CHAPTER 20

OUR FRESHWATER LAKES; STREAMS; WETLANDS; AND RIVERINE FORESTS

20. 1. APPRECIATING OPEN FRESHWATERS AND WETLANDS

20. 1. 1. Introduction

Have you ever wondered why is there such a big fuss about preserving and protecting our freshwater lakes, streams and wetlands? Well, you're definitely not alone.

Wetlands have long been a misunderstood and severely abused component of our natural environment. In the past, people perceived wetlands as useless, unproductive swamps. We have continually drained, filled, channeled, built on, and polluted them.

It has only been in the last 30 years that we have come to realize the significance and importance of these valuable ecological resources.

20. 1. 2. Wetland Values

Wetlands contribute to the essential functions of the hydrologic cycle, aid in shoreline stabilization, contribute to nutrient assimilation, and provide habitat for many important wildlife species.

Wetlands are like giant buffers and purifiers between natural ecosystems and climatic events. They are homes to unique groups of living organisms.

20. 1. 3. Wetland Biological Functions

Wetlands are now recognized as being some of the most unique and important natural areas on earth. As some of the world's most biologically productive areas, they provide essential food and habitat to support a wide diversity of wildlife, fish, and plant species.

A large percentage of the fish, shrimp, crabs, and other shellfish we eat lived in wetlands during some part of their life cycle. Waterfowl and other birds use wetlands, as do many amphibians, reptiles, and countless invertebrates such as insects and worms.

Wetlands also provide food and shelter and essential breeding and wintering grounds for many species of migratory wildlife. These natural areas along rivers, streams, and ponds are often linear corridors serving to create bridges within and between our remaining areas of wildlife habitat.

Wetlands are now recognized as being some of the most unique and important natural areas on earth.

Many endangered and threatened species seek wetland areas to live, including the Mariana common moorhen (PULATTAT) and the Nightingale reed-warbler (GAGA KARISU).

20. 1. 4. Other Wetland Functions

In addition to providing habitat for fish and wildlife to spawn, nest, live, and rest in, wetlands also serve as important buffers, filters, and reservoirs.

As some of our last wilderness areas, wetlands attract those who simply enjoy the beauty and sounds of nature in the wild.

Because they are often located between water bodies and high ground, wetlands buffer shorelands against erosion. Wetland plants bind soil with their roots and help to absorb impacts from storms and wave action.

By holding excess water and slowly releasing it to downstream areas, wetlands help control flood waters that damage property. Wetlands act as natural sponges that absorb flooding water.

Wetlands also serve as natural water treatment plants. Like giant kidneys, they help purify water by absorbing and processing nutrients, suspended materials, and other pollutants.

Wetlands also increase the availability of water by absorbing water in wet seasons, then gradually releasing it during dry periods.

Lastly, tidal and inland wetlands are typically areas of great natural diversity and tremendous scenic beauty. They provide recreational and visual enjoyment and offer many other opportunities which enhance our overall quality of life. Recreational activities such as hunting, fishing, crabbing, hiking, walking, and boating take place in and around our wetlands.

As some of our last wilderness areas, wetlands attract many photographers, painters, writers, and others who simply enjoy the beauty and sounds of nature in the wild.

By holding excess water and slowly releasing it to downstream areas, wetlands help control flood waters that damage property.

20. 2. FRESHWATER SYSTEMS AND WETLANDS

20. 2. 1. Freshwaters

Basically, there are two types of natural freshwater systems, **lotic** and **lentic**.

Lotic systems contain moving, flowing water, like springs, streams, creeks, and rivers. Lentic systems are quiet, still waters with no currents, including ponds, lakes, swamps, and marshes. In most cases it is easy to classify fresh waters by whether they are flowing or not.

20. 2. 2. What are Wetlands?

Although included within the lentic general category, wetlands are geographic areas with characteristics of both dry land and water. Wetlands typically occur in low-lying areas at the edges of lakes, ponds, streams, and rivers, or in ocean-fronting coastal areas protected from waves. They are found in a variety of climates on every continent except Antarctica.

Another way to classify such aquatic ecosystems is to call them all wetlands and use the accepted **wetland classifications**: **marine**, **estuarine**, **lacustrine**, **riverine**, and **palustrine**. These terms are further described below.

