Back to Nature: Jellyfish Lake Program

Student Guide

Palau

Coral Reef Research Foundation

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About Coral Reef Research Foundation & the Marine Lakes Project

The Coral Reef Research Foundation, or CRRF, is a research facility located on Malakal Island across from Kings Minute Mart and next door to NECO Marine Dive Shop. CRRF was started in 1991 by a group of marine scientists dedicated to research and education on coral reefs and other tropical marine environments. CRRF is a non-profit organization in both the U.S. and Palau. CRRF does scientific research to acquire the knowledge needed to understand and make intelligent decisions related to conservation, climate change and resource management.

Our current marine lakes research program began in 1999 after the strong El Niño/La Niña event that caused the Golden jellyfish population to disappear. Overall, the program emphasizes the origins, ecology, and evolution of marine lakes, including how their species vary through time, and how climate change impacts the lakes. CRRF is the only research facility in Palau that studies the marine lakes.

There are more than 55 marine lakes in Palau and they are all unique and different from one another. The majority of these lakes are concentrated in the Rock Island Southern Lagoon of Koror State, a UNESCO World Heritage Site. Of all the marine lakes in Palau, CRRF monitors 18 once a year and 3 once every quarter. This monitoring program includes documenting the temperature, salinity, oxygen, pH, and chlorophyll of the lake water from surface down to the bottom of the lake. CRRF also documents the population of the Golden jellyfish in Jellyfish Lake every quarter. There are also temperature-logging instruments that are deployed in 18 lakes. Studying temperature, salinity, oxygen and pH have been identified to be an essential part of the lake study. All of these physical parameters contribute to the health and reproduction cycle of the unique sub-species of *Mastigias papua etpisoni* that is endemic to Jellyfish Lake. Documenting and studying these variables can help us to understand how we can protect the lake for future generations. For more information see: **https://coralreefpalau.org/research/marine-lakes/**.

CRRF also runs a tower weather station (TWS) on Ngeanges Island. Its location, isolated from obstructions (e.g. tall manmade structures), reduces the effects of large land masses on weather observations and provides more accurate information on marine conditions for comparisons with other areas. The weather conditions monitored by the tower station closely approximate those occurring at Jellyfish Lake, only 5 km away from the station. The TWS has been running since 2007, and has recently gone online. Live hourly data from this station can be viewed at **https://weather.coralreefpalau.org/**

PROGRAM FUNDING

Acknowledgements

This field education program is a success because of the generous help and advice from numerous agencies, as well as individual people in Palau. The Coral Reef Research Foundation and its team would like to express our deepest gratitude to the grantors, the GEF Small Grants Programme and the New Zealand North Pacific Development Fund, for supporting the program's development and implementation for school year (SY) 2020–2021, and Canada Fund for Local Initiatives for program support in SY 2021-2022, and funds to institutionalize it within the Ministry of Education (MOE). We would also like to thank the Ministry of Education for working with us in planning and executing the program. Within MOE, we would like to give special thanks to former Minister Sinton Soalablai SY 2020-2021, Chief Raynold Mechol, Chief Magaria Tellei, Specialist Debbie R. Nagata and Specialist Sarah Sugiyama. We also thank all the schools, principals, teachers and parents for making this program possible. Lastly, we thank the hundreds of students for taking part in this program. We are very proud of all of you and we hope that you will use this as a window into a deeper appreciation of your home and a stepping stone toward future careers. You will be the leaders of Palau one day, and we are confident that you will protect and preserve our small islands for all the generations to come.

The Coral Reef Research Foundation would also like to thank Paddling Palau and its staff for assisting with our field trips. Special thanks are due to NECO Marine for accommodating our trips. Our partners at the Koror State Government, Koror State Legislature and the Koror State Department of Conservation and Law Enforcement are thanked for permitting us to implement the program in one of their most unique resources, Jellyfish Lake. Our intention is that the program can be continued annually to expose our children to the beautiful natural resources that we have, as well as educate them on how to preserve, conserve and protect these unique areas of biodiversity in Palau.

Welcome and Description

The Back to Nature: Jellyfish Lake program aims to foster environmental stewards who actively engage and work on protecting and conserving our natural environment. This program helps young people to connect to nature, increasing their appreciation and knowledge of the natural world that will encourage youth to advocate for changes that will protect and conserve our environment.

This particular program focuses on Jellyfish Lake, to foster a sense of ownership and increase knowledge of Jellyfish Lake. Why Jellyfish Lake? Jellyfish Lake is a unique marine environment that is special to Palau; it is home to millions of a unique Golden jellyfish found nowhere else in the world. Sadly, more tourists than our own students have visited and explored Jellyfish Lake. For this reason, we have created the program to ensure that students get the chance to visit and explore the lake, feel that connection to this special place, and foster a passion and desire to protect the lake.

The Back to Nature: Jellyfish Lake program reached students from Kayangel to Hatohobei, for two consecutive years, SY 2020–2021 & SY 2021-2022, covering all elementary schools in Palau and additional groups and high schools:

- **868 students**: 426 males, 442 females
- **73 teachers** from public and private schools
- **19 elementary schools**: 17 public schools, 2 private schools
- **4 high schools**: 1 public school, 3 private schools
- **2 organizations**: Ebiil Society Camp, Heirs to Our Oceans

This lesson plan and information packet was created by the Coral Reef Research Foundation to instruct the students of Palau in the Back to Nature: Jellyfish Program.

Introduction: On Day 1, provide useful background information that will give students a general overview of Jellyfish Lake and prepare them for the field day.
Field Day: On Day 2, guide students in learning through hands-on activities in Jellyfish Lake.
Wrap Up: On Day 3, help students synthesize the information they have learned, analyze the data they have collected, and present their work to their classmates.

We hope through this program, our youth will have fun learning about Jellyfish Lake, science and climate change.

LESSON PLANS

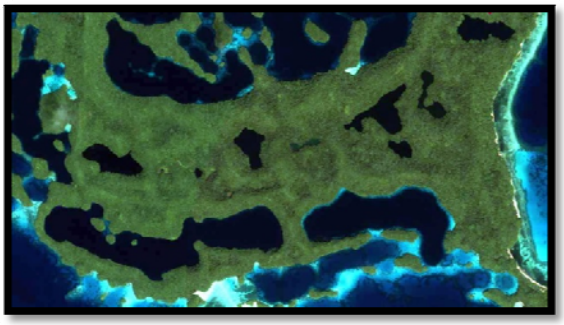
Day 1 – Introduction to Back to Nature Program and Marine Lakes

This first day of the program is held in the classroom where students will watch a Power Point presentation. Through the presentation, students will learn about the Jellyfish Lake environment and the unique organisms that are found in the lake. They will also hear about climate change and other threats to Jellyfish Lake and its Golden jellyfish. Toward the end of this unit, students will learn about the different scientific tools and methods they will be using during the field trip to Jellyfish Lake.

	LESSON	OBJECTIVES	MOE Objectives	STANDARDS
Lesson 01	**Marine Lake Habitat, Formation, and Types of Organisms**	Students will be able to do the following: -I can explain why Jellyfish Lake is important. -I can identify two threats to the health of Jellyfish Lake. -I can classify marine organisms to phylum level. -I can identify four methods used during the field trip.	Science Practices: -Obtain information, ask science questions, and plan investigations.	-Obtain and compare information about a scientific topic from different sources. -Ask questions that can be investigated and predict reasonable outcomes based on patterns, such as cause and effect relationships. -In planning an investigation, identify variables and ask questions about what would happen if a specific variable is changed.
Lesson 02	**Threats to Jellyfish Lake: Climate Change and Visitor Impact**			
Lesson 03	**Scientific Method and Tools**			
Lesson 04	**Classification System**			

Lesson 01: Marine Lake Habitat, Formation, and Types of Organisms

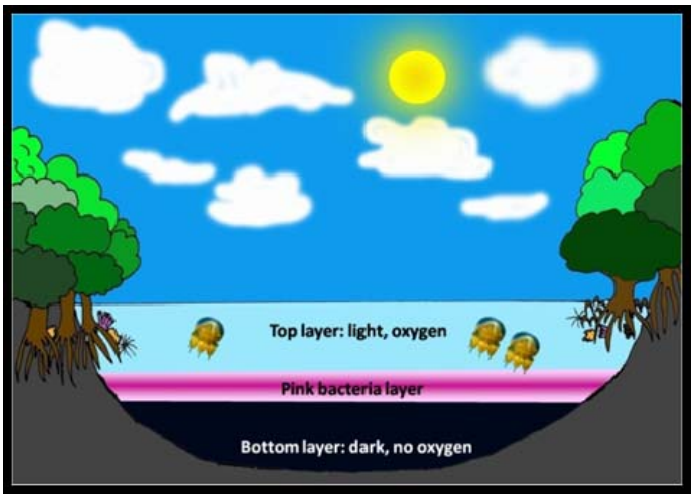
Background Information



A marine lake is a body of seawater that is completely surrounded by land. Thousands of years ago, sea level was much lower than today and all of Palau that is lagoon today was dry land. The marine lakes formed when sea level started rising and filled low spots with ocean water. As sea level rose, the sea and marine organisms made their way through open

tunnels, cracks and crevices in the rock islands as the low lying areas or depressions filled with sea water. These filled depressions became marine lakes, numbering over 50, with some still connected to the lagoon while others became more isolated.

