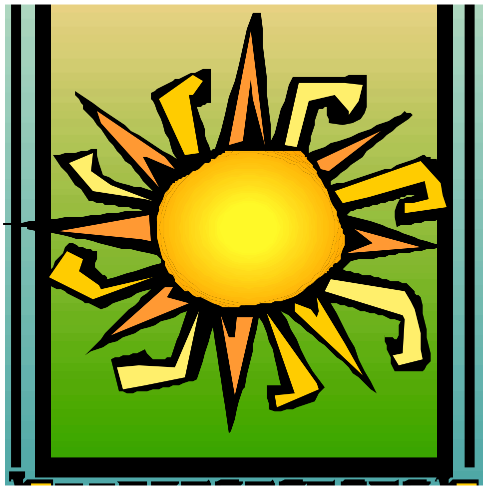
INTRODUCTION TO ECOSYSTEM SCIENCE CONCEPTS

The study of a region as complex and diverse as the Mekong River Basin (MRB) encompasses a number of scientific and technical disciplines. No one field of science can fully detail the multitude of physical, biological and chemical processes that occur within the MRB and make the region so vibrant and productive. This lesson will discuss some basic elements of various fields of study relevant to understanding the ecological functions of the Basin.

BIOLOGY

Biology is the study of all living things. From the basic cellular level up to an ecosystem the size of the MRB, and on to the scale of the biosphere, biology is the study of how living organisms harness the non-living energy sources provided by the earth and turn that energy into fuel for life processes. Biology examines how living things use such substances as water, carbon dioxide and oxygen for their growth, survival and reproduction.



The Building Blocks of Life

The cell is the basic structural and functional unit of all living organisms. The cell contains a nucleus, DNA (genetic material) and the cytoplasm, all enclosed in a protective membrane.

Various types of cells are present in nearly all living organisms. Cells of similar type and function that are grouped together form tissues. For example, a fish has specialized tissues for respiration, vision, sensory perception, swimming and all other functions necessary to its growth, survival and reproduction. Plants have tissues that protect their outer surfaces, enable the transformation of sunlight into energy (photosynthesis), move nutrients and chemicals through the plant tissues and allow the plant to grow and reproduce. Cells and tissues form complex integrations that are termed organs. Your skin, heart, and lungs are all examples of organs. A group of organs functioning together make up an organ system, such as the respiratory system or the reproductive system. And finally, a group of organ systems all function together to form an organism, such as the fish, a tree or yourself.

Energy

All life processes require some form of energy. Virtually all energy comes from the sun and is captured by plants through the process of photosynthesis. Most creatures cannot capture the sun's energy directly and therefore obtain their energy by eating plants, or by eating organisms that eat plants. Energy is thus transferred through a portion of an ecosystem via a food chain, or feeding sequence within the ecosystem. Energy moves to succeeding trophic levels. For example, algae and aquatic plants are eaten by bottom-feeding fish such as carp. Carnivorous fish then eat the bottom feeders, with humans finally eating the carnivorous fish.

Energy is further transferred through the ecosystem via a food web, or interlocking network of food chains. Some energy is released through respiration, but most is used to run all of the organism's body processes, collectively known as metabolism. Two basic laws govern the availability of energy to all of life's processes:

The First Law of Thermodynamics (the Law of Conservation of Energy) states that matter can neither be created nor destroyed. In effect, the energy needed to do work in a particular system, a cell for example, cannot be generated from nothing. Energy must initially be obtained from a source outside the system, be it a cell or a riparian swamp. Once the energy is within the system, it can be cycled through the system.

The Second Law of Thermodynamics states that in the universe as a whole, the total amount of energy available to do work is declining. This is because nearly every energy transfer generates heat that is then no longer available for doing work. In other words, the supply of energy available for life processes is not limitless.

ECOLOGY

Ecology is the science that studies the interrelationships, distributions and abundance of all organisms and their interconnections with their living and non-living environment. Ecology also examines the processes that determine ecosystem function, changes over time, and disturbances to the ecosystem.

We can begin a discussion of ecology with an expansion of the organizational levels of life. A group of similar organisms, such as Eastern Saurus crane, form a population. This population of cranes inhabits the same area and would potentially interbreed and share the same gene pool. Many populations of different organisms sharing the same geographical area form a community. A community consists of all the living organisms, including plants, mammals, fungi, and microbes.