20. 2. 3. Ecological Inputs from Land

To function well, aquatic ecosystems often require help from the land communities they run through or are surrounded by. They get fallen leaves and dirt from nearby shores and vegetation.

Food for carnivorous species is provided by aquatic and flying insects, and by the swimming larvae of toads and other land animals which lay their eggs in water.

Carnivorous species are maintained by aquatic and flying insects, and by the swimming larvae of toads and other land animals which lay their eggs in water.

20. 2. 4. A Closer Look at Lentic Systems

As mentioned, lentic ecosystems include aquatic systems without currents: ponds, lakes, bogs, swamps and marshes.

Lentic systems come in all sizes and shapes. A pond can be as small as a muddy footprint that holds water when it rains. A lake can be quite large indeed. The largest body of freshwater on earth is the 82,000-square-kilometer Lake Superior.

Generally speaking, a **pond** is defined as a very small, very shallow body of standing water usually with aquatic plants and hardly any wave action.

A **lake**, on the other hand, is a body of standing water which occupies a basin separate from the ocean, and is larger than a pond. (A basin abutting an ocean is a **lagoon**.)

A **marsh** is always shallow, with rooted herbaceous (soft-stemmed) plants; a **swamp** is also shallow and contains rooted woody vegetation.

Depending on their size, both marshes and swamps could be considered either specialized ponds or specialized lakes. They all have similar origins, and similar fates.

Alternatively, ponds, and lakes can be classified using the wetlands classification systems discussed below. It depends on how you look at it—as water with land around it—or as land with water on it.

Lentic ecosystems include aquatic systems without currents. These include ponds, lakes, bogs, swamps and marshes.

20. 2. 5. Wetlands Scientifically Defined

Most wetland scientists have basically agreed to three criteria that determine if an area is a “wetland”.

The first criteria is the presence of plants especially-adapted to being submerged by water. These are called **hydrophytic vegetation**.

Second is the presence of a soil type which shows clear evidence of **anaerobic decay**. This is decay without the presence of air, a condition caused when water completely covers soil for a long while. This soil type is called **hydric soil**.

The last criteria is continued submergence by water itself. This is the **saturated conditions** criteria. Wetlands in the CNMI must be saturated continuously for a 14 day period and have the other two criteria mentioned above to be classified as a wetland.

20. 3. WETLAND TYPES AND AMOUNTS

20. 3. 1. Marine and Estuarine Wetlands

Marine wetlands are wetlands exposed and submerged by seawater. Different agencies of the CNMI and Federal governments classify marine wetlands differently. Some agencies don't classify these marine areas as wetlands at all.

Mangrove swamps are a type of marine wetland.

Estuarine wetlands have a brackish water content and are located next to seawater. Often they are tidally influenced.

During very low tides, coastal *seagrass beds* are exposed above water. The muds beneath these beds have much the same forms of black, mucky, decaying sediments as our freshwater wetlands.

The tops of our *coral reefs* are classified by some as marine wetlands. This is because they have numerous plants growing on them and these can be exposed during very low tides.

Mangrove swamps are another type of marine wetland. We discuss each of these marine wetland ecosystems in separate chapters of this book (Chs. 13, 14, 15, and 17).

20. 3. 2. Springs and "Riverine Wetlands" (Streams and Rivers)

Geographical areas with flowing water are given the names "streams" and "rivers". Again, there is no clear distinction between these two terms.

Streams that flow all year are called **perennial streams**. Those which flow only during or shortly after a storm and not during the dry season are called **ephemeral streams**.

Geographical areas with flowing water are given the names "streams" and "rivers".

Springs

A location where the water within a raised aquifer flows out is called a **spring**. Many of our perennial streams result from the downslope movement of water flowing from springs.

Sometimes a spring is temporary; it exists only during the rainy season, or in very rainy years.

Streams and Rivers

"Stream" is a hard word to define. One place's stream is another place's river. Some "streams" in Taiwan become 2 miles wide from shore to shore during the monsoon season! It's hard to tell streams from rivers, so we'll discuss them together. You can decide, when you meet one in the field, whether you have waded in a stream or a river.