Palau has three types of marine lakes: stratified, mixed and transitional. Marine lakes can vary due to the types of connections they have with the surrounding lagoon. Some lakes are directly connected to the lagoon through large tunnels you can swim through. Other lakes are **isolated** with indirect connections to the lagoon through tiny tunnels and cracks.



The first type of lake is **stratified**, or **meromictic**, and is like a layer cake. The layers are water, separated from each other by differences in density. Stratified lakes usually have small tunnels and cracks. They will have an indirect and limited connection to the lagoon, and so are isolated from the ocean. High ridges of land will also surround most stratified marine lakes, and the surrounding land will slow down the wind blowing across the lake. These geographical characteristics contribute to the lack of mixing in the lake, which causes the water in the lake to stratify and oxygen to deplete at some depth. The top layer of the lake's water usually has oxygen, whereas the bottom layer lacks oxygen (anoxic). A pink bacteria layer is usually found at the interface, or boundary, of these two different layers of water. Because stratified lakes have a limited connection to the ocean, the timing and tidal range (or difference between low and high tide) in the lake are different from the ocean.

The biological community in stratified lakes has similarities to those of mangrove habitats, but some of the species are unique to these lakes. Some species are new to science, and still need to be described and given scientific names. In a stratified lake, dissolved oxygen is found only in the upper layer of water, and this is where all the organisms live because they must have oxygen to survive. The pink layer is thin, its color coming from pink bacteria in the water. Below it is the zone where no oxygen occurs, due to decomposition of living matter.

In contrast, the **mixed or holomictic lakes** have large tunnels that directly connect to the surrounding lagoon. This characteristic, along with lower lying ridges and more exposure to wind, contributes to the mixing of the water column. These lakes will have oxygen from the surface to the bottom of the lake. They have a uniform water column; temperature and salinity levels are the same from surface to the bottom and animals are able to move throughout the lake, as well as in and out of the lake through the tunnels to the lagoon. As a result, mixed lakes have a

similar community to the lagoon, with corals, sponges, and sea squirts that are common to the lagoon. The direct tunnels allow water to go into and out of the lake with the tides, so the lakes experience a very similar tidal cycle as the surrounding lagoon.

Transitional lakes are those that can be either mixed or stratified depending on the mixing by winds and other weather patterns. Generally they have small tunnels, but through exchange with the lagoon they can sometimes be mixed under the right weather conditions. Transitional lakes can have communities similar to both lagoon and mangrove habitats.

Vocabulary

Biology - the study of living organisms, divided into many specialized fields that cover their morphology, physiology, anatomy, behavior, origin, and distribution.
Habitat - the natural home or environment of an animal, plant, or other organism.
Holomictic or mixed lake - a lake that has a uniform temperature, salinity and density from top to bottom, with dissolved oxygen in the water at the lake's bottom. Mixed lakes have large, open tunnels that connect them to the surrounding lagoon.
Isolated - separated from other places with little communication.
Meromictic or stratified lake - a lake with layers of water, like a layer cake, that do not intermix due to density of the water. Stratified lakes have small indirect cracks and crevices that cause a delay in the lake's tidal cycle.
Transitional Lake - a lake that can be mixed or stratified depending on the wind mixing and other weather patterns.

Classroom Activities

- 15 minute long presentation on the program and marine lakes formation
  - Purpose of the program
    - To enhance knowledge of marine lakes and other local resources
  - Lake Formation
  - Types of marine lakes
    - Stratified or meromictic lake
    - Mixed or holomictic lake
    - Transitional lake
  - Compare and contrast the lake temperature-salinity-oxygen (TSO) profile between stratified, mixed and transitional lakes
  - Compare and contrast organisms between stratified, mixed and transitional lakes

Thinking Corner

1. How are marine lakes different from Ngardok Lake in Melekeok?
2. What conditions can cause transitional lakes to become mixed? stratified?
3. How old do you think marine lakes are? How old are the rock islands?

Lesson 02: Threats to Jellyfish Lake: Climate Change and Visitor Impact

Background Information

Jellyfish Lake is an excellent example of an area important for its biodiversity. **Biodiversity** is the variety of all living things. It is most famous for its Golden jellyfish, which is a unique subspecies found nowhere else in the world. Jellyfish Lake also has many other species, particularly along its sides, that make up a community unique to this specific lake. However, the lake is threatened by humans, through **visitor impact**, and **climate change**. Visitors affect the lake through particular behaviors, such as leaving trash in the lake and damaging the jellyfish while swimming. Climate change is a long-term threat, through changes in average weather conditions such as temperature, rain, sunlight and wind over a long period of time.

The actions of visitors can negatively affect the lake, but perhaps the most important is visitors introducing **non-native species**. Non-native species are animals and plants that do not occur naturally in a particular place, and can become an **invasive species** that take over once introduced to a new place. Visitors can introduce non-native species when they bring rocks, shells, sand, and other things from the lagoon into the lake. Often, these rocks and shells will have tiny organisms living on them. Remember that Jellyfish Lake has been isolated from the ocean for thousands of years, and we need to maintain that isolation, otherwise the entire ecosystem in the lake can be disturbed so the jellyfish no longer survive. Other ways that visitors affect the lake is through **water pollution**, either through using sunscreen that contains chemicals toxic to marine organisms or by leaving plastic bottles, food containers, bags, and trash in the lake. Visitors can also tear and kill the jellyfish by swimming too vigorously.

Climate change can have a huge impact on marine ecosystems. We know that climate change can cause the lake's normal temperature range to gradually rise. If the lake's temperature increases above the threshold level of 31.5°C (degrees Celsius), the population of the Golden jellyfish will decline. Drought, or when there is little to no rain, can also affect the salinity or salt content of the lake; these can have negative effects on the jellyfish population. In 2016, the Golden jellyfish population in Jellyfish Lake started to decline during an extreme drought as part of El Niño conditions. They continued to decrease, and the swimming form, the medusae, subsequently disappeared at the end of the El Niño when sea water temperatures rapidly increased over the temperature threshold. Changes in weather patterns and extreme climatic events like the 2016 El Niño can impact the lake and its Golden jellyfish population.

Vocabulary

Biodiversity - the variety of life in the world, or in a particular habitat or ecosystem.
Climate change - a change in average conditions such as temperature or rainfall in a region over a long period of time.
Invasive species - any kind of living organism that is not native to an ecosystem and causes harm.
Non-native species - an organism that does not occur naturally in an area.
Visitor impact - actions and behaviors of people that have an effect on the area that they visit.
Water pollution - the release of materials and substances, such as trash and sunscreen pollution, into bodies of water that degrades the quality of the water. When extreme, it makes the water unsafe for humans and other animals to drink or swim in.

Classroom Activities

- 10 minute long presentation on the importance of Jellyfish Lake to Palau and identifying threats to its health.
  - Important area of biodiversity
    - *Mastigias papua etpisoni*, the Golden jellyfish subspecies that is found nowhere else in the world
    - Organisms in the lake are hard to find in open ocean
    - New species discovered
  - Threats to Jellyfish Lake
    - Climate Change
      - Palau extreme drought in 2016
        - Warm sea temperature
        - Golden jellyfish population decline
      - Visitor impact
        - Water pollution (trash & sunscreen)
        - Introduction of invasive species
        - Damaging jellyfish

Thinking Corner

1. How is Jellyfish Lake different from the coral reef? Other marine ecosystems?
2. If the Golden jellyfish disappeared in 2016 because of high temperatures, how do you think they came back? What needed to happen for the Golden jellyfish to return?
3. What are things you can do to protect Jellyfish Lake? The environment?

