information about your research topic, questions, and objectives. Explain your research topic and why it is important. For example, if you researched bathymetry in a lake, explain that bathymetric mapping is important for navigation and for understanding physical habitat changes over time. Summarize the background research that you used to develop your research question. Describe how your research fits into the history and context of similar research that has been conducted. Clearly state your research question/s and your hypothesis/es. Outline what you aim to achieve with your research. This could be a simple statement such as, "our research aims to provide a clear description of the near-shore bathymetry in Pinto Lake".

Methods

The methods section of your report should provide a detailed description of where and how you conducted your research. Describe exactly where your research took place and why you chose your study sites. List all of the equipment and materials that you used. Explain all of the steps that you took to conduct your research. Make sure that your explanations are clear and detailed so that another group could replicate your study.

Results

Present your data using tables, graphs and/or images that clearly present your findings. The graphics that you choose will depend on the type of data you collected. Be sure to label all graphics clearly. For example, if you decide to show your data in a graph, label the x and y axis or if you show your data in pictures, include a description of each picture. Briefly summarize the main observations, patterns, and trends from your data, but leave the detailed interpretation for the next section.

Discussion

In this section, you will interpret the data from your research. Explain what your results mean, including how your research question was answered and whether your hypothesis was supported or not. If applicable, compare what you found with previous research that has been conducted on your topic. If your findings were different than expected, provide some educated guesses to explain this. Summarize any limitations in your study (e.g. limited time, limited number of replicates) and any potential confounding variables, and describe how these might have affected your results. Suggest areas for further research and investigation on this topic.

Conclusion

Your conclusion should summarize the key points of your research. Restate the significance of your findings.

References

List all the sources you used for your research, including books, articles, and websites. Follow a specific citation style (e.g. APA, Chicago, or CSE).

Appendices (optional)

The appendices are where you can include any additional material, such as raw data or photos, that supports your research but that is too lengthy for the main sections. This section is optional.

Glossary or terms and phrases

- **Research Report**: A formal document that presents the findings of a research project.
- **Collaborators**: People who work together on a project or research study.
- **Concise**: Brief and to the point, avoiding unnecessary words.
- **Abstract**: A short summary of a research report, typically including the background, purpose, methods, results, and conclusions.
- **Objectives**: Specific goals that a research project aims to achieve.
- **Replicate**: To repeat a study or experiment using the same methods to see if the results are consistent.
- **Graphics**: Visual representations of data, including charts, graphs, maps, and images.
- **Interpret**: To explain the meaning or significance of data or results.
- **Limitations**: Constraints or factors that might have affected the accuracy or generalizability of the research findings.
- **Confounding Variables**: Variables that could have influenced the results of a study but were not controlled for.
- **APA, Chicago, or CSE:** These are three examples of citation styles.
- **Appendices**: Supplemental sections at the end of a report that contain additional information, such as raw data, tables, or figures.

NGSS Connections

Science and engineering practices

Engaging in Argument from Evidence

Obtaining, Evaluating, and Communicating Information

Ocean Literacy Principles Connections

Ocean Literacy Principle #7: The ocean is largely unexplored.

Terminology Guide

Technical Terminology Used in this Curriculum

Autonomous Underwater Vehicle (AUV): A self-propelled, uncrewed underwater vehicle that operates independently of direct human control, often used for mapping, surveying, and data collection.

Ballast: Dense material, such as weights or tanks filled with water, used to control the buoyancy and stability of a vessel or underwater vehicle.

Bathymetry: The measurement of depth of water in oceans, seas, or lakes.

Benthic Macroinvertebrate: Aquatic animals without backbones that live on or in the bottom of bodies of water, large enough to be seen without a microscope.

Buoyancy: The ability or tendency of an object to float in water or another fluid, determined by the object's density relative to the fluid being displaced.

DVL (Doppler Velocity Logger): An instrument that measures the velocity (speed and direction) of an underwater vehicle relative to the sea bottom.

Echolocation: The location of objects by reflected sound, in particular that used by sonar equipment or animals such as dolphins and bats.

Echosounder: A device for determining the depth of the seabed or detecting objects in water by measuring the time taken for sound echoes to return to the listener.

Hydrodynamics: The study of fluids in motion, particularly how water interacts with underwater vehicles and objects.

Photogrammetry: The use of photography in surveying and mapping to measure distances between objects.

Remotely Operated Vehicle (ROV): An uncrewed underwater vehicle operated remotely by a person on the surface, often equipped with cameras, sensors, and manipulators for scientific, commercial, or exploratory purposes.

ROV Tether: A cable connecting the ROV to the surface control unit, providing power, communication, and sometimes data transfer.

Salinity: The concentration of dissolved salts in water, usually measured in parts per thousand (ppt) or practical salinity units (PSU).

Sonar (Sound Navigation and Ranging): A technique that uses sound waves to detect and locate objects underwater and determine water depth.

Substrate: The surface or material on or from which an organism lives, grows, or obtains its nourishment.

Transect: A straight line or narrow section through an object or natural feature or across the earth's surface, along which observations are made or measurements taken.

Turbidity: The cloudiness or haziness of a fluid caused by suspended particles, which can affect visibility and sensor performance underwater.

Uncrewed Surface Vessel (USV): A self-propelled, uncrewed watercraft that operates on the surface of the water, often used for surveying, monitoring, and data collection.

Upwelling: The process by which deep, cold, nutrient-rich water rises toward the surface, often supporting marine ecosystems and affecting water properties.

Water Column: The vertical section of water from the surface to the bottom of a body of water, often studied to understand physical, chemical, and biological characteristics.