Stream branches, brooks, and creeks—better known as "cricks"—are often tributaries of rivers. The name **tributary** means that streams "pay tribute". They donate water to rivers by dumping their contents into them.

Streams invariably cut channels because flowing water has great erosive power. Not only can the water itself wear away rocks, but it carries minerals and acids from decaying vegetation.

These react chemically with rocks. Water also carries larger materials—sand grains, pebbles, rocks and even boulders. These add to the “scour power” of flowing water.

Stream Deltas

As a river meets the sea, or a large lake, it is carrying clay, mud, sand and other things. At this point it slows enough to deposit its solids—the heavier first, and later and further out, the lighter stuff.

As time goes by, sediments pile up and spill out and down into the ocean basin. Eventually these **alluvial** (river-carried) deposits form a fan shape which ancient Greek writers felt looked like their letter “delta,” thus the name.

Rivers often cut additional channels through their sediments. This happens especially when the river is swollen with extra water and other materials in the rainy season.

As a river meets the sea, or a large lake, it is carrying clay, mud, sand and other things. Talofofo stream on Saipan is a clear example of this process.

20. 3. 3. Lacustrine Wetlands (Lakes)

Land continuously covered by water that is not flowing is given several names, none of which is clearly defined in size. Wetland scientists apply the name **lacustrine wetlands** to such ecosystems.

As mentioned, these are puddles, ponds, and lakes. Lakes can be shaped in any way. There are long narrow lakes and wide-round lakes. Lakes can be shallow or deep. Lakes can have freshwater or saltwater in them.

20. 3. 4. Palustrine Wetlands (Marshes and Swamps)

Marshes

Marshes are periodically or continually flooded wetlands with **emergent** herbaceous plants. Emergent plants are those adapted to living in shallow water or in saturated soils. Water in marshes varies from salt water to freshwater.

Marshes are periodically or continually flooded wetlands with emergent herbaceous plants.

Examples of very large marshes include the everglades in Florida and the prairie potholes of central North America. Locally, some marshes surround Lake Susupe and Lake Hagoi.

Swamps

Swamps are wetlands dominated by trees or shrubs. They occur in a variety of flooding conditions. Swamps often occur along river floodplains, in shallow, quiet waters next to lakes, and along subtropical to tropical coasts.

Examples of swamps include the mangrove forests located throughout Micronesia, the South Pacific, and much of the tropical world. The Magpo swamp on Tinian and Saipan’s mangrove swamps within American Memorial Park and near the Tanapag commercial port are two local examples.

Peat Wetlands

Peat wetland is another type of palustrine wetland though it is not present here in our islands. Peat, however, is a component of the sediments of Lake Susupe.

"Peatland" plants are produced more quickly than they can decay, and the partially decomposed plant material accumulates.

Peatlands are common in northern continental regions such as Canada, Scandinavia, eastern Europe, and western Siberia. We purchase this peat as peat moss from horticulture stores. It makes a great soil amendment. See more in our farms and gardening chapter (Ch. 30).

Ravine forests grow throughout Micronesia

20. 4. OUR STREAM-ADJACENT RAVINE FORESTS

20. 4. 1. Community Description

The ravine forest develops in valley areas and gullies on volcanic areas. Here water and moisture accumulate. This forest is usually an uneven mixture of many kinds of trees. These are usually of rather low stature, growing brushy and tangled.

Examples of this forest type are best evident on Rota along streams in the Talakaya Watershed. On Saipan, ravine forests grow along streams draining to Lau Lau Bay and at places along the I Hasñgot and Talofofo Watersheds.

The canopy is only a few meters above the ground, and its upper surface is typically irregular. A typical occurrence has a belt of very thick scrub around the edges, gradually changing inward to forest.

In the ravine bottoms, the forest may be tall enough and dense enough to permit free passage. In other areas, it may be low and tangled and choked with brush and saplings.

Cycads (FADANG) are always found in our stream-adjacent ravine forests.

A tree layer and a shrub layer can usually be seen in the deeper parts, but towards the edges these merge and become indistinguishable.