Lesson 03: Scientific Method and Tools

Background Information

The scientific method and tools are used to gather data and information about the world. We use the **scientific method** and tools to identify problems and seek solutions. In all research across the different science fields, scientists will conduct experiments according to the scientific method. The scientific method is a process that allows researchers to study a topic or problem, learn and gather information about that particular topic, and share what they learned. The scientific method consists of five steps: ask a question, gather information, form a **hypothesis**, test the hypothesis, and share the results.

In this lesson, students will learn how they will conduct their research and monitor the lake through four stations in Jellyfish Lake. On Day 1 in the classroom, students will focus on the first and second step, which is to make an **observation** with the information they get from the presentation. After viewing the presentation, they will gather information and ask necessary questions that will lead to a hypothesis that can be tested during the field day in Jellyfish Lake. During the field day (Day 2), students will make a prediction and test their hypothesis and share their results during the wrap up (Day 3).

There are four stations during the field day. Station 1 is the "**Temperature**, **Salinity** & **Oxygen** (TSO) Profile Station" where students will use a YSI **water quality meter** to record temperature, salinity, and dissolved oxygen in the upper 15 meters of the lake. Students focus on the first 15 meters because that is where all living organisms are found in Jellyfish Lake. Station 2 is the "Pink Bacteria Layer Station" where students will use a **Nansen bottle** to sample the pink bacteria layer in the lake, usually found around 13-15 meters. Station 3 is the "**Plankton** and Microscope Use Station" where students will catch plankton samples with a plankton net and look at them under the microscope. Station 4 is the "Scavenger Hunt for Lake Organisms" where students will be doing an invertebrate and vertebrate survey, determine the depth where they find organisms, identify the organism's color and **substrate**, and classify them to their phylum level.

Vocabulary

Hypothesis - a prediction or educated guess that can be tested and can be used to guide further study.
Nansen bottle - equipment used to capture water samples from different depths below the surface.

Observation - the action or process of observing something or someone carefully in order to gain information.
Oxygen - the colorless odorless gas necessary for most life, a small amount which can dissolve in water, and constitutes 20% of air.
Plankton - microscopic drifting organisms, plants or animals, in the sea.
Temperature - the measure of heat that is measured with a thermometer and expressed in different scales (Celsius, Fahrenheit, Kelvin).
Salinity - the quantity of dissolved salt content in a volume of water.
Substrate - a surface or material on or from which an organism lives and grows.
Scientific method - a method of procedure or a process consisting of systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses.
Water Quality Meter - instrument used to measure temperature, salinity, and oxygen in the water.

Classroom Activities

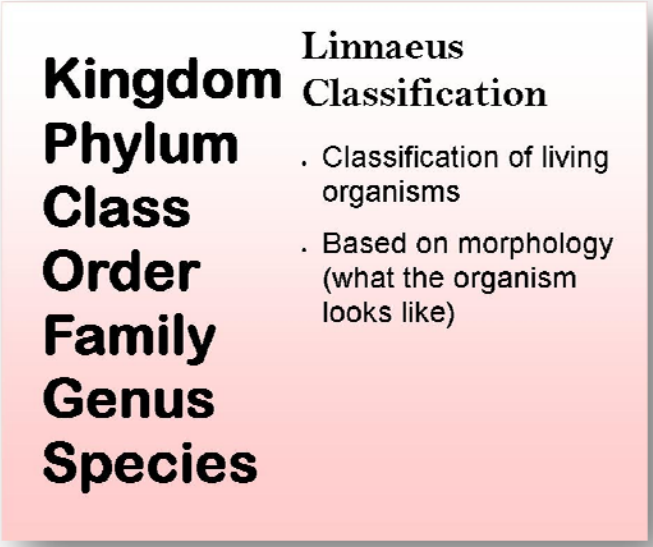
- 10 minutes presentation on the scientific method and tools
  - TSO station
    - YSI water quality meter
  - Scavenger Hunt station
    - Depth line
    - Underwater camera
    - Field guide
  - Pink Bacteria Layer station
    - Nansen bottle
  - Plankton & Microscope Use station
    - Microscope
    - Concave slides and cover slip
    - Field guide
    - Zooplankton net and line

Thinking Corner

1. What do you think happens to temperature and oxygen as you go deeper in the water?
2. Which animal do you think will be easiest to find? Hardest to find? Why?
3. What do you think the pink bacteria layer will smell like?

Lesson 04: Classification System

Background Information



Classifying organisms is an important process that helps with identifying the different species and understanding their relationships with each other. It also allows us to measure the diversity (number of species) of living things as well as learn about similarities and differences between organisms. The **Linnaean classification system** is a method of classifying living things based on **morphology** (the structure, shape and size of an organism). Species are given a unique two-part scientific name, referred to as **binomial nomenclature**, consisting of the genus (first) and species (second) name. This system is very important as it helps us to categorize and identify animals or plants and separate them from one another. It also helps us to understand the relationship between groups of plants or animals at different levels. In this lesson, students will learn to classify organisms found in the lake to their **phylum** level. It will help familiarize themselves with the kind of living organisms that can be found in Jellyfish Lake versus organisms found in the lagoon in coral reef environments.

Vocabulary

Binomial nomenclature - a system of nomenclature in which each species of animal or plant is given an identifying two part "scientific" name (genus and species). The name of this species is used by everyone in the world, no matter what language they speak.
Classification - to organize or arrange species in groups or categories according to shared qualities or characteristics.
Linnaean classification system - a method used to identify and classify living things based on their morphology.
Morphology - study of the size, shape, and structure of animals and plants and of the relationships of their constituent parts.
Phylum - a major principal taxonomic category that represents the major groups of plants and animals.

Classroom Activities

- 5 minutes on Classification System & organisms found in Jellyfish Lake.
  - Common name
  - Phylum
  - Genus & species
- 5 minutes on Q & A and practice using scientific tools.

Thinking Corner

1. Name a common type of reef organism (invertebrate) that is NOT found in Jellyfish Lake?
2. Other than morphology, what are other ways to classify (or find similarities or differences) between organisms?

Day 2 – Exploring Jellyfish Lake Using the Scientific Method and Tools

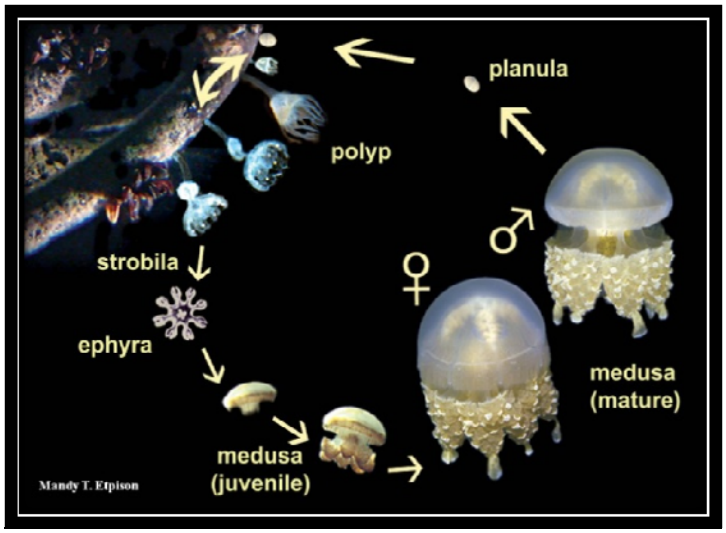
	LESSON	PROGRAM OBJECTIVES	MOE OBJECTIVES	STANDARDS
Lesson 01	**Temperature, Salinity and Oxygen (TSO) Profile**	Students will be able to do the following: -I can practice observation skills, using my five senses and recording what I see, hear, smell, taste, and touch. -I can use the Nansen bottle to locate the pink bacteria layer in Jellyfish Lake. -I can compare and contrast living things in Jellyfish Lake. -I can identify the invasive sea anemone in Jellyfish Lake. -I can use a microscope to observe zooplankton in the field.	Science Practices: -Get, analyze, and interpret data. Life Sciences: -Investigate local environments and research other kinds of island environments to describe, classify, and compare the biodiversity of animals in these environments. -Analyze the adaptations that help the populations of different organisms to be successful in their environments.	-Make and record observations and/or measurements that can be used as evidence to explain a phenomenon. -Classify animals in Palau environments as vertebrates, invertebrates, sponges, cnidarians, worms, mollusks, arthropods, echinoderms, amphibians, fish, reptiles, birds, and mammals. -Compare and contrast the biodiversity of animals in different Palau environments. -Define adaptation as a feature or behavior of a species that makes it possible for organisms of that species to survive in their natural environment.
Lesson 02	**Pink Bacteria Layer**			
Lesson 03	**Plankton and Microscope Use**			
Lesson 04	**Scavenger Hunt for Lake Organisms**			

During the field day, which will take up a whole school day (8am - 2:30pm), students will cover a few steps of the scientific method such as gathering information, forming a hypothesis, and testing their hypothesis. After traveling by boat through the rock islands, students will arrive at Jellyfish Lake. On the dock, they will first go through the Golden jellyfish life cycle before the hike over the hill to the lake. There they will split into four (4) groups and complete the four study stations. The four stations are: (1) Temperature, Salinity & Oxygen (TSO) profile; (2) Pink Bacteria Layer; (3) Plankton and Microscope Use; (4) Scavenger Hunt for lake organisms. These groups will rotate stations, and each group will complete at least two stations, depending on time. After the activities in the lake, students will pack up and leave to a nearby rock island for lunch. Students should read the lesson plans for Day 2 (below) the night before to prepare for field trip.

