What is Dissolved Oxygen?

Shelly Krueger
Florida Sea Grant Agent
University of Florida IFAS Extension, Monroe County
ShellyKrueger@UFL.edu/305-292-4501
monroe.ifas.ufl.edu

DISSOLVED OXYGEN (DO)

Dissolved oxygen, oftentimes abbreviated as DO (dee-oh), is the measure of the amount of free oxygen (O_2) that is dissolved in the water. Fish and invertebrates use their gills to breathe oxygen gas underwater, just like humans use lungs to breathe oxygen gas from the atmosphere. It is one of the most important water quality indicators, because respiration is fundamental for life.

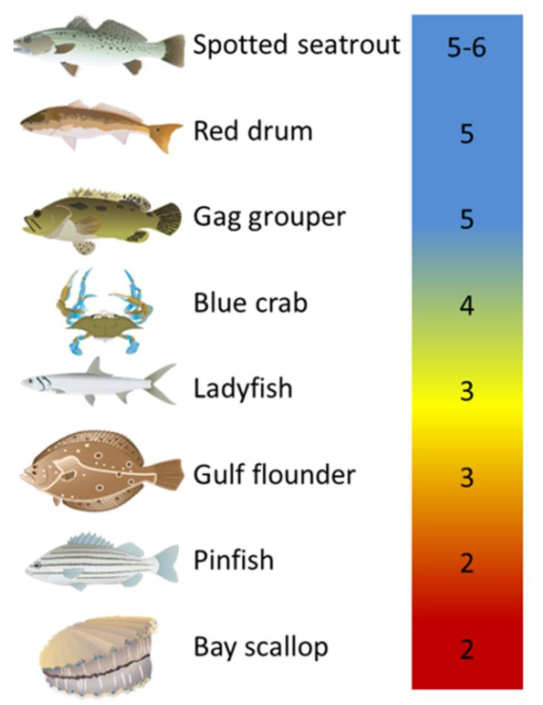


Figure 1. Minimum DO levels (mg/L) by species. Credit SCCF

In general, dissolved oxygen values 5 mg/L and above support proper metabolism, growth and reproduction for marine animals. Many fish can handle very low DO levels, which is why we still see pinfish, tarpon and mullet in canals with very low DO; however, fish with higher oxygen requirements, like grouper, will leave areas with low DO (Fig. 1).

TEMPERATURE and SALINITY

The temperature, salinity and atmospheric pressure determine the amount of oxygen that can physically be dissolved into the water. Dissolved oxygen has an inverse (opposite) relationship with temperature:

Temperature ↑ Dissolved Oxygen ↓

Salinity also effects oxygen saturation. Seawater holds about 20% less oxygen than freshwater at the same temperature and altitude. When the ocean temperature is 30°C (86°F), the oxygen content is 5 milligrams of oxygen per liter (mg/L), which is equivalent to 80% dissolved oxygen saturation (Fig. 2).

