Pacific Northwest
NATIONAL LABORATORY

Exploring Aquaculture in the Classroom

Note:
This lesson was developed for elementary school students to learn about aquaculture and the potential to power aquaculture farms with renewable forms of energy, such as marine energy. This packet includes background reading for the teacher to use as a resource and useful links to helpful resources if the teacher or students would like more information on any of the topics presented.

This lesson and all related materials were developed by Pacific Northwest National Laboratory (Ruth Branch, Candace Briggs, Molly Grear, Kristin Jones, and Deborah Rose).

Background Information for Teachers

Educational Standards

Next Generation Science Standards

- 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
- 4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
- 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

Common Core Standards for Literacy and Math

- Claim, evidence, reasoning (*RI.4.1*)
- Reading material and comprehension questions (*W.4.9*)
- Charts/graphs (*RI.4.7*)
- Experimental design information and instructions *(W.4.7)*
- Measurement (*4.MD.A.1*)

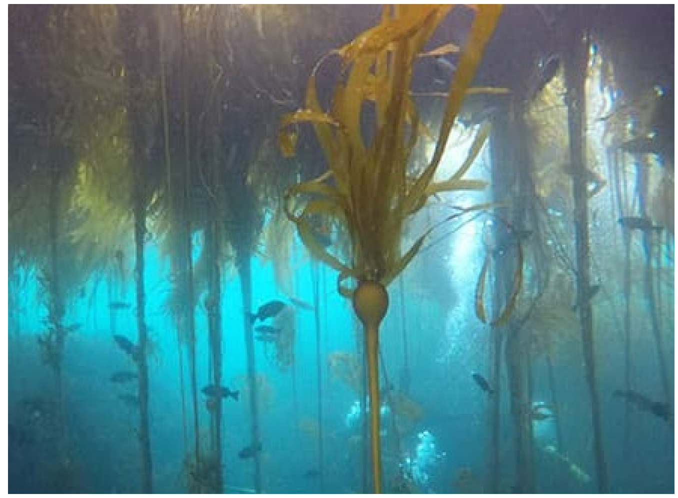
What is aquaculture and why is it important?

Aquaculture is defined as the breeding, raising, growing, and harvesting of fish, shellfish, and plants and can be in freshwater or seawater. This "farming" of aquatic species can be beneficial for a variety of reasons. Aquaculture can help support the food industry, medicine, other commercial industries, and can help to restore endangered or threatened species, as well as create healthier marine habitats. There are a variety of different types of aquaculture, including finfish, shellfish, and seaweed/algae.

Seaweed and algae aquaculture is used predominantly in the food industry for salads, sushi, chips, sauces, seasonings, etc. However, farmed seaweed/algae also has uses in fertilizer, cosmetics, animal feed, extracts, and is increasingly used in biofuel research. Seaweed farming provides opportunities for strengthening local marine habitats by contributing to seaweed restoration, in addition to creating valuable commercial products.

Common seaweeds species grown in aquaculture in the US:

Dulse (*Palmaria palmata*)
Credit: Maine Coast Sea Vegetables



Bull Kelp (*Nereocystis luetkeana*)
Credit: NOAA

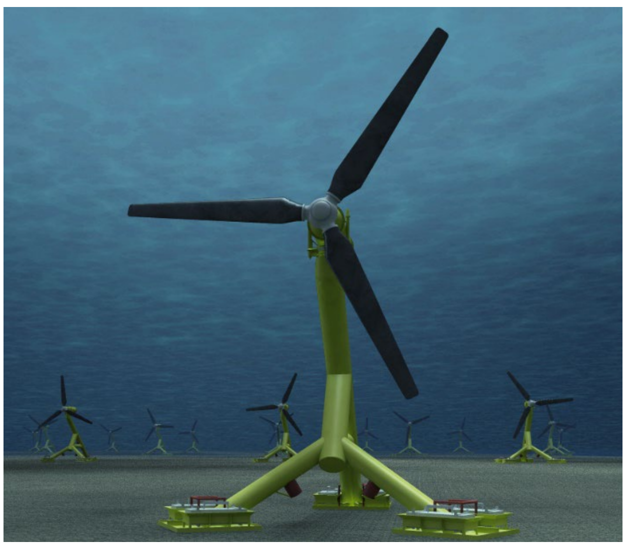
Sugar Kelp (*Saccharina latissima*)
Credit: NOAA Fisheries