Lesson 01: Temperature, Salinity & Oxygen Profile (TSO Station)

Background Information

Temperature, Salinity and **Oxygen** (TSO) are important parameters to consider when studying Jellyfish Lake and organisms that reside in the lake. All three affect the numbers and distribution of Golden jellyfish found in the lake. For example, if temperature of the lake increases above 31.5°C (degrees Celsius) for a long time (weeks to months), then the number of the Golden jellyfish will decrease. Since life in Jellyfish Lake is only found in the upper 15 meters of the lake water, students will record their data from 0–15 meters on a datasheet to document how TSO changes with depth (Attachment 1: TSO Profile & Pink Bacteria Layer Datasheet).



Jellyfish have a life cycle with two stages: the **medusa** and the **polyp**. The polyp form lives on the side of the lake, and does not move. The medusa is the swimming form of the jellyfish. Male and female medusa release sperm and eggs. The egg is fertilized, and it develops into a swimming **planula** or larva. The larva has hair-like structures, or **cilia,** that help it to swim to the side of the lake where it attaches to the substrate (bottom or other object). The larva, now attached to the lake's side, will turn into a polyp. The polyp eventually starts to produce **ephyrae** or baby jellyfish that break free from the polyps and grow into free-swimming medusae.

When the lake becomes too warm (above 31.5°C), the medusa (or free swimming) stage will eventually disappear, but the polyps are more resistant to high temperatures and will survive on the sides of the lake. However, at those temperatures, the polyps will not produce any ephyrae or

baby jellyfish. Instead, they go into a "resting" state. If the temperature of the lake continues to increase, then the Golden jellyfish will disappear as the older jellyfish die and no young ones are produced to replace them. Only when conditions go back to normal (lower temperatures) will the polyps start producing ephyrae and medusae again, resuming the cycle of life. This is how the medusae population is able to recover after they have "disappeared" from the lake for a long time.

Vocabulary

Cilia - hair-like structure surrounding a planula that helps it to swim.
Ephyra - a larval jellyfish, after it has separated from the strobila/polyp, or very tiny medusa (<0.5 cm). Ephyrae is the plural form.
Medusa - the swimming form of the jellyfish with an umbrella-shaped bell and oral arms. Medusae is the plural form.
Oxygen - the colorless odorless gas necessary for most life, a small amount which can dissolve in water, and constitutes 20% of air.
Planula - a free-swimming jellyfish larva, planulae is the plural form.
Polyp - the bottom-dwelling stage of the jellyfish life cycle found on the sides of the lake.
Salinity - amount of salt dissolved in a volume of water.
Temperature - the measure of heat that is measured with a thermometer and expressed in different scales (Celsius, Fahrenheit, Kelvin).

Field Activities

- 40 minutes recording TSO and observe jellyfish
  - 10 minutes to give time for students to look at jellyfish as they swim from the dock to the station
  - 20 minutes to record TSO data from 0m down to 15m on datasheet
  - 10 minutes to discuss how documenting TSO is important to the lake and the Golden jellyfish
- 5 minutes to pack gear and move to the next station

Thinking Corner

1. What depth in the lake has the highest temperature?
2. At what depths do marine organisms live in Jellyfish Lake?
3. What depth has the lowest salinity? Why?

Lesson 02: Pink Bacteria Layer

Background Information

Jellyfish Lake is a stratified lake, with three layers of water like a cake. The top layer of water has oxygen and the bottom layer has no oxygen. The thin middle layer is pink from a type of **bacteria**. Below the pink bacteria layer, hydrogen sulfide is present in the water. **Hydrogen sulfide** is a poisonous gas dissolved in the water that forms from the decomposition of living matter which has fallen into the lake and comes to rest on the bottom. High levels of hydrogen sulfide can kill most living things, so it is a good thing the hydrogen sulfide is trapped beneath the pink layer.

The students will be given a **Nansen bottle**, a device that is lowered on a line from the surface and used to capture water samples at different depths. They will use the Nansen bottle to locate the pink bacteria layer and note the smell and color of the water collected from different depths and record results on their datasheet (Attachment 1: TSO Profile & Pink Bacteria Layer Datasheet).

Vocabulary

Bacteria - a tiny unicellular microorganism with a cell wall but lacking an organized nucleus. They are found almost everywhere, in large numbers and some types can cause disease.

Hydrogen sulfide - a colorless gas with the distinct bad odor of rotten eggs. It is poisonous.

Nansen bottle - a device that is lowered on a line from the surface and used to capture water samples from different depths.

Field Activities

- 40 minutes locating the pink bacteria layer
  - Learn how to use the Nansen bottle
  - Determine the range of depth you will sample
  - Students will take turns to drop the Nansen bottle and search for the pink layer
  - Students will smell and identify the color of the captured sample, and record results on datasheet.
  - Discuss why it's important to monitor the depth and thickness of the pink layer
  - Explain to students why the layer is there and why it smells
- 5 minutes to swim to the next station

Thinking Corner

1. What makes this layer pink?
2. What makes the layer smell?
3. What other habitat smells like the pink layer?

Lesson 03: Plankton and Microscope Use

Background Information

There are two types of tiny plankton in Jellyfish Lake. The first, **zooplankton**, are tiny drifting animals, and the second, **phytoplankton**, are tiny drifting plants (microalgae). Phytoplankton are generally much smaller than zooplankton and are eaten by zooplankton for food. Both are essential parts of the Golden jellyfish **food web**. The Golden jellyfish gets its food in two ways. Jellyfish use their oral arms to sting and eat zooplankton. They also get food through another type of microalgae that lives inside their tissue, called **zooxanthellae**. This algae produces food from sunlight through **photosynthesis**.

In this part of the lesson, students will collect samples using a **plankton net** with a very small mesh size of 80 **microns**. The net allows for water to filter through, leaving plankton trapped by

the net and funneled into a bottle screwed to the end of the net. After about 3 tows with the plankton net, the students will have enough samples. They will bring samples to the dock where **microscopes** are set up in the ranger's station. Students will use the microscopes to identify plankton and draw what they see on their datasheet (Attachment 2: Scavenger Hunt and Zooplankton Datasheet). Students are also given a field guide (Attachment 3: Plankton Field Guide) that will help them to identify zooplankton and phytoplankton.

Vocabulary

Food web - a graphical model depicting the many food chains linked together to show the feeding relationships of organisms in an ecosystem.
Microscope - an optical instrument used for viewing very small objects, such as animal or plant cells, typically magnified several hundred times.
Micron - a very small unit of measurement, also known as micrometer. There are about 25,000 microns in an inch.
Photosynthesis - the way in which green plants and some other organisms use sunlight to produce food.
Phytoplankton - tiny drifting plants (algae) in the sea.
Plankton net - filter net with a very small mesh size of 80 microns used for collecting samples of plankton.
Zooplankton - tiny drifting animals in the sea.
Zooxanthellae - a golden-brown symbiotic, microscopic algae, or plant, present in the tissue of many marine invertebrates, such as corals and some jellyfish.

Field Activities

- 40 minutes on plankton and microscope use
  - 20 minutes collecting plankton samples
  - 5 minutes overview of importance of plankton and the Golden jellyfish food web
  - 15 minutes looking for them under the microscope, identifying and drawing plankton
- 5 minutes to get ready for the next station

Thinking Corner

1. Why is it important to study plankton in Jellyfish Lake?
2. How do phytoplankton get their food?
3. What do the Golden jellyfish in Jellyfish Lake eat?