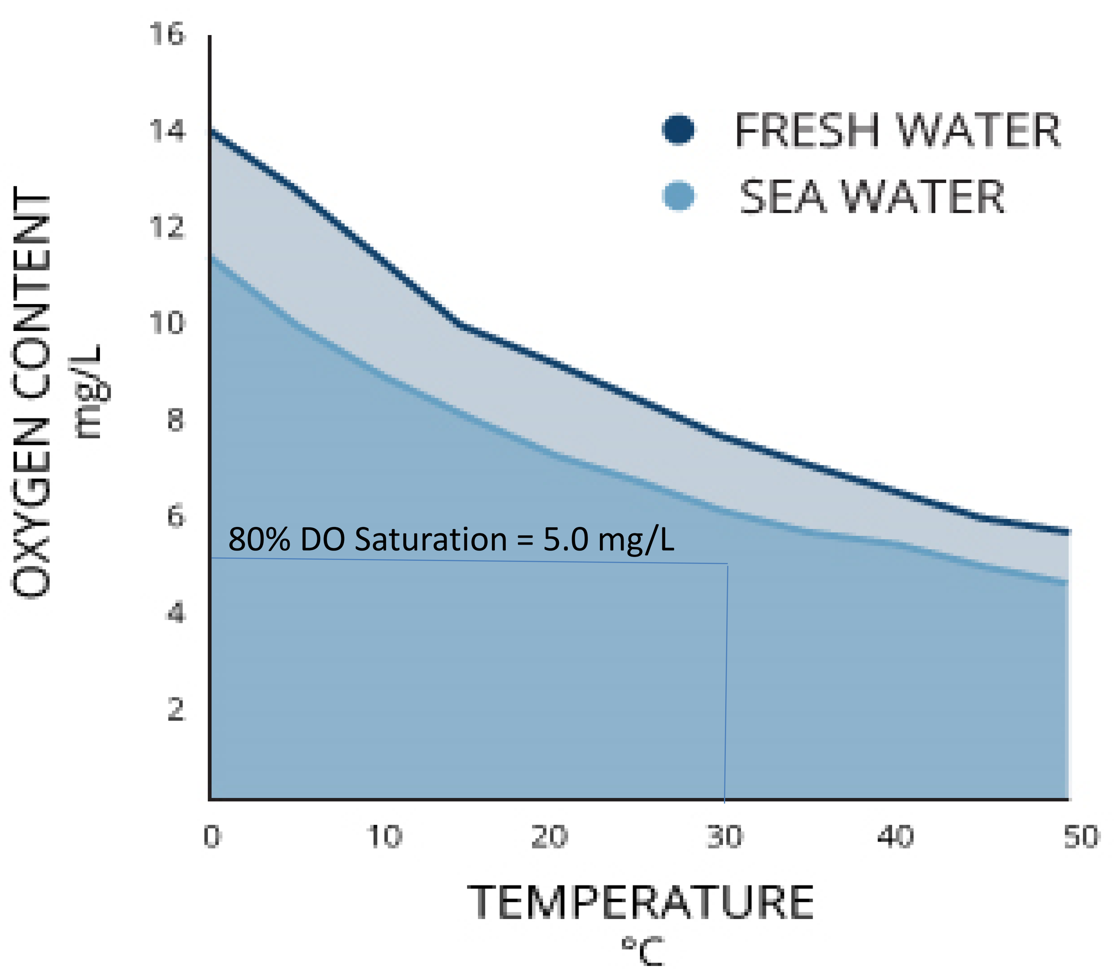


Figure 2. Dissolved oxygen concentrations as temperature increases for freshwater (top line) and saltwater (bottom line). Credit Fondriest

How does oxygen enter the water?

- **Diffusion – Atmospheric O_2 via mixing from waves, wind, currents, tides and groundwater**
- **Photosynthesis – O_2 production in the water from seagrasses, algae and phytoplankton**
- **Artificial – water over a dam, aerators and fountains**