Ribbon Kelp (*Alaria marginata*)
Credit: Seaweeds of Alaska

Marine energy and aquaculture

Aquaculture farms and facilities often require power to run their equipment, from their boats, to lighting to other specialized equipment. While most of the power is generated via fossil fuels, the coastal location of aquaculture facilities can present an opportunity to switch to more renewable methods of energy generation, such as marine energy sources. Examples of marine energy methods are wave energy (horizontal and vertical movement of the waves), tidal energy (tidal currents), ocean thermal energy conversion (temperature gradients), ocean current energy, salinity gradient energy.

Determining which type of marine energy may be feasible in a particular aquaculture location would be dependent on a variety of factors, such as power needs, physical and ecosystem characteristics, permitting requirements, and logistic considerations, among others. Tidal energy devices are the most technologically ready of the marine energy methods and are therefore the device that we chose to focus on for this project. Tidal devices use the movement of tides to harness energy and create electricity.



Tidal energy device
Credit: Andritz Group

Wave energy converter
Credit: Ocean Energy Europe

There are many advantages as well as challenges to using marine energy methods to power aquaculture.

Advantages include:

- Removing the need for fuel and reducing fuel cost
- Avoiding potential fuel spills
- Minimizing noise from diesel generators

- The ability to scale to small and large aquaculture facilities

Challenges include:

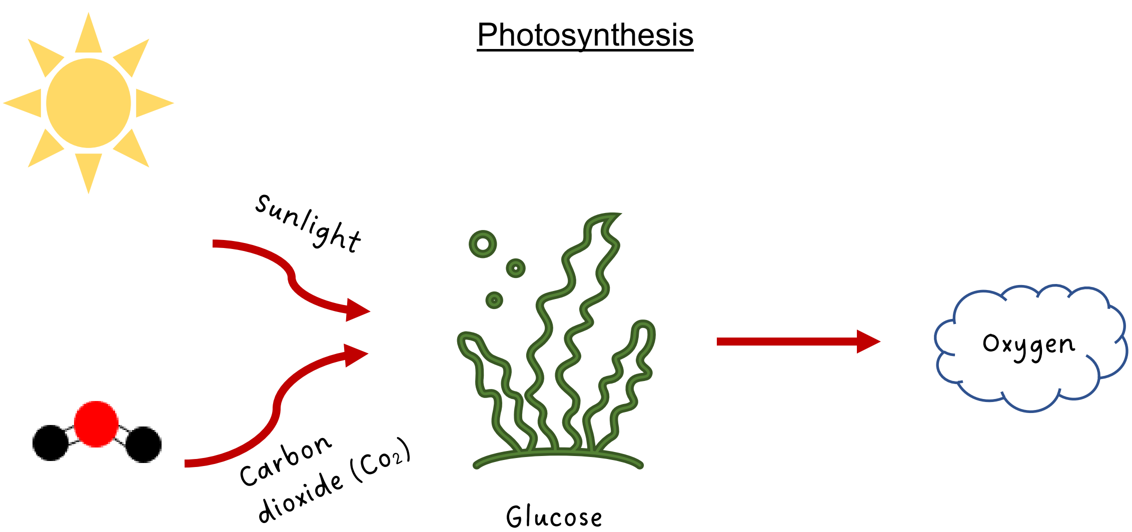
- Installation of technology could be expensive
- Device needs to be a good fit for the aquaculture site, requiring extensive siting and design considerations before it can be implemented

(Freeman et al. 2022)

