Natural Systems

Hydrological Cycles and Hydroperiods

In simplest terms, the hydrological cycle is the process by which water that rains on the land eventually flows to the sea, and water in the sea evaporates into the atmosphere, is blown over land, and falls on the land as rain, completing the cycle. In Florida, rainfall at times is torrential, leading to flood conditions in rivers, lakes, and wetlands. At other times, scarce rainfall leads to periods of drought when river, lake, and groundwater levels fall, and wetlands dry out. Floods and droughts both create stressful conditions to which the plants, animals, and natural communities of Florida have evolved a variety of adaptations. To a great extent, the locations of plants, animals, and communities are determined not only by seasonal rainfall patterns and geographic location but also by floods and droughts.

Florida is relatively flat with abundant rainfall and a water table that is near the soil surface in many places. As a result, wetlands are a common feature of the landscape. A factor which plays a strong role in determining the locations of wetland-adapted species, and therefore wetland communities in Florida, is hydroperiod (Ewel 1990).

Hydroperiod refers to the depth and duration of standing water in wetlands following rain events. For example, the forested wetlands found in the floodplains of major rivers typically are inundated for 1 to 6 months each year. Hydric hammocks, which are usually found where limestone is very near the earth's surface and groundwater seepage is constant, typically are inundated for 3 to 6 months each year. Most forested wetlands typically are inundated for 5 to 9 months each year. Bay swamps and shrub bogs, both of which occur on sites that have constantly saturated soils that rarely flood, have hydroperiods of 9 to 11 months each year. Herbaceous freshwater wetlands are inundated 7 to 12 months each year to depths of less than 20 inches, and they dry out to depths of less than 12 inches below the ground surface (Kushlan 1990). Hydroperiods are determined in part by wetland location and soil type. For example, river floodplains, obviously, extend landward from the banks of rivers. The species of wetlands plants typical of these areas tolerate frequent, often deep, inundation by flowing waters, but they are intolerant of still-water situations. On the other hand, wetlands found in flatwoods (e.g., cypress ponds, gum ponds, prairie marshes) are in environments where the water does not flow, but rather fluctuates up and down, and inundation may extend for longer periods of time. The species of plants adapted to flatwoods wetlands require adaptations that allow their roots to survive in soils that are low in oxygen for extended periods. Bay swamps often are found at the bases of sandy ridges where rainwater drains through the excessively drained soils, reaches the groundwater table, and then migrates to the base of the ridge where it constantly seeps out. In this situation, the soil remains constantly saturated but rarely floods. The bay swamp at the base of the southeastern end of the Lake Wales Ridge in Highlands County was formed in this manner.

Fire

Naturally occurring wild fires have played a defining role in shaping Florida’s natural communities. Florida has one of the highest frequencies of lightning strikes of any region in the United States and more thunderstorm days per year than anywhere in the country (Abrahamson and Hartnett 1990). In response to thousands of years of frequent lightning-set wild fires, many natural communities in Florida actually are maintained in a stable, nonsuccessional state by frequent fires. Pine flatwoods, longleaf pine (*Pinus palustris*)-wiregrass (*Aristida stricta*) sandhills and clayhills, prairies, scrubs, and herbaceous wetlands all are maintained by regularly occurring fires. In the absence of fires, fire intolerant species, particularly hardwoods, invade a site, and over time the vegetation of a site will succeed to a hardwood forest.

Longleaf pine, formerly the dominant tree of sandhills, clayhills, and flatwoods in the northern two-thirds of the state, is well adapted to frequent wildfires. Longleaf pine is even credited with having adaptations that promote frequent fires. The bark of longleaf pines is highly fire-resistant such that the base of a tree will be scorched by a fire, but the entire tree rarely burns. Juvenile longleaf pines go through a “grass” stage in which the delicate growing bud is closely surrounded by densely packed needles that protect it from ground fires. Longleaf pines also drop their needles like a carpet on the forest floor or on any low-growing vegetation beneath them. Highly flammable when dry, the pine needles readily carry a ground fire of low intensity such that flames rarely reach the forest canopy. In a natural state, longleaf pines grow in a fairly open, park-like situation which does not allow a fire to spread through the canopy even if flames manage to reach the canopy of some trees. Ground cover species such as wiregrass and saw palmetto (*Serenoa repens*) also are highly flammable, promoting the spread of fires, but they rapidly send up new shoots from underground stems and roots after a burn.

Specific burn frequencies are necessary to maintain fire-adapted communities. Sandhills and clayhills burn every 2 to 3 years, pine flatwoods and prairies burn every 3 to 7 years, scrubs burn no more often than every 40 to 55 years, deep water marshes burn every 3 to 5 years, shallow water marshes burn on 1- to 3-year cycles (Kushlan1990), shrub bogs burn every 11 to 33 years, dwarf cypress savannas burn every 11 to 12 years, and cypress ponds and strands burn as often as once every 20 to 25 years (Ewel 1990).