The community can be considered in the larger context of an ecosystem. An ecosystem encompasses all living organisms together with the abiotic environment (the soil, water, air and nutrients) that function together to circulate nutrients and create energy flow. A key concept here is that while we tend to emphasize the component parts of an ecosystem, it is the processes acting on or initiated by the component parts that make the ecosystem function.

Population Ecology

The concept of carrying capacity is fundamental to the understanding of populations. Carrying capacity refers to the number of organisms of a given species and quality (health) that can survive, through the least favorable conditions per unit time, in a given ecosystem without causing its deterioration. Consider the Plain of Reeds, for example. The Plain lies in the flat lowlands of the MRB and experiences significant changes in water levels annually. In October, at the end of the wet season, some parts of the Plain become a vast lake up to 4 m deep. In the dry season, the Plain dries out, except for scattered ponds and swamps. With such wild fluctuations in water level and availability, the populations of aquatic plants that can survive are limited by the severity and duration of the annual dry period.

The environment of the Plain of Reeds imposes limitations on the abundance and diversity of aquatic plant species. This limitation is felt by the animal species that depend upon the availability of vegetation, such as fish, shrimp and water birds. In short, the quantity and availability of water each year in part determines the numbers of various wildlife and plant populations. A finite carrying capacity exists within this ecosystem.

The Plain of Reeds example can be developed further to illustrate the scale of carrying capacity. The small ponds and swamps that remain after the flood waters receed no longer face the limiting factor of water, but of space. The quantity of aquatic plants and animals that the micro-habitats can sustain year-round will be directly related to the amount of physical area available. Even an ecosystem the size of the MRB will exert the pressures of carrying capacity on its resident populations of plants and animals. Factors such as nutrient availability, water levels and the health and abundance of photosynthetic plants and prey species all interact to determine the finite quantity of life that the MRB can sustain.

Extensive ecosystem disturbance and resource extraction by man has tremendous potential to negatively alter the natural carrying capacity of a given ecosystem.

Community Ecology

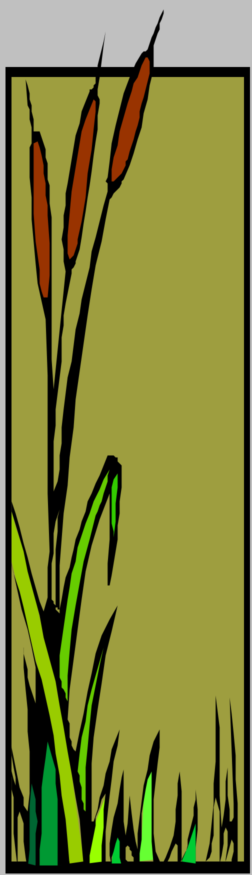
The development of communities and the succession of ecosystems are intimately linked processes. Succession refers to the series of dynamic changes in ecosystem structure, function and species composition over time. The relative dominance of one or several species within the ecosystem changes through the course of succession, and the ecosystem eventually becomes mature and self-sustaining, experiencing few subsequent changes. The ecosystem is then termed a climax community, supported by climax vegetation.

Ecosystems in the early stages of succession are dominated by pioneer species. If we were to enter a portion of forest that had recently been logged, we would see vast quantities of bare soil supporting little more than a few weeds. If we return several weeks later, we would probably be surprised at the number of new plants that we see. The site would be in the early stages of succession, and those new green plants would be the pioneer species or, in ecological terms, the r-selected species. These plants come in quickly after disturbances, when environmental conditions are unstable or unpredictable and little organic matter is present in the soil. They are relatively small, short lived, and generally reproduce annually by seeds or by sending out new shoots from buds near the ground.

Animal r-selected species also move in early. Like the plants, these species are normally small, short-lived, and reproduce early in their life cycle. They tend to give little or no care to their young, and can breed more than once a year. Small rodents like mice are good examples of early animal colonizers. As a general rule, r-selected species are tough, adaptable, and have means of wide dispersal in a relatively short time frame. They are generalists. Ecosystems in the early stages of succession tend to have only a few species present, or what would be termed low species diversity.