Lesson 04: Scavenger Hunt for Lake Organisms

Background Information

The Linnaean classification system is a method used to classify living organisms based on their different characteristics. This system is very important as it helps distinguish different species among millions of living organisms. It also helps us to understand the relationships among groups of plants or animals.

As part of our marine lakes research, Coral Reef Research Foundation has conducted invertebrate surveys around Jellyfish Lake and other marine lakes to identify the different types of organisms found in the various lakes. Within Jellyfish Lake, surveys have been done to determine how much of the lake side (the percent cover) has been taken over by the invasive brown sea anemone, as well as other marine invertebrates living on the side of the lake.

In this activity, the students look for and identify different types of living things in a marine lake and document where they are found. Students will be given a field guide (Attachment 4: Scavenger Hunt Field Guide) and a datasheet (Attachment 2: Scavenger Hunt and Zooplankton Datasheet) with a list of targeted organisms to look for in the lake. For example, they will be asked to look for the **invasive** brown sea anemone and compare it with the lake's **endemic** white sea anemone. Students are required to determine the depth and substrate where each organism occurs, as well as their color and **phylum**. Students will also take photos of the organisms they find. This activity will allow students to explore the community of organisms living in the mangrove habitat of Jellyfish Lake.

Vocabulary

Endemic species - any living organism that is native and limited to a single defined geographical location, such as an island.
Invasive species - any living organism that is not native to an ecosystem and causes harm.
Phylum - a major principal taxonomic category that represents the major groups of plants and animals.

Field Activities

- 40 minutes scouting, identifying, and classifying lake organisms
  - Students will be given a list of organisms to look for in the lake along with their field guides

- On their datasheet, they will take notes on each organism
  - Classify them to their phylum level
  - Determine the depth of organism
  - Identify color
  - Identify substrate
  - Photograph each organism for class reference
- 5 minutes to prepare for the next station

Thinking Corner

1. What lake organisms are similar to those in the lagoon?
2. What was the smallest organism that you found?
3. Are there seagrass in Jellyfish Lake?

Day 3 – Data Analysis and Presentation of Results and Conclusions

In this part of the program, students will cover the last step of the scientific method, which is analyzing data and sharing the results and conclusions. Now that the students have gathered the information and data, it's time to make sense of it. Data analysis is an important step of scientific surveys as it helps us to understand our results and draw conclusions based on our results. Data are analyzed and presented in the form of a presentation or printed report that is easy for the audience to understand. The students will graph their data and use photos to identify species.

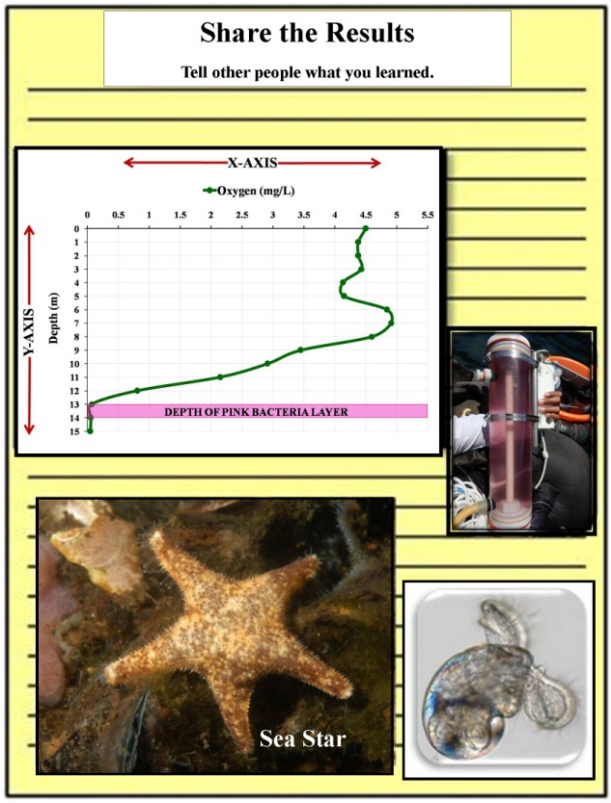
	LESSON	OBJECTIVES	MOE Objectives	STANDARDS
Lesson 01	**Analyze Temperature and Salinity Data**	Students will be able to do the following: -I can make informative statements based on my data and observations I collected during the field trip. -I can explain why Jellyfish Lake is important. -I can identify ways to protect the environment.	Science Practices: -Get, analyze, and interpret data -Make, evaluate, and communicate conclusions.	- Organize collected data in a table and/or graph that helps show a pattern of relationship -Use data to evaluate conclusion about causes and effects. -Use tables, diagrams and/or charts to communicate results of an investigation. -Communicate investigation procedures, data, reasoning and conclusion orally and in written formats including various forms of media.
Lesson 02	**Analyze Pink Bacteria Layer and Oxygen Data**			
Lesson 03	**Identify Plankton samples and Explain Food Web**			
Lesson 04	**Identify Organisms to Phylum and Identify Common Species**			

Students will discuss with their group members and teacher about how to make informative statements with their data, so that everyone and anyone can understand what they did and why. After analyzing the data, each group will take turns going up to the front of the class to present their data to the class.

Lesson 01: Analyze Temperature and Salinity Data

Background Information

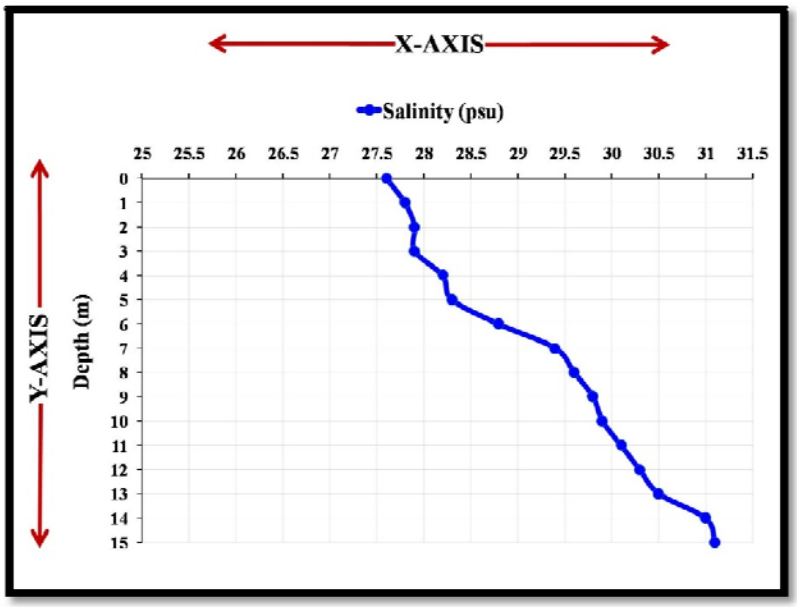
Temperature and **salinity** are monitored in Jellyfish Lake, because they affect the marine organisms, especially the Golden jellyfish population, in the lake. If water temperature is too high (over 31.5°C) for a long period of time (weeks to a month), the polyp stage of the jellyfish will stop producing baby jellyfish or ephyrae, leading to a decline in the jellyfish population. The Golden jellyfish medusa will also bleach; meaning the zooxanthellae that live in its tissue will leave the body of the jellyfish. Without the zooxanthellae, the jellyfish will look white or clear. It is not well understood if a bleached jellyfish can reproduce or not; however, it is very clear that warm water temperature does affect the polyps and the life cycle, and that is why it is important to document the lake's water temperature.



Studying the salinity of the lake will help us to understand how freshwater input, evaporation and mixing of the lake water can affect salinity. Salinity can affect marine life in the lake. We also study how local weather patterns, such as wind and rainfall, affect lake water temperature and salinity. If there is no wind to mix the top layer of water and no freshwater input from rainfall, both temperature and salinity can increase in the top layer of Jellyfish Lake.

Students will graph their temperature and salinity data using a line graph. Students can either use Microsoft Excel on a computer or graph paper. To graph their data, students should learn the parts of the graph. The **x-axis** is the horizontal line of the graph that displays the values of temperature and salinity. Numbers increase from left to right on the x-axis, with the minimum value on the left end and the maximum value on the right end of the x-axis. The **y-axis** is the vertical line that displays the depth of the lake. To match the lake depth profile, we put the x-axis at the top of the graph, and label the y-axis with zero (0) at the top (representing the lake

surface), increasing in number (depth) as you go down. The line graph will show how temperature and salinity changes as depth increases. As depth increases, does the temperature and salinity increase or decrease?