Although the plant types vary, one always finds PAGO (Beach Hibiscus), FADANG (Cycads), PUGUA MACHENA (Betel Nut Palms), and NUNU (Banyan Figs). Several lianas and numerous epiphytes, including ferns, grow here.

The ravine forest lines both sides of streams and their tributaries. These flow either year round (perennially) or only occasionally (ephemerally).

Such streams are usually limited to areas with Akina soils developed over volcanic-derived igneous rocks. Talofofo Stream on Saipan is a good example. The Talakaya Watershed area of Rota is another.

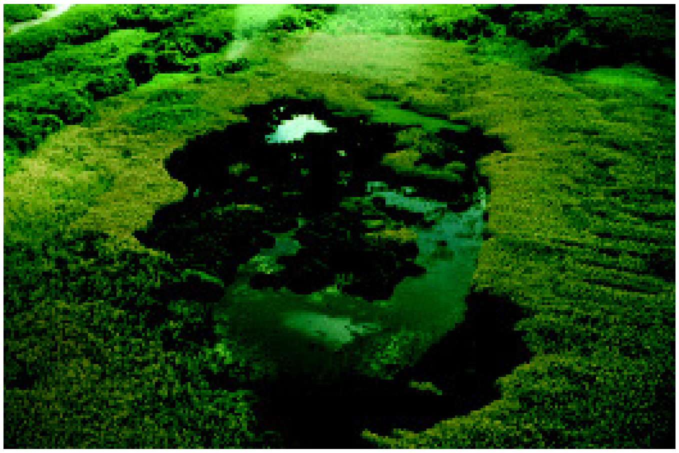
20. 4. 2. Ancestral Use

The abundance of artifacts, especially broken pottery, shows that these parts of our islands were densely populated in pre-Spanish times. Undoubtedly the ravines were used largely for agriculture—taro and rice growing and coconut culture.

Betel nut chewing was a widespread or universal habit. The betel palms (*Areca catechu*) now found here are probably descendants of planted ones. So too, likely, are the DUKDUK and FADANG trees (*Atrocarpus mariannensis* and *Cycas circinalis*).

20. 5. LAKE AND WETLAND SUCCESSION (HYDRIC SUCCESSION)

Geologically, all lentic systems are temporary. All are fated to disappear. All lakes become ponds; all ponds evolve into marshes or swamps; all marshes into dry land. This evolution is constant and orderly.



All lakes become ponds; all ponds evolve into marshes or swamps; all marshes into dry land. Hagoi Lake on Tinian is a clear example of this.

Let's try to understand it. Start with a geologically formed basin. Rainfall, and water from surrounding hills will fill the basin with water and materials dissolved in it, plus some sand, rocks and boulders.

In time, bare rock around the lake starts to support living plants and animals. First come the primitive and tiny kinds (mosses and lichens), then larger and larger forms (recall ecological succession and soil formation from our earlier chapters?).

There's a good chance that some plant material—decaying leaves and dirt—will slowly begin to wash into the lake.

At the same time, the lake is slowly undergoing succession of its own. Microscopic algae are brought in by the wind. Initially they reproduce slowly; many die and sink to the bottom.

Eventually some insects lay eggs in the water, and their larval stages hatch and feed on the algae. Eggs and cysts of other animals—microscopic ones—fall in and hatch.

Maybe even small fish are able to move in from other lakes. At this time the lake is clear and clean and probably cold, especially in the deeper parts.

More and more sediments collect in the bottom from runoff and from organisms dying and sinking. The shoreline now has plants growing on it and they hold mud with their roots. They die down adding soil to the edge of the lake, which gets shallower.

The middle of the lake also get shallower. The lake is filling in, but very slowly. The bigger the basin and the deeper it is, the longer this takes.

At first, algae live only at the shallow edges, where sunlight can get through. As the lake fills in and gets shallower, algae can live everywhere in the water.

Algae and plants, using sunlight to make food (what's the process called?), must live where they can get it. At first, algae live only at the shallow edges, where sunlight can get through. As the lake fills in and gets shallower, algae can live everywhere in the water.

More algae living means more algae dying, providing more food for herbivore and detritivore animals. So more animals can live there, too. And plants with roots have more soil to put more roots into.