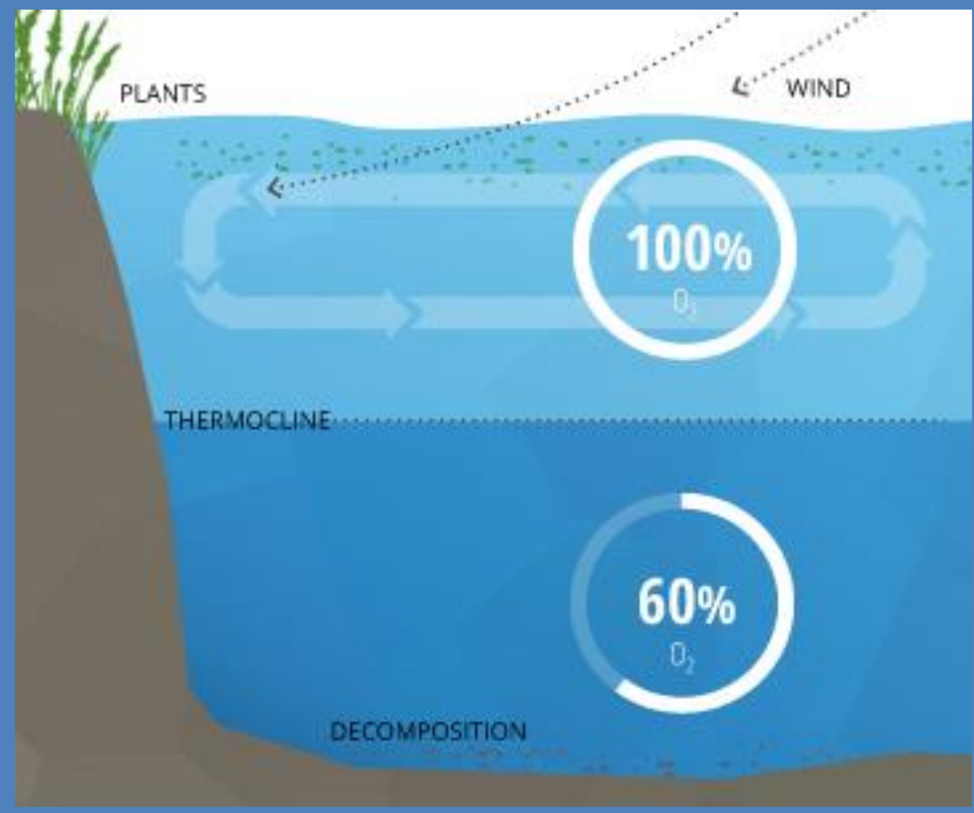


Figure 3. Not all water depths reach 100% saturation. Credit Fondriest

What Factors Affect Dissolved Oxygen (DO)?

Dissolved oxygen (DO) levels vary depending upon a number of physical and biological factors. DO levels are highest at the poles and lowest at the equator. DO levels are highest when the water is cold and lowest when the water is warm. DO levels are higher during the day and decrease at night.

