Also, when surface waters are cold, it is easier for deeper water to rise to the surface, bringing nutrients to sunlit areas where phytoplankton can use them. When surface water is warm, cooler, nutrient-rich water is trapped below. Because the vertical layers of the ocean aren’t mixing, nutrients that have built up in deep waters can’t reach the surface.

<https://earthobservatory.nasa.gov/global-maps/MY1DMM_CHLORA/MYD28M>

The turbidity of a body of water is related to the cleanliness of the water. Waters with low concentrations of total suspended solids (TSS) are clearer and less turbid than those with high TSS concentrations. Turbidity can be caused by high concentrations of biota such as phytoplankton, or by loading of abiotic matter such as sediments. Turbidity is important in aquatic systems as it can alter light intensities through the water column, thus potentially affecting rates of photosynthesis and the distribution of organisms within the water column. Lowered rates of photosynthesis may in turn affect the levels of dissolved oxygen available in a given body of water, thus affecting larger populations such as fish.

<https://serc.carleton.edu/microbelife/research_methods/environ_sampling/turbidity.html>

At the base of the ocean food web are single-celled algae and other plant-like organisms known as phytoplankton. Like plants on land, phytoplankton use chlorophyll and other light-harvesting pigments to carry out photosynthesis. Where phytoplankton grow depends on available sunlight, temperature, and nutrient levels. Because cold waters tend to have more nutrients than warm waters, phytoplankton tend to be more plentiful where waters ware cold.

Places where chlorophyll amounts were very low, indicating very low numbers of phytoplankton are blue. Places where chlorophyll concentrations were high, meaning many phytoplankton were growing, are dark green.

<https://earthobservatory.nasa.gov/global-maps/MY1DMM_CHLORA/MYD28M>

Increased nutrient availability, for example from human activity (e.g. agricultural runoff, soil erosion, discharges of sewage and aquaculture waste) usually leads to an increase in chlorophyll concentrations in coastal waters because of increased phytoplankton biomass.

<https://eatlas.org.au/data/uuid/eb16c150-c7b4-11dc-b99b-00008a07204e>

Chlorophyll a is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll a concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. They can be an effective measure of trophic status1, are potential indicators of maximum photosynthetic rate (P-max)2 and are a commonly used measure of water quality. High levels often indicate poor water quality and low levels often suggest good conditions. However, elevated chlorophyll a concentrations are not necessarily a bad thing. It is the long-term persistence of elevated levels that is a problem.

It is natural for chlorophyll a levels to fluctuate over time. Chlorophyll a concentrations are often higher after rainfall, particularly if the rain has flushed nutrients into the water. Higher chlorophyll a levels are also common during the summer months when water temperatures and light levels.

Elevated concentrations of chlorophyll a can reflect an increase in nutrient loads (see Figure 1) and increasing trends can indicate eutrophication of aquatic ecosystems.

<https://ozcoasts.org.au/indicators/biophysical-indicators/chlorophyll_a/>

Phytoplankton productivity is one of the main forces regulating our planetary climate for via impacts on atmospheric carbon dioxide levels which are closely linked to the oceanic carbon dioxide concentrations6. However, excessive water column productivity, expressed by high chlorophyll a concentrations, can supply large amounts of easily decomposition (i.e. labile) organic matter to the sediments. The decomposition of algal biomass can increase the diurnal amplitude of water column pH and dissolved oxygen fluctuations, and in some cases may lead to anoxic & hypoxic events. Moreover, elevated chlorophyll a levels indicate high numbers of phytoplankton and free floating macroalgae which can shade seagrass meadows leading to a decline in seagrass distribution7. The above changes can translate into changes in animal and plant species diversity8.

Blooms of Trichodesmium colonies likely play key roles in the ecosystem because of their ability to fix atmospheric nitrogen [13, 14], thereby contributing to new nitrogen inputs in oligotrophic waters [15–18].

In general, hot water puts coral under stress. Under such conditions, the coral expels the tiny algae, zooxanthellae, that live in symbiosis with it. The algae give the coral its color and produce nutrients through photosynthesis, so when the algae are expelled, the coral turns white and eventually dies. The process is called coral bleaching.

But coral bleaching is only one symptom of an ecosystem in hot water: high temperatures have a negative impact on other parts of the marine ecosystem as well. “All marine species operate within a range of environmental parameters. Once this changes, the effects cascade through the food-chain,” says Scarla Weeks, an ocean researcher at the University of Queensland, Australia, funded by the Pew Institute for Ocean Science. Ocean currents are driven in part by water temperature, and if a current shifts, this may impact an entire ecosystem. Warmer temperatures may result in decreased concentrations of phytoplankton, the tiny plants that grow in the upper sun-lit layer of the ocean. Because phytoplankton form the base of the marine food chain, their decline will cascade through the food chain. Larger animals like fish will have little to eat and either die or move elsewhere. Loss of fish impacts the sea birds that feed on them. In 2002, says Weeks, high sea surface temperatures led to the worst bleaching event on record in the Great Barrier Reef. The same year, 50 percent of seabird chicks on Heron Island in the southern Great Barrier Reef starved because the adult birds were unable to find enough fish.

<https://earthobservatory.nasa.gov/images/6441/bleaching-on-the-great-barrier-reef>

Coral and algae live in a delicate, mutually-beneficial relationship with each other. Nutrients are the big concerns in reef environments because if their levels are too high they can upset the natural balance of these ecosystems. For example, some plants grab the extra nutrients and grow to dominate in size or quantity more than they normally would.

Levels of these nutrients get too high when excess amounts are washed into the sea from the land. Annual discharge of nutrients into the Great Barrier Reef has more than doubled since European settlement.

There is strong evidence for several effects of nutrients in the Great Barrier Reef including increased outbreaks of coral-eating crown-of-thorns starfish, lower coral diversity, algal blooms (that reduce light and add their own nutrients), increased susceptibility to coral bleaching and some coral diseases. While most effects occur in the wet season, some effects may continue for many years, for example crown-of-thorns starfish outbreaks.

The current scientific consensus is that nitrogen inputs are more likely to cause crown-of-thorns starfish outbreaks than other nutrients.

Sometimes problems are caused by the patterns of the excess growth, such as with mangroves. Nutrients – again especially nitrogen – stimulate the growth of shoots relative to roots, which causes physical instability of the mangrove trees and increases their risk to sea level rise.

<https://www.reefplan.qld.gov.au/resources/explainers/the-good-and-bad-of-nutrients>

<http://www.bom.gov.au/climate/enso/lnlist/>

<http://www.bom.gov.au/climate/updates/articles/a020.shtml>

"Corals are sensitive organisms, known to only tolerate slight changes in their environment. Thriving in clear, sunlit waters -- the majority of reef-building corals are found in tropical and subtropical waters with a salinity between 32 to 42 parts per thousand," said senior author Prof David Miller of Coral CoE.

<https://www.sciencedaily.com/releases/2019/02/190228093626.htm>

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How do these findings affect coral reef health?

## Higher temperatures cause a decline in salinity levels