Now the lake is shallow, the water not so clear because it has lots of algae and animals and more mud. It's not quite so cold at the bottom, this is because more sunlight reaches there.

The increase in biomass in an evolving lentic system provides plants more soil to put their roots into.

We can see what's coming—the lake will fill in more and more. Every year more things can live in it. More organisms can also die in it and add more decaying matter. The shoreline grows more and more into the lake. The lake gets smaller. Pretty soon our lake becomes a pond.

From being pond-sized, the next step is for the bottom to be covered with rooted plants—grass-like ones, maybe some floating viny types. By this time the edge is dry and the center is a marsh.

With more and more vegetation, even this marsh becomes filled in, and a grassy meadow grows where the lake—pond—marsh—had once been. A forest might replace the meadow.

These steps are typical of the evolution of a lentic system. This is hydric succession (hydro = water). Even man-made lakes go through these steps.

This happens over long periods of time, over hundreds or even thousands of years.

20. 6. LAKE SUSUPE; OUR LARGEST FRESHWATER AQUATIC ECOSYSTEM

20. 6. 1. Introduction

Lake Susupe lies in a broad, shallow depression on the western edge of an extensive low wetland. The lake is perennial, meaning that it never dries up completely.

In a study done in 1978, scientists found that the lake does not show detectable surface changes with tidal ebb and flow. Other scientists have looked at this more recently and stated that the lake is influenced by tides.

20. 6. 2. Lake Size

The size of Lake Susupe has not changed much since 1921, according to an old Japanese map of the period. The depth and size of the lake varies with the rainfall.

The normal surface area of the lake is about 45 acres. There is an additional 372 acres of surrounding marsh. The marsh contains about 17 small ponds.

Most observers are amazed when they learn how shallow it is. The maximum depth was determined to be 7.2 feet.

Lake Susupe lies in a broad, shallow depression on the western edge of an extensive low wetland.

20. 6. 3. Lake Origin

Geologists believe Lake Susupe and several of Saipan's other near-coastal wetlands are the slightly elevated remnants of coastal lagoonlets. These are believed to have previously existed within the larger Saipan Lagoon.

According to this hypothesis, storm waves, winds and littoral currents all contributed to the formation of the lime-sand blanket now underlying Chalan Kanoa.

This new land closed off the lagoonlet from the sea. We know that both coastal limesands and marsh deposits are of recent geologic origin.

This hypothesis matches the archaeological record which shows a very high prehistoric cultural use of a bivalve shellfish of the ***Family Tellinidae***.

Cultural use of this resource was very high until about 2,500 years ago. These uses likely disappeared along with their previously supportive lagoonlet habitats. (Recall our discussion of this in Chapter 2.)

Uses of Lake Susupe have severely degraded its ecological integrity.

20. 6. 4. Flooding

Presently the lake has no outflow. It loses the water draining into it from its 2,520 acre watershed basin only through percolation and evaporation.

During periods of extremely heavy rainfall, this causes flooding of the surrounding areas. This happened on August 10-12, 1978 when the lake rose 5.4 feet above the average lake level.

20. 6. 5. Lake Use

Recent uses of Lake Susupe have severely polluted its waters. The marshlands were used extensively for agriculture during the Japanese period. Waters were used for rice and sugar cane irrigation.

Sugarcane covered most of what is now in KARISU (see below). Rice was also planted extensively in the northeast “pothole” area of the lake.

Natural and synthetic fertilizers used in wetland farming of the surrounding low paddies entered the lake and created a great oxygen demand on the environment.

The area of the marsh formerly used for rice cultivation is now fully choked with KARISU. The remnants of dikes and irrigation canals for rice and sugarcane are still evident throughout the marshland.

Water from the lake was also used for cane washing at the nearby Chalan Kanoa sugar mill. Used wash water effluent containing soil, rocks, cane trash, and possibly pesticide residues is believed to have been directed back into the lake through a winding unlined channel (visible in old aerial photographs).

The sugar industry on Saipan used water from Lake Susupe in the washing process.

Finally, after the invasion, American forces used lake water for showers, toilet flushing, and fire fighting.