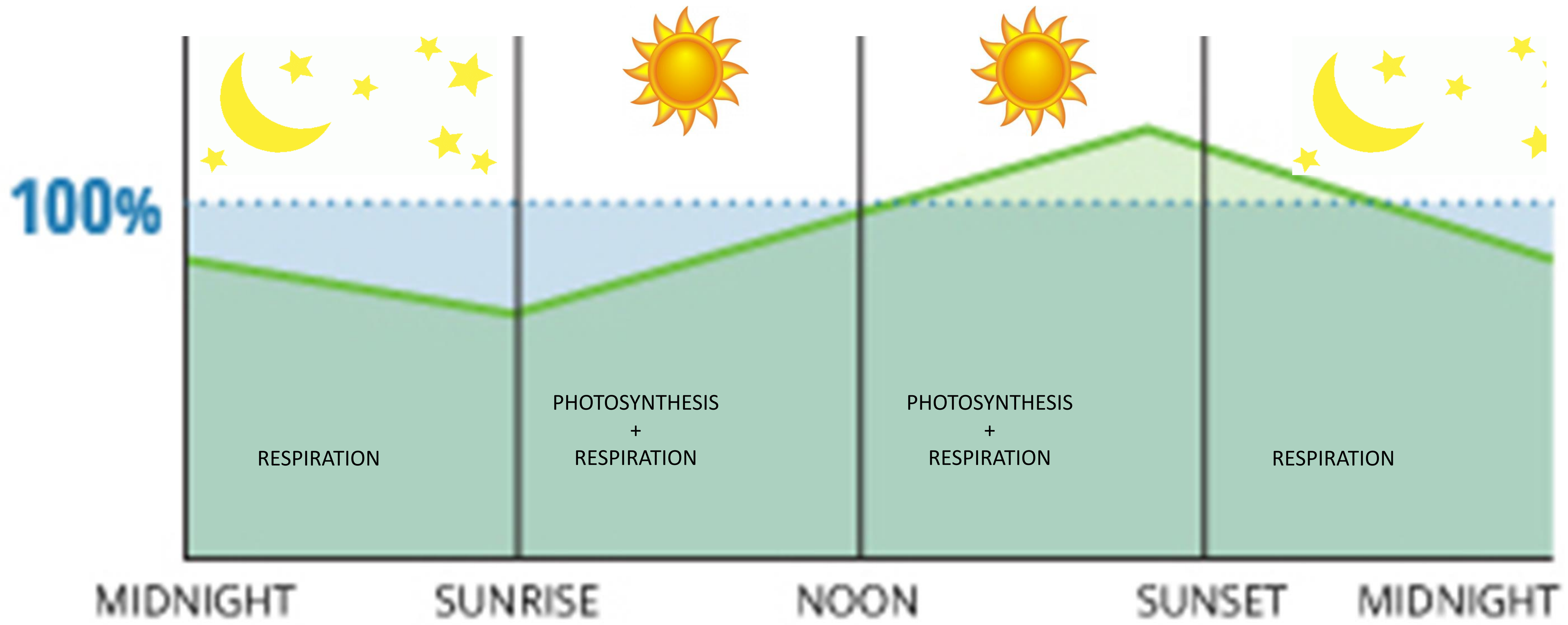


Figure 4. 24 hour (diel) variations in dissolved oxygen levels due to photosynthesis and respiration. Credit Fondriest

DIEL = NIGHT + DAY

Diurnal means during the day, and nocturnal means during the night. Diel refers to the 24 hour period of both day and night. Just like the plants and trees on Earth, the plants and algae in the water produce oxygen, and need oxygen to breathe. When the sun shines, they produce oxygen, but at night, they only consume oxygen – this is why early morning tends to have the lowest levels of dissolved oxygen -- until the sun rises, when photosynthesis starts again. Afternoon oxygen levels can exceed 100% DO saturation (super-saturated) because the rate of photosynthesis is high from solar energy (Fig. 4).

STRATIFICATION

Stratification is when the waterbody has different layers that create a barrier for mixing. These strata develop based on the different densities between the water layers and the general term is pycnocline. Warmer water is lighter than cold water, which creates a thermocline. Freshwater is lighter than saltwater, so after a rain event freshwater may sit on top of the denser, saltier water, thus creating a halocline. Wind, waves, currents and tides help these layers to mix. Many of the Keys canals are deeper than the basins they are adjacent too, which means there is really only mixing of the top layers, and oxygen saturation decreases greatly with depth when the surface oxygenated layers cannot mix with the bottom layers (Fig. 3). This can lead to very low oxygen environments (hypoxia) and even the absence of oxygen at the bottom (anoxia).

DECOMPOSITION

Decomposition is the decay of organic matter. When seagrasses and algae decay the microbes that break them down consume oxygen through their metabolism, which depletes the water of oxygen. In the absence of oxygen, the process of decomposition can create hydrogen sulfide, which releases the characteristic “rotten egg” smell.

DISSOLVED OXYGEN SATURATION

Dissolved oxygen saturation varies throughout the day and night. When there is more oxygen consumption by animals, plants and bacteria than oxygen production by plants and mixing from the atmosphere, oxygen saturation values naturally go down. The oxygen is being consumed by animals, plants and bacteria faster than it is being replenished. DO saturation also declines with depth (Fig. 3). The highest dissolved oxygen levels tend to be at the surface because oxygen concentrations are higher in the atmosphere and most mixing occurs at the surface through diffusion. In order to meet Florida Department of Environmental Protection (FDEP) state standards for water quality, coastal waters must have a diel average at or above 42% DO saturation. Percent dissolved oxygen saturation is a good calculation for marine life because it incorporates local conditions for temperature, salinity and atmospheric pressure.

Literature Cited:

Engineering ToolBox. 2005. “Oxygen Solubility in Fresh Water and Sea Water.”
FDEP. 2013. “Derivation of dissolved oxygen criteria to protect aquatic life in Florida’s fresh and marine waters.” DEP-SAS-001/13, 232 pp.
Fondriest Environmental, Inc. 2013. “Dissolved Oxygen.” Fundamentals of Environmental Measurements.
Sanibel-Captiva Conservation Foundation. 2018. “Hypoxia.”