Over time, probably within the first two to three years at our logged site, we would see signs of further succession. Many of the weedy plants would have died off – they would have enriched the soil – and slower growing, perennial plant species would be coming in. Young trees would also grow, as seeds remained in the soil even after the older trees were harvested. A larger variety of grasses and shrubs would be present, forming what would later be the understory of the new patch of forest. More animal species would move in, as there would be a more substantial food source. The ecosystem would eventually begin to favor the slower growing, larger plants and animals, or k-selected species. We'll call them specialists. These species tend to reproduce much later in their life cycles and may spend quite a lot of energy raising their offspring. These species require a more specific range of environmental conditions than the generalist species, which is why they will only thrive when an ecosystem

Succession of Aquatic Ecosystems in the MRB



Wetlands have traditionally been thought of as transitional stages between open lakes and terrestrial forests. This is a classical view of succession, with plant communities changing and the ecosystem as a whole evolving into a stable, mature climax community. New evidence, however, suggests this may not always be the case. The vegetation found at a wetland site consists of species adapted to the particular environmental conditions of the site, such as seasonal changes in water levels and nutrient availability. Inland freshwater marshes, salt marshes, mangrove forests and riparian swamps all contain plant species uniquely adapted to the specific environmental conditions of each ecosystem. Plant species will also be arranged along a hydrologic gradient in each system. Species more tolerant to flooding will be located closer to open water, while other species will be found only in areas of saturated soil. This organization of species can remain relatively for quite some time if the ecosystem is not disturbed.

As ecosystems, many MRB wetlands appear mature in some ways and young in other ways. Primary productivity is generally high and nutrient cycling is very open; these are both characteristics of young ecosystems. However, organic matter accumulation is often quite high and life cycles within the wetland tend to be complex. These are patterns suggestive of a mature ecosystem. So what determines how a wetland ecosystem changes over time? Changes in hydrologic conditions are the major factor controlling the wetland vegetation patterns. Natural or man-induced disturbances to a wetland ecosystem, such as water drainage or sediment deposition, can have drastic effects on the stability and species composition of the ecosystem.

has progressed through several stages of succession.

As an ecosystem approaches the climax stage, plant and animal species diversity would increase. Only in older, climax communities would we start to see the stunning array of species that represent what we would consider high biological diversity. Creatures like the kouprey, the Sun bear, the Saurus crane, the Giant ibis and the hairy-nosed otter can only survive where there is sufficient plant or prey biomass to sustain their populations. It can take years, decades, or longer for an ecosystem to develop to a point where it can sustain some of the rare species found in the MRB.

LIMNOLOGY

Limnology is the study of freshwater inland ecosystems, primarily rivers and lakes. To better understand the connections between the natural environment and water quality it is important to know the background of the water bodies within the MRB. Lakes and rivers within the Basin are essential components of the long term health of the region.

Geomorphology

The geomorphology of lakes and rivers refers to the development and present-day shape and structure of a lake or river. It is intimately reflected in physical, chemical, and biological events within a basin and plays a major role in the control of a lake's or river's patterns.

The geomorphology of a lake or river controls the nature of its drainage, inputs of nutrients to the lake and river, and the volume of influx in relation to flushing-renewal time. Thermal (temperature) and stratification (spatial arrangement) patterns are markedly influenced by basin morphometry and volume of inflow. Basin morphometry refers to a lake's or river's underwater contour lines, its shape and its geologic origin.

More than 76 types of lakes have been differentiated on the basis of their geomorphology. Usually types can be limited to nine distinct groups of lakes, each formed by different processes.

Most natural lakes were formed by catastrophic events, including:

- Tectonic lake basins
- Volcanic activity
- Temporary or permanent lakes can result from landslides into stream valleys
- The erosion and sedimentation activity of glaciers.

Other natural lakes form by gradual events:

- Solution lakes result from sinks (sinkholes)
- The erosion and sedimentation action of river water can isolate depressions to form lakes
- Wind erosion can form shallow depressions which often contain water temporarily or seasonally
- Coastal lakes often form along irregularities in the shoreline.

Reservoirs are impoundments created largely by man by damming river valleys. They can also be created through natural disturbances.