Today the lake’s waters are only occasionally used by humans for recreation. For the most part, however, its use is restricted to wetland conservation.

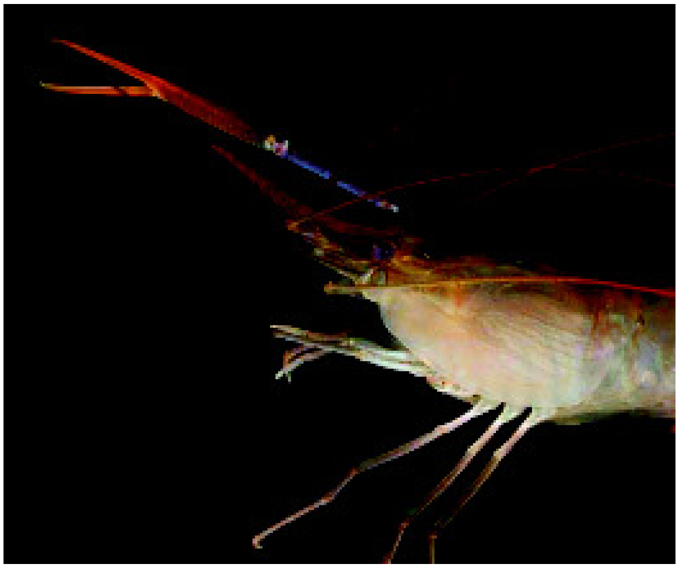
20. 6. 6. Exotic Species Introductions

Several exotic animal species have been introduced to Lake Susupe, including prawns, toads, turtles, and a few species of fish.

Scientists feel that the introduction of exotic tilapia and mosquitofish have played a major role in the lake’s ecological degradation, on par with the degrading impacts from the lake’s uses.

Both species have been distributed virtually world-wide for purposes of aquatic plant and mosquito control and as a fishing resource.

Each has created tremendous problems and damage to native ecosystems in many areas.



Freshwater prawns are among the species of exotic animals introduced to Lake Susupe.

Both of these species are hardy, temperature and salt tolerant, omnivorous species capable of invading and colonizing ponds, lakes, streams, rivers, estuaries, and embayments.

Mosquitofish cause extinctions of native species by direct predation and competitive exclusion. Tilapia consume all available emergent vegetation and lake invertebrates. They effectively out-compete native and migratory waterfowl for food.

Scientists found that these species contributed to the decline of populations of endemic fishes and crustaceans in Hawaiian freshwater ecosystems, particularly on Oahu.

Because of a lack of studies, the specific ecological impacts each has had in our islands is not, and unfortunately may never be known.

Introduced rats, cats, dogs, and monitor lizards each prey on nesting birds, eggs, and hatchlings. Even anguillid eels have been shown to prey on ducklings, causing a serious pest problem to duck farmers in Australia.

20. 6. 7. Lake Water Quality

Ecological Category
Lake Susupe is described by lake scientists, (called **limnologists)**, as dystrophic. It is neither oligotrophic, nor eutrophic. (See below for discussion of these terms).

pH
Lake Susupe is an alkaline freshwater lake containing chemically "hard" water. Hard waters contain high levels of dissolved alkaline earths caused by aquifer flows through limestone.

Scientists feel that the introduction of exotic tilapia and mosquitofish (shown) have played a major role in the lake's ecological degradation.

These alkalines, mostly calcium and magnesium carbonates, cause the pH of the surface and open water to be higher than neutral (pH 7). Measurements have ranged from pH 7.2 just after storms to pH 8.5.

Confined pothole water and lake water just along its fringe can show a lower, acidic pH. This results from humic acids released during plant decay. An acidic measurement of 4.5 has been recorded.

Saltiness
Chloride or "salt" concentration in the lake water has ranged from 261 mg/L (milligrams per liter), four months after the flood of Aug 10-12, 1978 to 4,800 mg/L in 1983. Salt levels are normally too high for human consumption.

Color and Transparency
How clear a water body is affects its ability to support photosynthesis at lower depths. Lake Susupe's waters have low **transparency**, meaning they are murky and not very clear. Water clarity of the lake is mostly affected by suspended particulate matter, including phytoplankton.