Funding provided by the EPA South Florida Initiative Grant #00D41115

Sea Grant Florida | NOAA | UF University of Florida | UF IFAS University of Florida

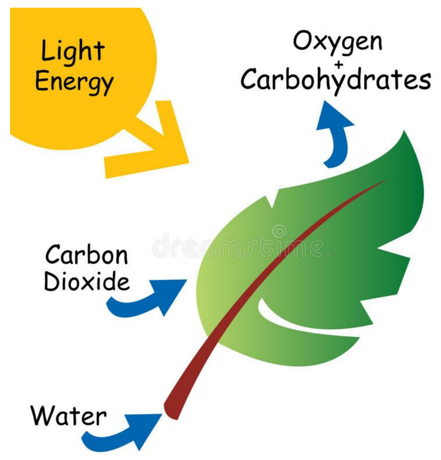
What are Nutrients?

Shelly Krueger
Florida Sea Grant Agent
University of Florida IFAS Extension, Monroe County
ShellyKrueger@UFL.edu/305-292-4501
monroe.ifas.ufl.edu

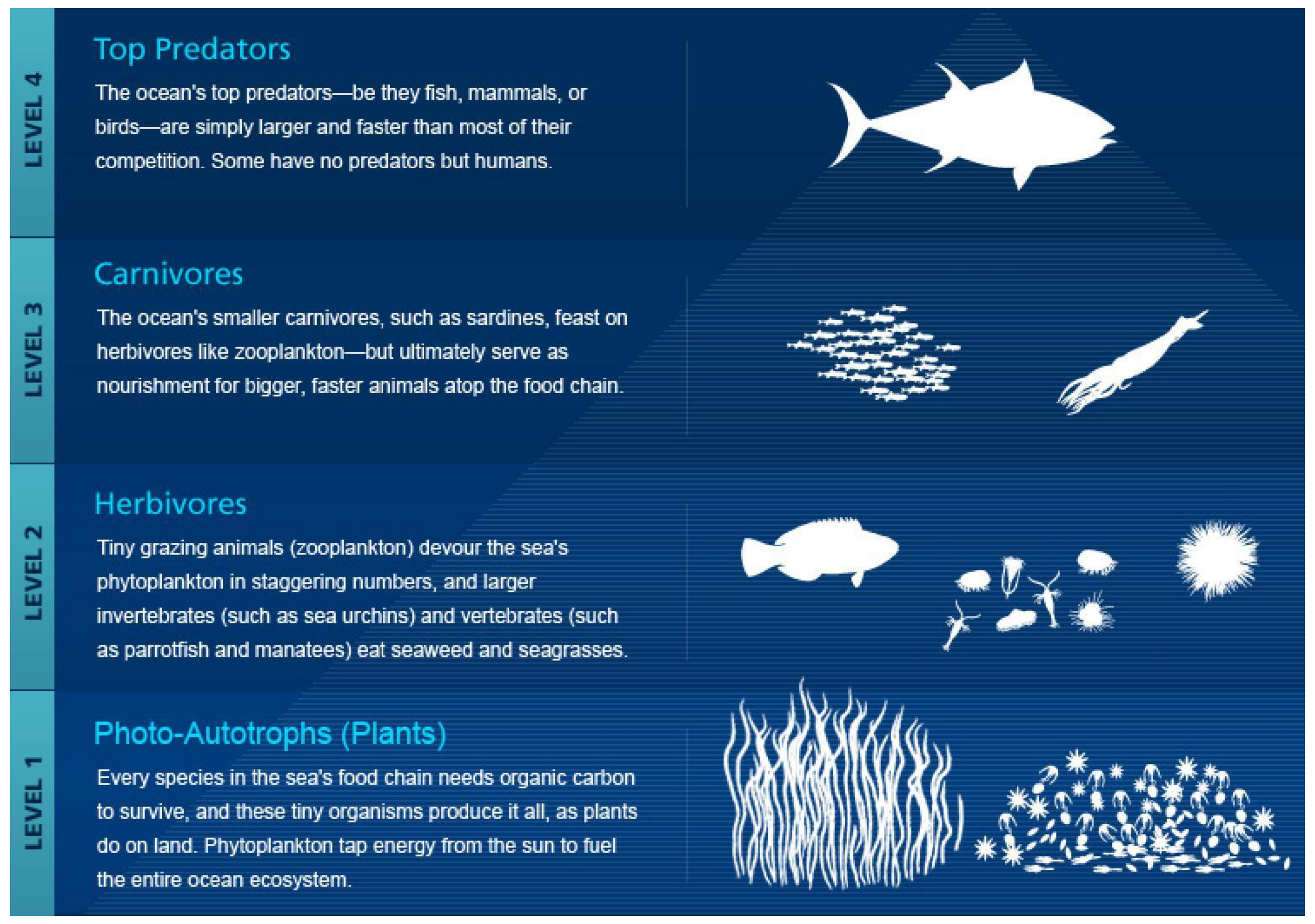
EUTROPHICATION

Eutrophication (you-trof-eh-cation) is just a really big word for too many nutrients. In the marine environment, when we talk about too many nutrients, we are talking about nitrogen (N) and phosphorus (P). Just like the fertilizers that grow plants on land, N and P stimulate plant and algal growth in the marine environment. One of the biggest consequences of too many nutrients = too much phytoplankton, followed by low dissolved oxygen in the water.