Seaweed Biology

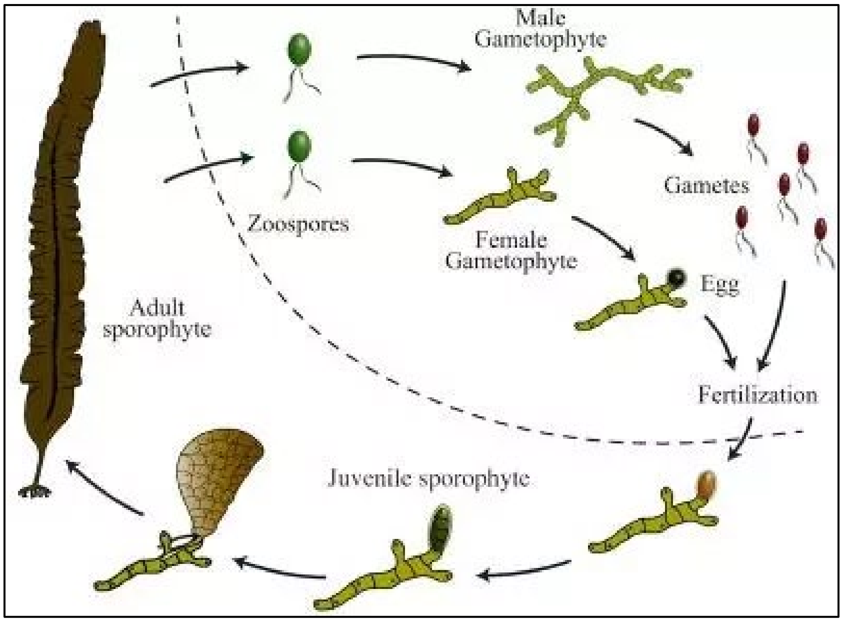
Seaweed, or macroalgae, are a group of mostly photosynthetic algae, found both in freshwater and saltwater environments. Seaweed uses energy from the sun and takes up CO_2 to produce carbohydrates for the plant, and releases oxygen as a byproduct.

Photosynthesis



The seaweed life cycle is different from land plants. Instead of reproducing with flowers and pollen, seaweed produces spores. These spores release into the water column and attach to a suitable substrate, using a holdfast (unless it is a surface algae). The lifecycles of seaweed can be complex and can change depending on the species of seaweed.

An example is given below:

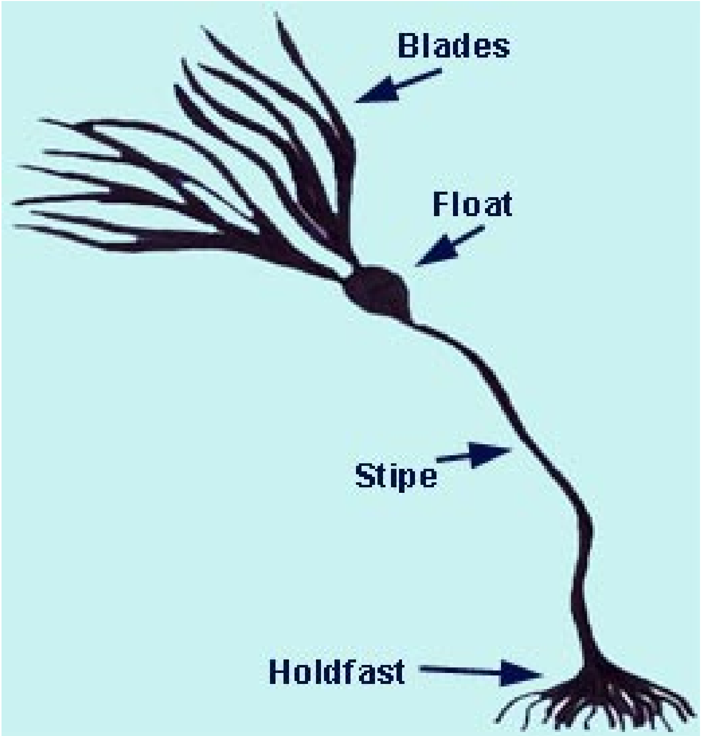


Seaweed life cycle of sexually reproducing species
Credit: [California Sea Grant]

The structure of seaweeds can change depending on species. Below is a general overview of seaweed structure.