The lake's waters are very abundant with phytoplankton. The color of the lake water is described as dark brownish-green with a faint yellowish-brown tinge.

The growth of phytoplankton is so dense that an instrument called a *secchi* dish, used to measure water clarity, disappears at 3.5 ft below the water's surface. This was found to be true throughout the lake.

Dissolved Oxygen

Oxygen in lake water is important for metabolism. It is a common indicator of "health" or "quality" of a lake ecosystem. Oxygen in the lake, (called **dissolved oxygen**) mostly comes from the air, just at the place where the air meets the water's surface.

Oxygen absorption is enhanced by wind and waves. Oxygen is also added by plants and phytoplankton.

Except for the very bottom, generally Lake Susupe is well oxygenated throughout its water column. This comes from its high surface to depth ratio and its abundance of phytoplankton. Oxygen is slightly higher at the surface of the lake, and in its "potholes", than towards the bottom.

When water is not mixed well, the high oxygen demand imposed by the decomposition of plant litter creates a stagnant, highly **reducing environment**. "Reducing" here refers to a rapid use of oxygen in organic matter decay processes.

The low transparency and the lower levels of oxygen near the bottom are two reasons why the lake does not have more emergent vegetation growing within it.

The lake's waters are very abundant with phytoplankton. The color of the lake water is described as dark brownish-green with a faint yellowish-brown tinge.

Nutrients

The nutrients phosphorus and nitrogen are relatively high in Lake Susupe. These serve to support the abundant phytoplankton and it in turn, serves as the base of the lake's food chain.

Of these two nutrient parameters, phosphate tends to be the limiting one. The lake's green plants take up this nutrient as fast as it can be recycled by the lake's decomposers, leaving little for additional plant production.

20. 6. 8. Lake Bottom Sediments

Lake sediment samples reveal a black, gelatinous, sedimentary peat. When sniffed the samples yield an overpowering odor of **hydrogen sulfide gas** (H_2S). This gas is a byproduct of anaerobic decay.

Scientists hypothesize that these deep lake sediments act as a seal against brackish and salty groundwater intrusion.

20. 7. OTHER CNMI LAKES

20. 7. 1. Lake Hagoi

After Lake Susupe, Lake Hagoi is considered the second most important wetland ecosystem in our Commonwealth. Lake Hagoi, located near Tinian's North Field runways, has developed into a classic circular lake fringed by rings of marshland.

Hagoi is highly valued today by both endemic and migratory bird dries up on a yearly basis.

This keeps tilapia and mosquito fish from inhabiting the lake. This results in the absence of their detrimental impacts on other species.

After Lake Susupe, Lake Hagoi is considered the second most important wetland ecosystem in our Commonwealth.

20. 7. 2. Pagan's Two Lakes

Pagan has two lacustrine wetlands. An inner lake occurs at the foot of Mt. Pagan. It is called Sanhalom Lake.

A second lake lies next to the coast, behind a long black, volcanic sand barrier. It is called Lagona Lake.

Today neither lake has emergent vegetation, even around its borders. The lakes are both rich in phytoplankton, however. Each has an abundant population of tilapia inhabiting them.

The 1981 volcanic eruption spread ash over each, killing all of the aquatic emergent vegetation.

Since then there has been an ongoing impact from the feral goats, cows, and pigs which now, "own" the island. Every bit of reed or other plant is quickly gobbled up by the hungry ungulates and by the eruption-surviving tilapia.

Pagan has two lacustrine wetlands.

20. 8. GOLF COURSE PONDS, WATER TREATMENT FACILITIES, MITIGATION PONDS, AND OTHER OPEN "FRESH" WATERS

20. 8. 1. No Net Loss

In accordance with the US national wetland policy of **no net loss**, mitigation for the "filling" of wetlands is both a local and a federal permit requirement. [Read more about wetlands and mitigation requirements in our chapter on federal laws-see Clean Water Act.]

These mitigation wetlands serve to make up for — and if designed correctly — actually improve upon, wetland habitats lost to development.

20. 8. 2. Golf Course Ponds

Golf courses often plan for and construct water bodies as part of their landscape beautification efforts. The pond water also provides water for greenskeepers during dry seasons to irrigate fairways and putting greens.