PRIMARY PRODUCERS



Primary producers are plants and algae that perform photosynthesis to create energy and oxygen. Primary producers are incredibly important because they form the base of the food chain and produce the oxygen we breathe in the atmosphere. Primary producers are the only group that create their own food; all other organisms on Earth must eat to obtain energy for growth and reproduction. There are two types of primary producers in the ocean: seagrasses, which are true plants, and algae. Algae are divided into two groups: micro-algae and macro-algae.



Ocean Food Chain. Credit NOAA

- **Phytoplankton (Micro-algae)**

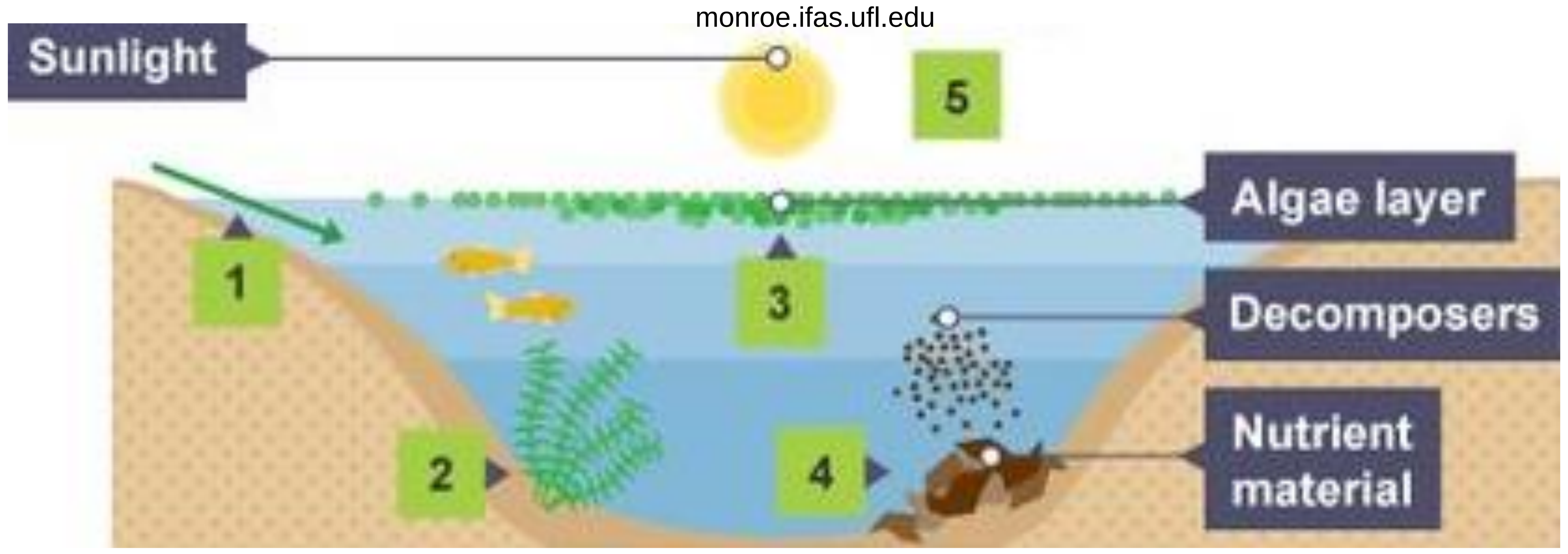
Phytoplankton are microscopic, single-celled organisms that float in the top layers of the Earth's oceans and produce 40% of the Earth's oxygen supply.