For their presentation, students should be able to explain parts of the graph (x and y axis), what the graph is showing and what the different numbers on the y-axis and x-axis represent. They should explain the pattern of temperature and salinity with depth—how does temperature and salinity change with depth? Students can use the review questions (Attachment 6: Review Questions for Each Station) to guide them in their presentation.

Vocabulary

Salinity - the quality or degree of being saline, the amount of salt in water.
Temperature - the measure of heat that is measured with a thermometer and expressed in different scales (Celsius, Fahrenheit, Kelvin).
X-Axis - is the horizontal axis of a graph that displays text labels and numerical values.
Y-Axis - is the vertical axis of a graph that displays text labels and numerical values.

Classroom Activities

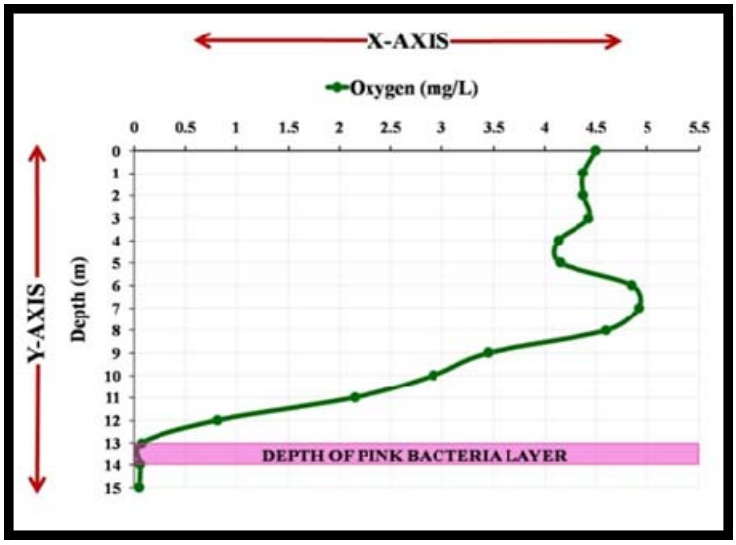
- 15 minutes discussion and analyzing data
  - Graph
  - Answer and discuss review questions
    - What is temperature?
    - What is salinity?
    - How did you measure temperature and salinity? To what depth?
    - Explain graphs (x-axis, y-axis, lines).
    - Explain what is happening to temperature and salinity.
    - Why are temperature and salinity important?
    - Optional: Compare lake temperature and salinity to ocean.
- 25 minutes presentation
- 5 minutes Q & A

Lesson 02: Analyze Oxygen Data and Pink Layer of Bacteria

Background Information

Nearly all life on Earth depends on **oxygen** for living. The levels of oxygen dissolved in the water determine where organisms live in Jellyfish Lake; most living things will be found in the upper layer of water that has oxygen. Living things can die in the lake when oxygen levels become too low. Below the **pink layer of bacteria**, there is no oxygen and only other types of **bacteria**. Instead of oxygen, there is **hydrogen sulfide** dissolved in the water, a poisonous gas produced by decomposing living things. It is the hydrogen sulfide that makes the lake water smell like rotten eggs. High levels of hydrogen sulfide can kill living things.

The pink layer is only an interface or boundary between the layer with oxygen and the layer without oxygen. It is there because it is a suitable habitat/depth for these particular bacteria, which gives the layer a pink color. Below the pink layer, it gets dark because the pink layer blocks light from reaching depths below. The pink layer and **anoxic** layer can move up or down with **density** changes in lake water. Over years, the pink layer has been as shallow as 8m and deep at 15m.



During this part of the lesson, students will join their group from the field day to discuss and analyze their data. Students will either be given a computer or graph paper to graph their oxygen data. If both are not available, they can use a white board to graph their oxygen data. Similar to the temperature and salinity graphs, the oxygen graph will be a line graph. The x-axis, or horizontal line, will represent oxygen. Values will increase from left to right, with the minimum oxygen level on the left end and the maximum oxygen level on the right end. The y-axis, or vertical line, will represent the depth of the lake. Values will decrease from top to bottom, with the minimum value (0m) at the top end and the maximum value (15m) at the bottom end of the y-axis. The x-axis will be at the top of the y-axis, crossing the y-axis at 0m. The oxygen is graphed by connecting each data point that shows the oxygen level at each depth, and the results should show how oxygen levels change with depth.

After graphing their oxygen data, students can identify and highlight the depth of the pink bacteria layer within their oxygen graph. The depth of the pink layer, determined from the

Nansen bottle collection, should match the depth where the oxygen level is zero (or close to it). There are also review questions (Attachment 6) that students should answer as these will help them to better understand and explain their data to their classmates.

When presenting data, students will define oxygen and explain what the y-axis and x-axis on their graph represent. They should explain the changes in dissolved oxygen with depth. Students will also show the depth where living organisms are found in the lake based on their oxygen graph. The students will also define the pink bacteria layer and describe the smell. It is important for students to point out the depth or thickness of the pink bacteria layer.

Vocabulary

Anoxic - absence of oxygen in a body of water.
Bacteria - a tiny unicellular microorganisms with a cell wall but lacking an organized nucleus. They are found almost everywhere, in large numbers and some types can cause disease.
Density - mass of a substance per unit volume; lighter water will float on top of heavier water.
Hydrogen sulfide –-a colorless gas with the characteristic bad odor of rotten eggs. It is poisonous.
Pink layer of bacteria - A layer of pink bacteria that usually forms in stratified lakes between the top and bottom layers of water in the lake.
Oxygen - the colorless odorless gas necessary for most life, a small amount which can dissolve in water, and constitutes 20% of air.

Classroom Activities

- 15 minutes discussion and analyzing data
  - Graph
  - Answer and discuss review questions
    - What is Oxygen & why is it important?
    - How did you measure oxygen?
    - Explain graphs (x-axis, y-axis, lines).
    - Explain the data line, what is happening to oxygen?
    - Show where living organisms are, and where you would not find living organisms.
    - What is the pink layer?
    - What makes it pink?
    - What makes it smell?
    - At what depth did you find the pink layer?
    - **BONUS:** Why is the smell only at a certain depth? What keeps it there?
- 25 minutes presentation
- 5 minutes Q & A

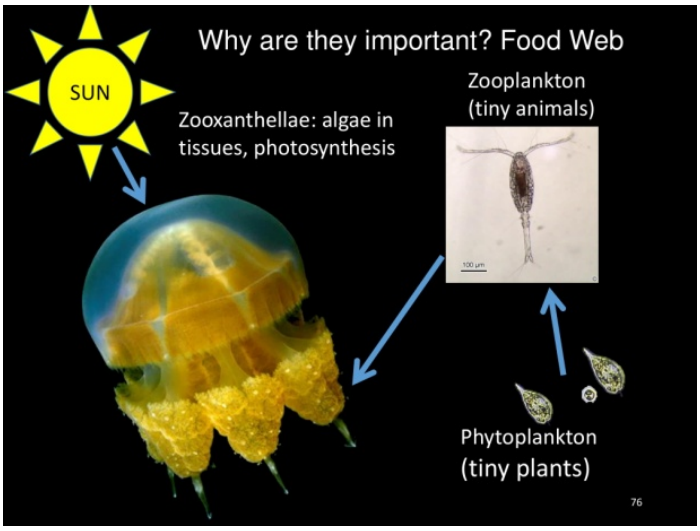
Lesson 03: Identify Plankton Samples and the Food Web

Background Information

Plankton in Jellyfish Lake

There are two types of plankton in Jellyfish Lake. There are **zooplankton**, which are tiny drifting animals. **Phytoplankton** are much smaller tiny drifting plants, which zooplankton feed upon. The zooplankton found in Jellyfish Lake are mostly copepods, but also include mussel and snail larvae. There are different types of phytoplankton in Jellyfish Lake, including a group called **diatoms** (such as *Chaetoceros* sp.) which are abundant. Both zooplankton and their prey phytoplankton are essential parts of the Golden jellyfish **food web** (Attachment 5).