Structures:

- **Thallus**: entire body of the seaweed
- **Lamina or blades**: structure that resembles a leaf
- **Air bladders or floats**: gas filled organ that allows the seaweed to float
- **Stipe**: stem like structure
- **Holdfast**: anchors the seaweed to a surface such as sediment or rock



Credit: mesa.edu.au

Importance of Seaweed in the Ocean

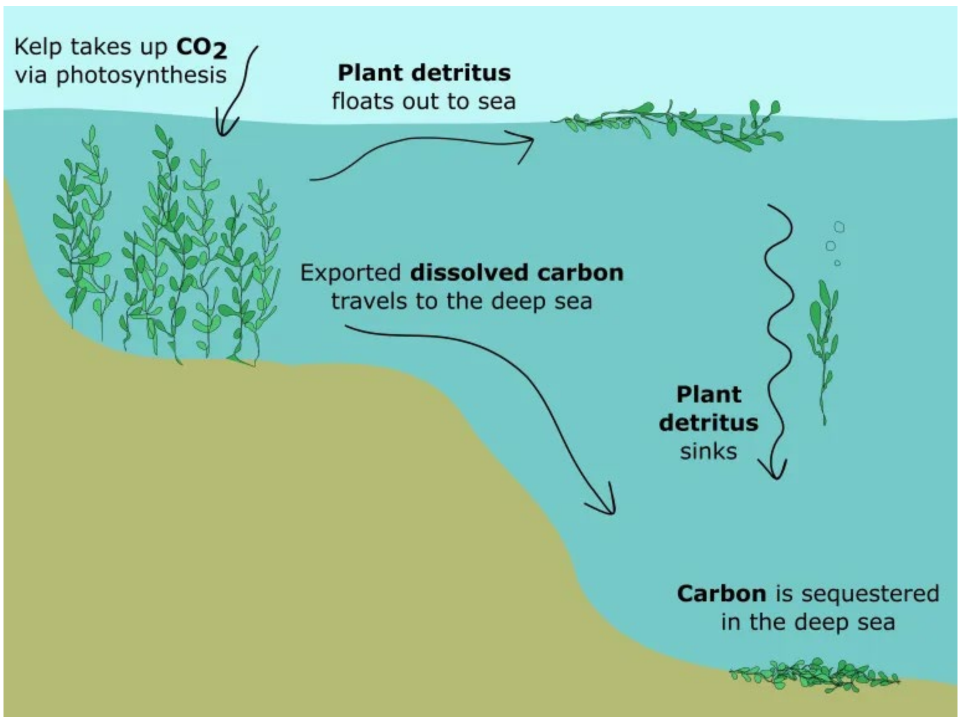
Seaweed plays a critical role in many marine ecosystems. These beneficial roles include:

- Providing food, habitat, and shelter to marine organisms
- Reducing coastal erosion by lowering wave energy
- Mitigating coastal pollution
- Reducing deoxygenation in marine environments

(climatehubs.usda.gov)

Seal in a kelp forest
Credit: Ocean Conservancy

Seaweed also can also help lower atmospheric CO_2 levels and reduce climate change due to greenhouse gases. During photosynthesis, seaweed takes in carbon dioxide (CO_2) from the water and converts it to energy for the seaweed to use. This carbon will slowly be replaced by the carbon in the atmosphere, as the CO_2 from the air dissolves into the ocean to maintain an equilibrium. When the seaweed dies and eventually sinks or is transported to the deep sea by other organisms the carbon is then sequestered, or trapped, in the deep sea, preventing it from returning to the atmosphere for up to hundreds of years (Hurlimann, 2019).



Seaweed carbon sequestration
Credit: harvard.edu

Useful Resources

Aquaculture – General

https://oceanservice.noaa.gov/facts/aquaculture.html

https://tethys.pnnl.gov/sites/default/files/publications/oes-aquaculture-and-ocean-energy.pdf

Aquaculture - Seaweed

https://www.fisheries.noaa.gov/national/aquaculture/seaweed-aquaculture

https://www.climatehubs.usda.gov/hubs/northwest/topic/seaweed-farming-alaska

Marine Energy

https://tethys.pnnl.gov/marine-renewable-energy-educational-resources

https://www.marineenergywales.co.uk/educate/school-resources

https://tethys.pnnl.gov/technology/tidal

https://tethys.pnnl.gov/technology/wave

https://tethys.pnnl.gov/technology/ocean-current

https://tethys.pnnl.gov/technology/otec