- **Seaweed (Macro-algae)**

Seaweed is the common name for large, visible algae. Sargassum, halimeda, mermaid's cups, shaving brushes and hair algae are common seaweeds in the Florida Keys.

- **Seagrasses (True Plants)**

Did you know the Florida Keys are surrounded by one of the largest seagrass beds in the world? The three most common are turtle grass, manatee grass and shoal grass.



Timeline for Eutrophication. Credit BBC Bitesize

Timeline for Eutrophication

1 Nutrient Loading: Nitrogen (N) and phosphorus (P) enter the waterbody from the surrounding watershed from urban runoff, agriculture, fertilizers, detergents, animal and human waste.

2 Primary producers proliferate: The N and P act like fertilizers, stimulating exponential phytoplankton (microalgae), seaweed (macroalgae) and seagrass growth.

3 Algae Bloom: The abundance of phytoplankton creates an algae bloom. The phytoplankton may become so thick they can block light to the seagrasses at the bottom. The water may appear very green or red-brown.

4 Decomposition: The phytoplankton decay, and the decomposition of the organic matter by microbes removes oxygen from the water.

5 Very low oxygen levels lead to fish kills. Some phytoplankton blooms cause health effects in humans, and death for dolphins and manatees.

What is Non-Point Source Pollution?

Non-point source pollution is the type of pollution that comes from diffuse sources. The more impervious surfaces, like parking lots, roads and urban development, the more nonpoint source pollution enters waterways. This is because after a rain event, the rainwater literally runs-off into the nearest waterbody – rivers, lakes, estuaries and oceans. When rainfall travels over the ground, it picks up whatever pollutants the water encounters – sediment, fertilizers, pesticides, fossil fuels, animal waste and heavy metals, and carries them through the watershed via gravity to waterways. It is important to educate residents about nonpoint source pollution because we can all prevent pollution entering waterways in the first place.

What is a Harmful Algal Bloom (HAB)?

A proliferation of algae is called an algal bloom. Algal blooms can deplete the water of oxygen and cause fish kills. Some phytoplankton species contain toxins that are harmful to humans, which are called Harmful Algal Blooms (HABs). The red tide causing species, *Karenia brevis*, causes respiratory problems in humans, fish kills and dolphin deaths. Drinking or inhaling contaminated water from some toxic blooms, or eating contaminated shellfish, can cause liver disease and long-term cognitive dysfunction in humans and marine mammals.