Food Web in Jellyfish Lake



The golden color of the Golden jellyfish comes from symbiotic algae (zooxanthellae) that live in their tissues. The zooxanthellae provide part of the food for the jellyfish through photosynthesis. Golden jellyfish also get some of their energy by capturing (using **stinging cells**) and eating zooplankton. The small zooplankton feed on the even smaller phytoplankton, which like the **zooxanthellae**, get their energy from the sun through photosynthesis. Both food sources are needed for the Golden jellyfish and if just one food source is depleted, then that can affect the population of the Golden jellyfish.

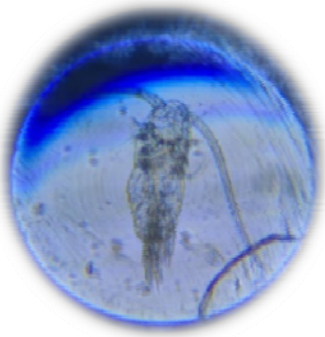
During this last day of the class, students will join their group from the field day and organize their field photos of their samples taken through the microscope. While organizing their photos and drawings, students will need to identify their plankton and separate zooplankton photos and phytoplankton photos. Students will also be given the food web of the Golden jellyfish to review before presenting their data. Showing the food web to the class will make it easier for other students to understand how both types of plankton are important to the Golden jellyfish. There are also review questions (Attachment 6) for this exercise that students will need to answer and use as a guide to their presentation.

Vocabulary

Diatoms - single-celled algae that live in houses made of glass (a cell wall made of silica).
Food web - a graphical model depicting the many food chains linked together to show the feeding relationships of organisms in an ecosystem.
Phytoplankton - tiny drifting plants in the sea.
Stinging cells- specialized cells that contain the stingers and poison used to kill prey for feeding.
Zooplankton - tiny drifting animals in the sea.
Zooxanthellae - tiny plant-like organisms (microalgae) that live in the jellyfish tissue giving it its golden color.

Classroom Activities

- 15 minutes discussion and analyzing data
  - Answer and discuss review questions
    - What is zooplankton?
    - What is phytoplankton?
    - How did you collect them? Describe the method.
    - What did you find using the microscope?
    - Why are plankton important?
      - Explain the food web.
- 25 minutes presentation
- 5 minutes Q & A



Lesson 04: Identify Organisms to Phylum and Identify Common Species

Background Information

Jellyfish Lake is an important area of biodiversity. While it does have some unique elements (such as the endemic Golden jellyfish) it also has some similarities to a mangrove habitat. Many of the organisms in the lake do not live in the open ocean. In Jellyfish Lake, you will find an invertebrate community of sponges, mussels, sea squirts and sea stars, and algae. However, unlike the reefs, there are no corals in Jellyfish Lake. The scavenger hunt is a good way for the students to identify and classify organisms that live in this type of marine environment and be able to compare them to familiar organisms on the lagoon coral reefs.

Classification is important because it helps students to learn and understand the features, similarities and differences between organisms. Classifying organisms is an important part of any biological survey and provides information to help the community or resource managers designate areas for conservation. For example, if a **threatened species** is identified within the study area, then the resource managers can close the area in order to protect that species. Other

times, if species are identified to be abundant in only one particular area, then the area can be closed to protect that population.

In this lesson, students will join their group from the field day and organize their photos and field notes. Students will identify marine species found during the scavenger hunt; they should identify both the common names and phylum. Students are also given review questions (Attachment 6) that will help them to present data.

During the presentation, students will explain to their classmates their site study, what they did and what makes the survey an important part of the lake sampling. Students will also go through the list of their **targeted species** with photos from the field day. By doing this, the rest of the class will be able to see the photos as well as learn about the common name, phylum, genus and species for targeted organisms.

Vocabulary

Targeted species - chosen group of species for monitoring or to be studied.
Threatened species - species that can be endangered in the near future.

Classroom Activities


Seastar, new species


Linckia multifora

- 15 minutes discussion and analyzing data
  - Answer and discuss review questions
    - What is the habitat like?
    - What did you find? Name the phylum and common name of organisms in your pictures.
    - Explain the phylum by describing what kind of animals are in those phyla?
    - What was the easiest to find?
    - What was the hardest to find?
    - Are there corals in Jellyfish Lake?
    - What gives the Golden jellyfish its golden color? Does the Moon jellyfish have the same color?
- 25 minutes for all four presentations (about 6 min/presentation)
- 5 minutes Q & A

Thinking Corner

1. What makes Jellyfish Lake unique?
2. Is monitoring useful? In what ways?
3. What can we do to protect Jellyfish Lake and our natural environments?

TSO PROFILE & PINK BACTERIA LAYER DATASHEET

TSO PROFILE			
Depth (m)	Temperature (°C)	Salinity (psu)	Oxygen (mg/L)
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

PINK BACTERIA LAYER NOTES							
	Smell		Color				
Depth (m)	Yes	No	Clear	Light Pink	Pink	Very Pink	Other

Answer the following questions based on the data that you have just collected.

1. What depth has the highest temperature?

2. What happens to the salinity as you go deeper in the lake?

3. What depth does oxygen go close to zero?

4. Based on the nansen data that you have just collected, what makes the water pink or light pink?

Notes:

SCAVENGER HUNT & ZOOPLANKTON DATASHEET

Date: _____ Group#: _____ Camera #:_____

Group Members: _____

School:_____ Grade: _____

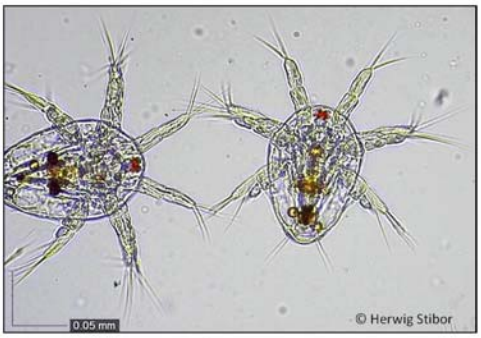
SCAVENGER HUNT					
Phylum	General name	Depth (m)	Color	Substrate	Note
☐ Mollusca ☐ Porifera	Sponge				
☐ Chordata ☐ Cnidaria	Sea Squirt				
☐ Chlorophyta ☐ Porifera	Algae				
☐ Echinodermata ☐ Cnidaria	Invasive Sea Anemone				
☐ Cnidaria ☐ Mollusca	Endemic Sea Anemone				
☐ Mollusca ☐ Porifera	Mussel				
☐ Chlorophyta ☐ Mollusca	Snail				
☐ Chordata ☐ Annelida	Tubeworm				
☐ Echinodermata ☐ Mollusca	Starfish				
☐ Chordata ☐ Porifera	Cardinal Fish				
☐ Cnidaria ☐ Chordata	Golden Jellyfish				
☐ Annelida ☐ Cnidaria	Moon Jellyfish				

ZOOPLANKTON DRAWING

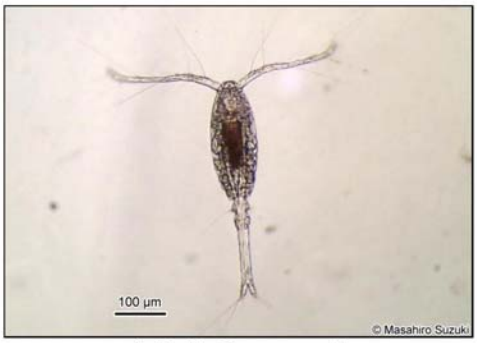
PLANKTON FIELD GUIDE

PLANKTON _ IN JELLYFISH LAKE

ZOOPLANKTON: tiny drifting animal in the sea.



Juvenile Copepod

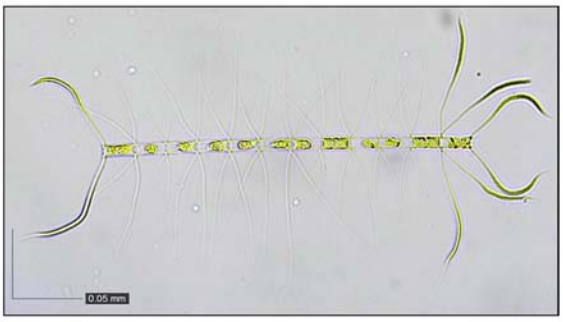


Adult Copepod

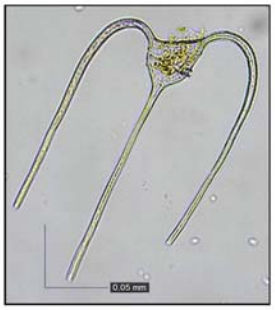
Mussel larvae

Gastropod snail larva

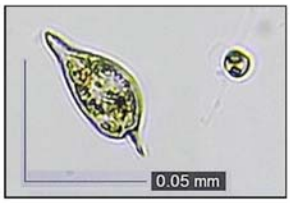
PHYTOPLANKTON: tiny drifting plant in the sea.