Rivers can be classified according to the type of flow regime and magnitude of discharge. The flow regime of the Mekong River and its tributaries is often subject to considerable modification by natural impoundments, lakes, dams, or water storage. The flow characteristics of many sections of the river have been changed by canalization or requirements for water uses, such as withdrawal for irrigation or other water supply needs. Changes in flood characteristics also occur from modifications of the soil infiltration capacity as a result of agriculture and urbanization.

River systems represent the dynamic flow of drainage water, which is the final product of surface run-off, infiltration to groundwater and groundwater discharge.

Figure 1 illustrates various zones of the Mekong River. The lotic zone refers to the portion of the river with the highest flow velocity. Water is generally always moving in this portion of the river, carrying nutrients, sediment, and potential pollutants and depositing them at various locations downstream.

The lentic zone is characterized by slower moving water and a fairly pronounced vertical temperature gradient. Sediments in the water column can begin to settle out and aquatic vegetation may be present.

The hyphoeric zone is the area just below the river bottom substrate. It is distinct from groundwater, as it is still flowing (though quite slowly) and is similar in chemical composition to river water.

The Mekong's floodplain is perhaps one of its most dramatic features. Flooding is usually a cue for biological activity, from fish spawning to seasonal aquatic growth. In this warm, tropical environment where temperature and day-length are similar year-round, the flood is critical for the maintenance of the river's biological rhythms. Both aquatic and terrestrial organisms can adapt to the alternating wet and dry conditions caused by flooding. During the dry season, floodplain cultivation of rice is a principle economic and nutritional staple in the region.

HYDROLOGY

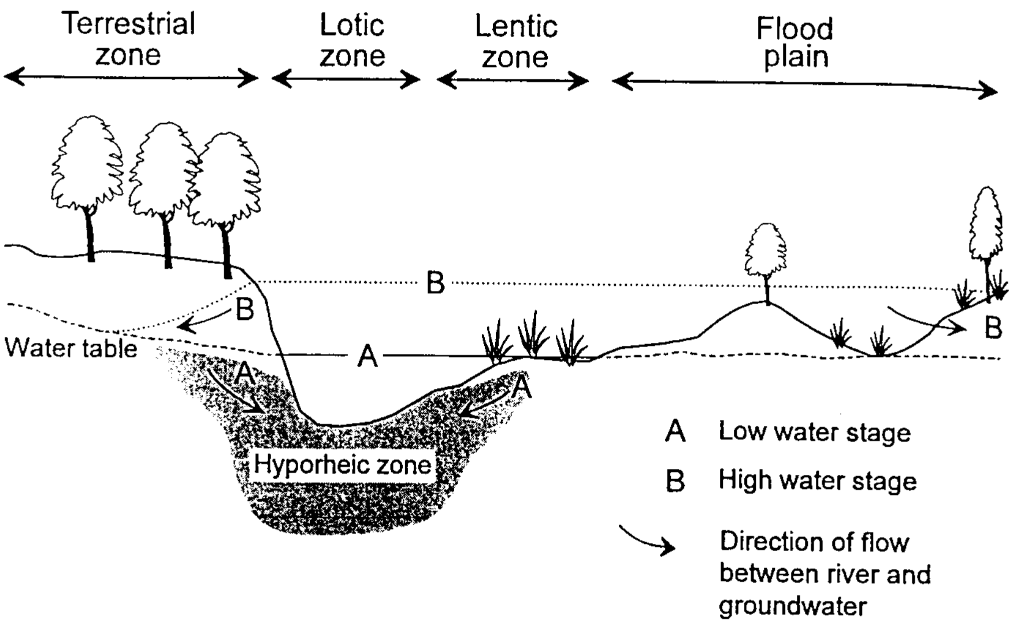
Hydrology is the study of the movement of water through the hydrologic cycle. We have already looked at the specific hydrology of the wetlands of the Mekong River Basin. Now we will look take a broader view of the discipline of hydrology.

Water evaporates. It travels into the air and becomes part of a cloud. It falls down to the earth as precipitation, in the form of rain or snow. Then it evaporates again. This cycle repeats over and over again in a never-ending hydrologic cycle. Water keeps moving and changing from a solid to a liquid to a gas, over and over again.

Precipitation creates run-off that travels over a ground surface and helps to fill lakes and rivers. It also percolates or moves downward through openings in the soil to replenish aquifers under the ground. Areas close to the oceans and large bodies of water that allow more water to evaporate and form clouds receive more precipitation than others. Often these areas are far from water or near mountains. As clouds move up and over mountains, the water vapour condenses to form precipitation and freezes. Snow falls on the mountain peaks.

