**Syllabus for the Reef Care Curacao workshop on nutrient pollution with Dr. Brian Lapointe, Curacao, 23 Oct 1998**

Living nature can be divided in different areas with specific plants and animals. The group of organisms in a certain area and the way in which these organisms interact with each other is called an ecosystem. Examples of ecosystems are coral reefs, deserts, taigas, rain forests and savannas. The outward boundaries of ecosystems are set by physical factors such as temperature, rain and geological shape of the land. Polar regions are different from the tropics in temperature, but within the tropical zone there are wet and arid areas. The geological shape can mean plains or mountains, small islands or large continents, shallow or deep sea. Organisms are adapted to live under specific circumstances and the occurrence of such circumstances determines which animals and plants can be found where. These influences are called abiotic factors. Relations between the organisms determine the detailed composition of that ecosystem (e.g. predators eating prey, trees create a place for birds to build a nest, corals and sponges compete for space on a reef flat, etc.). Such influences of organisms on each other are called biotic factors. The availability of nutrients depends on a combination of abiotic and biotic factors.

The term 'nutrient' in a broad and general sense means food. Organisms need nutrition or food to obtain the necessary energy and building materials to grow, maintain and reproduce. However, more commonly the term nutrients is used for the chemical elements nitrogen and phosphorus. With nutrient pollution or eutrophication we mean an increase in nitrogen (usually as ammonium or nitrate) and phosphorus (as phosphate) in a natural environment. Before I go into the details of eutrophication, let me first explain the role of the elements in an ecosystem.

Plants fix energy from sunlight into organic material in a process called photosynthesis. Plant eating animals (herbivores) obtain the necessary energy to live by eating plants. Animal eating animals (carnivores) eat herbivores or other carnivores. This way energy is transferred through the food chain from plants to herbivores to carnivores. It is important to realize that there is only one input in the system: plants fixing sunlight. All other organisms depend on the presence of plants for their energy. Energy is transferred through the ecosystem until it is lost.

Aside from fixing energy into organic material, a plant needs building materials to make itself: stem, leaves, roots, flowers; the whole thing. These materials usually expressed as their chemical elements, e.g. carbon (C), nitrogen (N), phosphorus (P), hydrogen (H), oxygen (O), etc. In reality these elements are bound in organic molecules. C, O and H form the largest part of living or organic matter. Nitrogen is a necessary element in for example protein molecules and phosphate occurs in cell membranes. Also, both elements N and P are necessary parts of DNA. Other elements are needed in small amounts to form a body, such as iron or copper. In a whole living body these materials are needed in certain amounts. Plants in sea consist of C and N and P in a ratio of approximately 106:45:5. Plants need to obtain these different elements in different amounts from the environment. C is present in $CO_2$. H is in water ($H_2O$), N in $NH_4$ (ammonium) or $NO_2$ (nitrate) and P in $PO_4$ (phosphate). O is present in almost all of these molecules. The

ratio in which these building materials are available is mostly not the same as the ratio in which they are needed. Of one of these elements there will be less available relative to the others, which means that this element becomes limiting for growth. In the sea there is of course water enough and H and O are never a problem. CO2 dissolves into the water from the atmosphere and is usually sufficiently present as well. The limiting nutrient is most commonly N or P (although there are areas where neither N or P, but iron is limiting). Hence the common use of the term nutrient pollution for excess inputs of ammonium (NH4), nitrate (NO3) and phosphate (PO4).

Like energy, nutrients are transferred through the ecosystem as one organism eats another. There is, however, an important difference: nutrients are not used up, but become released again. Animals that eat plants burn 80-90% of their food for energy and use only the rest for growth of their body and reproduction. This means that they eat far more N and P than they need and the surplus has to be excreted. Also every organism dies at some time and when bacteria break down the remains, nutrients become available again. The essential difference with energy is that nutrients are cycled through an ecosystem. Plants take up inorganic nutrients from their environment and fix them in organic material, animals eat plants and excrete organic nutrients, and bacteria convert these back to inorganic nutrients, which can be used by plants again. As long as none are lost, nutrients could in theory be recycled forever through an ecosystem. In reality, ecosystems are not closed and nutrients are imported and exported: animals move in or away, water currents bring or take away organisms and molecules, dead organisms disappear into deep water, etc. In Long living ecosystems the import and export of nutrients are usually balanced: as much comes as goes out.

One of the major effects of humans on their environments is that we change the nutrient balance by increasing the nutrients concentrations. We use fertilizers in agriculture, which is nothing else than nutrients for plants we wish to grow. These plants cannot use all the nutrients we supply and much of the loading is lost to the environment. Sewage consists of nutrients in organic and, if treated in a sewage plant, inorganic forms. These nutrients are generally discharged into our environment. At the same time we often reduce the capacity of nature around us to use these nutrients by removing the natural vegetation for agriculture or urban development. Humans eutrophy their environment and the larger and denser the population is, the stronger the nutrient pollution.

So, why is this a problem? We are basically giving plants and thereby all the animals in the ecosystem materials that they need, don't we? The answer is that reality is not that simple. Yes, plants need nutrients, but only a limited amount. The problem is that increases in nutrients lead to changes in the ecosystem. Some plants are specialized to survive in an environment with low nutrient concentrations, while other plants dominate with high nutrient concentrations. When nutrient levels are increased the ecosystem shifts from low nutrient specialists to high nutrient specialists. Ultimately this leads to completely different ecosystems under long term eutrophication. Generally this leads to a reduction of the diversity within ecosystems and variation between ecosystems.