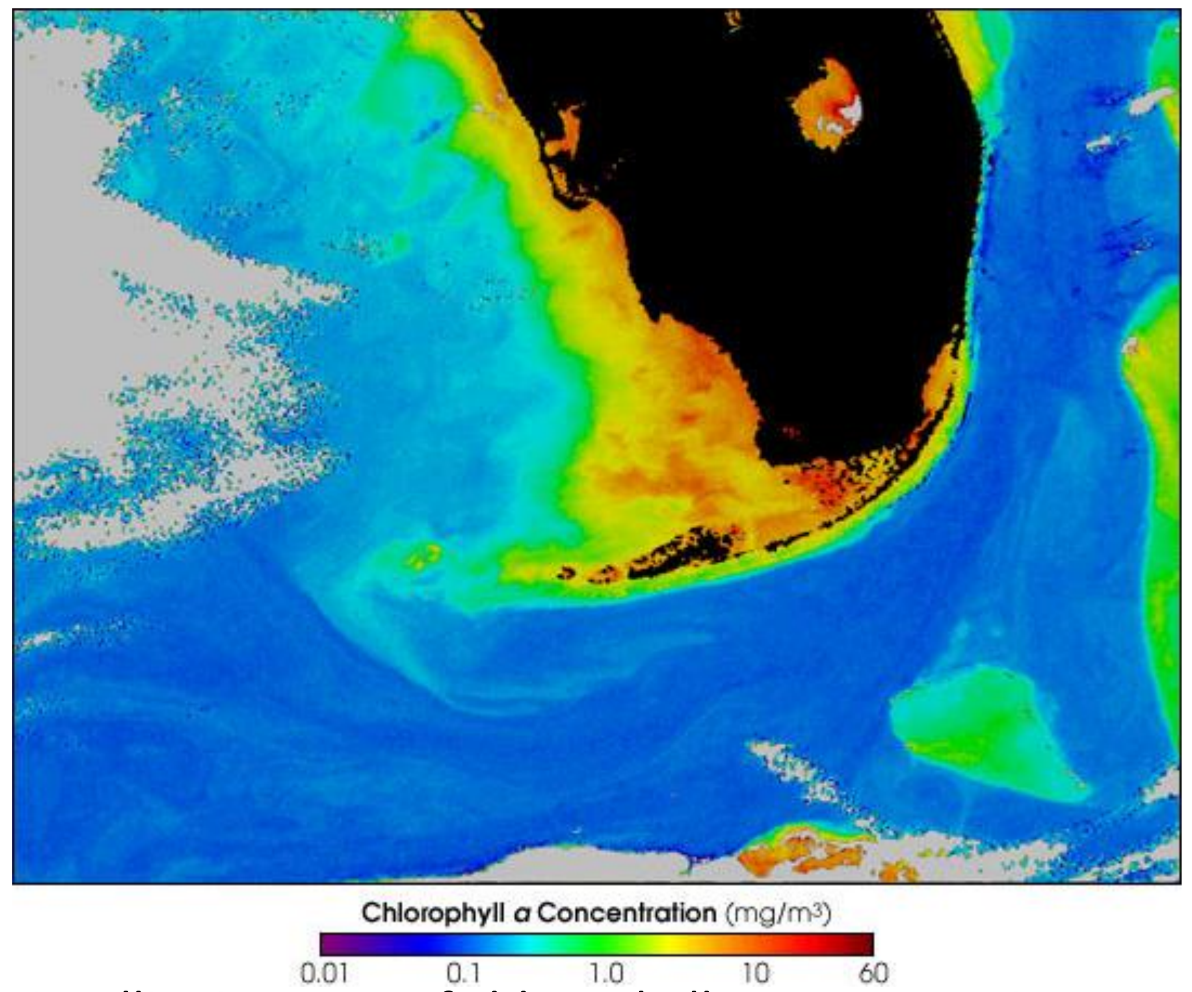
NITROGEN

Nitrogen is an organic element with the atomic symbol N, and it is present in all life forms. The majority of the air we breathe is nitrogen gas (N_2; 78%) followed by oxygen gas (O_2; 21%). Nitrogen gas in the atmosphere is inert, and must be converted into a usable form for living organisms to build amino acids for proteins and nucleic acids for DNA and RNA. Nitrogen is taken up by seagrasses, seaweed and phytoplankton in the form of nitrate (NO_3) and ammonium (NH_4) and incorporated into their tissues, which forms the base of the food chain.

PHOSPHORUS

Phosphorus is an organic element with the atomic symbol P, and it is required for aquatic plant growth. Phosphorus is a building block for energy. It is also a key element in fertilizer, because it increases plant growth.

When concentrations of N and P are high, it is like a buffet for phytoplankton, which causes them to multiply exponentially. The Gulf of Mexico Dead Zone is an example of a low oxygen area from too much N and P entering the Gulf of Mexico from the Mississippi River watershed.



Satellite imagery of chlorophyll A concentrations in South Florida. Credit SEAWiFS

What is Chlorophyll A?

Chlorophyll A is the primary photoreceptor used for photosynthesis by aquatic plants and algae. Chlorophyll A gives plants and algae their green pigment and it is used as a proxy to estimate the amount of phytoplankton in the water column. There are scientific instruments and even satellites that measure the chlorophyll A pigment to estimate the abundance of phytoplankton in the environment.

Funding provided by the EPA South Florida Initiative Grant #00D41115