Chaetoceros sp.



Ceratium sp.



SCAVENGER HUNT FIELD GUIDE

Common English Name: Cardinal Fish
Scientific Name: *Sphaeramia orbicularis*

Common Name: Green Algae
Scientific Name: *Caulerpa verticillata*

Common Name: Mussels
Scientific Name: *Brachidontes* sp.

Common Name: Sea Snail
Scientific Name: *Drupella margariticola*

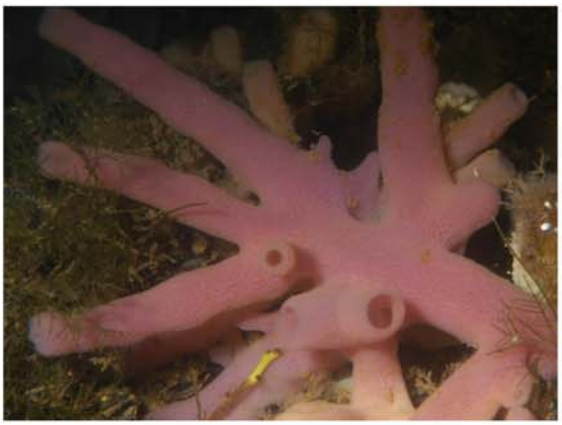
Common Name: Sea Squirt
Scientific Name: *Ascidia gemmata*

Common Name: Starfish
Scientific Name: *Linckia multifora*

Common Name: Endemic Sea Anemone
Scientific Name: ***Entacmaea medusivora***

Common Name: Invasive Sea Anemone
Scientific Name: ***Exaiptasia pallida***

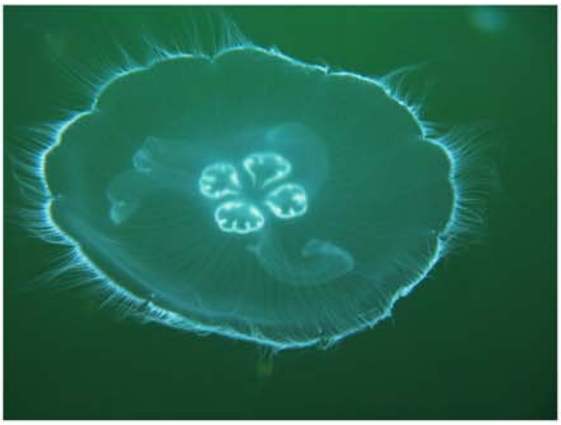
Common Name: Pink Tube Sponge
Scientific Name: ***Haliclona*** **sp.**



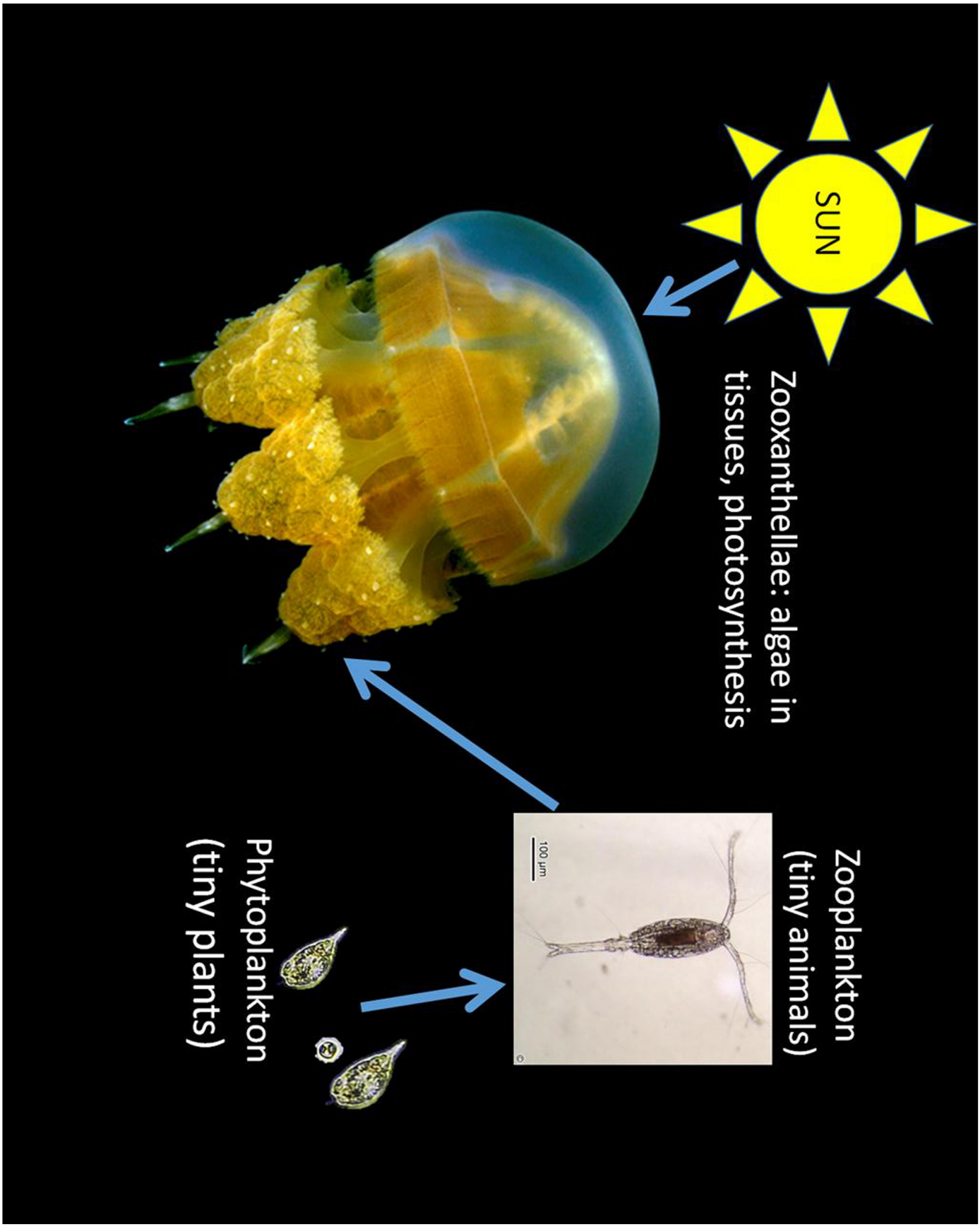
Common Name: Tubeworm
Scientific Name: Unidentified species

Common Name: Golden Jellyfish
Scientific Name: ***Mastigias papua etpisoni***

Common Name: Moon Jellyfish
Scientific Name: ***Aurelia sp.***



JELLYFISH LAKE FOOD WEB



REVIEW QUESTIONS FOR EACH STATION-

Back to Nature: Jellyfish Lake

I. Zooplankton

1. What is zooplankton?
2. What is phytoplankton?
3. How did you collect them? Describe the method.
4. What did you find using the microscope?
5. Why are plankton important? Explain the food web.

II. Temperature & Salinity Profile

1. What is temperature?
2. What is salinity?
3. How did you measure temperature and salinity? To what depth?
4. Explain graphs (x-axis, y-axis, lines).
5. Explain what is happening to temperature and salinity.
6. Why are temperature and salinity important?
7. Optional. Compare lake temperature and salinity to ocean.

III. Oxygen & Nansen bottle

1. What is oxygen? Why is it important?
2. How did you measure oxygen?
3. Explain graphs (x-axis, y-axis, lines).
4. Explain the data line – what is happening to oxygen?
5. Show where living organisms are, and where you would not find living organisms.

For Nansen

6. What is the pink layer?
7. What makes it pink?

8. What makes it smell?

9. At what depth did you find the pink layer?

Bonus: Why is the smell only at a certain depth? What keeps it there?

IV. Scavenger Hunt

1. What is the habitat like?

2. What did you find? Name the phylum and common name of organisms in your pictures.

3. Explain the phylum by describing what kind of animals are in those phyla.

4. What was the easiest to find?

5. What was the hardest to find?

6. Are there corals in Jellyfish Lake?

7. What gives the Golden jellyfish its golden color? Does the Moon jellyfish have the same color?