If properly designed, large open golf course ponds are quickly adopted by resident and migratory wetland birds. These include ducks, moorhens, and egrets. The presence of these native birds adds to the golf course's attractiveness and its overall harmony with its surroundings.

Adoption by waterfowl occurs best when about a third or more of the ponds are allowed to have a gently sloping fringe of emergent vegetation and if inside-the-pond "islands" are constructed and allowed to become vegetated.

Ideally there would be a provision of fluctuating water levels which seasonally overflow these islets to insure that only wetland plant species inhabit them. Floating *Acrostichum* ferns also can add cover and forage.

Most important, however is the keeping out of the omnivorous tilapia and mosquitofish. Construction provisions allowing the thorough draining and complete drying of the ponds, should these be introduced, is another good design measure.

20. 8. 3. The Surprising Rota Resort Sewage Treatment Wetland

On Rota, a sequence of ponds were constructed as part of the Rota Resort development's sewage treatment system. The system modeled an innovative process developed in the US by fisheries and engineering professors at California State University, Humboldt. Near that college there is a similar facility serving as a working alternative to an otherwise extremely expensive technology-based treatment plant.

Ironically, a pair of an endemic species PULATTAT, which had not been seen on the island during historic times, adopted the ponds. This occurred even before the golf course had completed its construction.

They stayed, nested and have since raised a brood of hatchlings. These have also stayed and it is very likely that more of these endangered birds will inhabit the site.

Golf courses often plan for and construct water bodies as part of their landscape beautification efforts.

20. 8. 4. The Price-Costco Wetland

On Saipan, several mitigation ponds have been developed in compensation for filling activities. The most prominent and accessible site is the one next to the Price-Costco store.

This wetland dries up completely, just as it is designed to. There is a fringe of an aquatic moat. This retains water year-round serving as a refuge for waterfowl during the dry season.

Within-pond islands were constructed. These flood regularly during the wet season, allowing only the waterfowl-preferred wetland vegetation to grow upon them.

The site has become a haven for our migratory and endemic wetland birds. Shorebirds love it as well. As engineered, it also serves to store floodwaters, absorb upland nutrients, and filter runoff sediments.

The most prominent and accessible mitigation pond site is this one next to the Price-Costco store.

20. 9. CATEGORIES OF LAKES

Ecologically, lakes have been studied longer than other bodies of water. Limnologists have described all kinds of them.

20. 9. 1 Oligotrophic Lakes

A lake that is clear and clean, with few organisms—is **oligotrophic**. 'Oligo' means 'few', and 'trophic' means 'feeding'. This type of lake supports few feeding, living organisms.

An easy way to know an oligotrophic lake is to visit it in the warmest part of the year. Take a water sample from the bottom; test it for dissolved oxygen.

Warm weather is the time to find organisms, and most of them need oxygen. If you find oxygen at the bottom of the lake, there can't be many organisms because they would have 'breathed' it all up.

A lake that is clear and clean, with few organisms—is oligotrophic.

Oxygen at the bottom in the warmest part of the year means an oligotrophic lake.

20. 9. 2. Eutrophic Lakes

Lakes that are shallower and not so clear—are **eutrophic**. 'Eu' means 'true' (and 'trophic' still means 'feeding')—so a eutrophic lake supports many organisms, all feeding like mad.

You can check this lake in the same way—on the warmest days, sample the deepest water for oxygen. You'd expect that so many organisms would use up the oxygen. You don't find any.

No oxygen at the bottom during the warmest part of the year means you have a eutrophic lake.

20. 9. 3. Dystrophic Lakes

There's one more kind of lake, **dystrophic**. 'Dys' means 'bad.' This maybe a bad choice of prefixes, because the lake isn't 'bad', nor are the organisms. It is just that the trophic situation isn't like most.

Many man-made lakes are dystrophic. When you sample them there are many organisms so you think 'Ahah, it's eutrophic!' But when you check the bottom water, there's plenty of oxygen!

Dystrophic lakes don't fit the usual pattern. As mentioned earlier, Lake Susupe on Saipan is dystrophic.

Lakes that are shallower and not so clear—are eutrophic.