The hydrological cycle consists of the global processes affecting the distribution and movement of water:

Figure 1 Hydrological profile of the Mekong River



- Greater evaporation from the oceans is counterbalanced by greater precipitation onto land masses.
- Although the amount of water in the atmosphere is small, its retention time is low, and it cycles on the average every nine days.
- Once moved from sites of evaporation, water is returned by precipitation. Much of this water is returned to the atmosphere by evaporation and plant transpiration.
- On land, water is absorbed by soil, stored within ground water, and moves by gravity to stream channels and lake depressions. Retention times within groundwater reservoirs are variable, and depend on the composition of the soil and rock, slope gradients, vegetation cover, and climate. Groundwater flow rates are generally slow and the pathways long.
- Retention times in lakes are generally short (6-7 years on the average, but can be much longer).
- Human modification of the environment can result in alterations in the global water balance and the climate.

Changes in water storage and retention in lakes result from alterations in the balance between input rates from all sources and rates of water losses.

Water income results from:

- Precipitation directly on the lake surface
- Water from surface influents of the drainage basin
- Groundwater seepage below the surface of the lake through the sediments or as discrete subsurface springs.

Losses of water from lakes occur by:

- Flow from an outlet in the most common drainage lakes or by seepage through the basin walls into the ground water in seepage lakes
- Direct evaporation from the lake surface
- Evapotransporation from emergent and floating-leaved aquatic plants.

Hydrodynamic Features

All freshwater bodies are inter-connected, from the atmosphere to the sea, via the hydrological cycle. Thus water constitutes a continuum, with different stages ranging from rainwater to marine salt waters.

Rivers are characterized by uni-directional current with a relatively high, average flow ranging from 0.1 to 1 metres/second (m/s). River flow is highly variable in time, depending on the climatic situation and the drainage pattern. In general, thorough and continuous vertical mixing is achieved in rivers due to the prevailing currents and turbulence. Lateral mixing may take place only over considerable distances downstream of major confluences.

Lakes are characterized by a low, average surface current velocity of 0.001 to 0.01 m/s. Therefore, water or element residence times, ranging from one month to several hundred of years, are often used to quantify mass movements of material. Currents within lakes are multi-directional. Many lakes have alternating periods of stratification and vertical mixing; the periodicity of which is regulated by climatic conditions and lake depth.

Groundwater is characterized by a steady flow pattern in terms of direction and velocity. The average flow velocities commonly found in aquifers range from 10^{-10} to 10^{-3} m/s and are largely governed by the porosity and permeability of the geological material. As a consequence, mixing is rather poor and, depending on the local hydrological features, the groundwater dynamics can be highly diverse.

Reservoirs are characterized by features which are intermediate between rivers and lakes. They can range from large-scale impoundments, such as Lake Nasser in Egypt, to small dammed rivers with seasonal pattern of operation and water level fluctuations closely related to the river discharge, to entirely constructed water bodies with pumped in-flows and out-flows. The hydrodynamics of reservoirs are greatly influenced by their operational management regime.

Flood plains constitute an intermediate state between rivers and lakes with a distinct seasonal variability pattern. Their hydrodynamics are, however, determined by the river flow regime.

Marshes are characterized by the dual features of lakes and phreatic aquifers. Their hydrodynamics are relatively complex.

Alluvial and karstic aquifers are intermediate between rivers and groundwaters. They differ generally in their flow regime which is rather slow for alluvial and very rapid for karstic aquifers. The latter are often referred to as underground rivers.

The hydrodynamic characteristics of each type of water body are highly dependent on the size of the water body and on the climatic conditions of the drainage basin. The governing factor for rivers is their hydrologic regime (i.e., their discharge variability). Lakes are classified by their water residence time and their thermal regime resulting in varying stratification patterns. Although some reservoirs share many features in common with lakes, others have characteristics that are specific to the origin of the reservoir. One feature common to most reservoirs is the deliberate management of the inputs and/or outputs of water for specific purposes. Groundwater greatly depends upon its recharge regime (i.e., infiltration through the unsaturated aquifer zone) which allows for the renewal of the groundwater body.