Almost all upland and wetland communities are affected by fire at one time or another. Even forested wetlands, such as river swamps, hydric hammocks, mixed hardwood swamps, gum ponds, lake fringe swamps, and bay swamps, are likely to experience fire once a century. Hardwood forests are about the only upland type of community that does not burn regularly. Fires that burn hardwood forests typically are catastrophic, and other types of communities are likely to vegetate a site after a hardwood forest has burned.

Historically, naturally occurring wild fires could burn over large areas, impeded only by water bodies or saturated wetlands. However, Florida is now crisscrossed with roads and fire lanes, urban developments have sprung up next to flatwoods and sandhills, and timber has been cleared. The net result of human intervention has been that naturally occurring wild fires no longer occur with their former frequency, and fire-maintained communities are no longer able to sustain themselves without help. Many forests must now be burned under controlled conditions in order to reduce fuel and eliminate hardwoods. Otherwise, unburned sites will either succeed to hardwood forests or will burn catastrophically due to over-accumulation of fuel. However, even controlled burning of fire-maintained communities is becoming more difficult as Florida continues to develop. Smoke from controlled fires may drift across an increasing number of roads, creating traffic hazards, or it may blow into urban neighborhoods where the residents are likely to have health or safety concerns.

A further issue with burning pertains to season of burn. Most natural wild fires occur in the summer months when thunderstorms and lightning are more likely. Summer is the growing season for most plants as well as the reproductive season for most animals. Plant ecologists, in particular, believe that the growing season is the appropriate time to conduct controlled burns of Florida's fire-maintained communities as many species of plants are stimulated to reproduce by fires. However, most controlled burns have been conducted in the winter when weather is cooler and plant materials are dead or dry and highly flammable. Many ecologists believe that the long history of winter burns has subtly shifted the composition of many plant communities away from that which occurred naturally. Land managers are experimenting with conducting controlled fires during the growing season in an effort to shift fire-maintained communities towards a more natural state.

Nutrient Cycling and Food Webs

The phrase "ashes to ashes, dust to dust" is an age-old acknowledgment of the existence and fundamental necessity of nutrient cycling. All plants and animals require nutrients in order to live and grow. Whereas plants require nutrients in elemental or ionic form, animals are more dependent on nutrients in organic form. The principal nutrients affecting life on earth are nitrogen, phosphorus, potassium, sulphur, oxygen, and carbon. Since the earth contains a finite quantity of the nutrients needed for life, plants, animals, and communities have evolved complex mechanisms for recycling nutrients for repeated use.

Plants obtain nitrogen, phosphorus, potassium, and sulphur from the soil, and they obtain carbon and oxygen from the air around them. These raw ingredients are used to capture sunlight energy and build plant tissues. The process of growing depletes nutrient reserves in the soil, and, in order for life to continue, mechanisms are needed to return nutrients to the soil. This is accomplished in several ways. Plants may die and fall to the ground where decomposing organisms, such as fungi and bacteria, slowly break organic materials down into inorganic form for reuse by plants. Fire is a more rapid way of recycling nutrients. Wild fires or prescribed burns quickly turn organic plant (and animal) materials into inorganic form, bypassing the decomposer organisms and making nutrients available to plants.

Another way that nutrients are recycled is through the food web. Most plants and plant parts are eaten by some type of animal. Animal species have evolved a tremendous variety of adaptations to take advantage of specific species of plant or particular parts of plants. For example, butterfly larvae eat leaves, aphids suck plant juices, sandhill cranes feed in part on plant roots, cedar waxwings prefer berries, and gopher tortoises eat grass. In turn, animals are eaten by other animals, which are eaten by still other animals. All along the way, all animals excrete dung, which usually ends up on the ground where it is reduced to inorganic form by decomposer organisms. Animals may also simply die of illness or old age and be recycled to the soil, again by decomposer organsims.

Nutrients often are exported from one ecosystem to another by water. Falling rain carries with it dilute quantities of dissolved nutrients which are readily available to plant life. As water from rainfall seeps into the soil or flows off the land, nutrients are leached from the soil and carried downstream, ultimately fueling life in rivers, lakes, estuaries, and the ocean.

A very special form of nutrient recycling without which life could not exist is anaerobic decomposition, the break down of organic materials in environments where oxygen is lacking. Such environments typically occur in sediments at the bottoms of lakes, wetlands, estuaries, or marine ecosystems. In these environments, specially adapted bacteria are capable of using the energy available in organic compounds to break organic materials into inorganic nutrients. In the process, these special decomposers release elemental nitrogen and hydrogen sulfide gases which bubble to the surface and are released into the atmosphere. Anaerobic decomposition is the only way that nitrogen and sulphur are recycled for reuse by plants and animals. In the absence of anaerobic decomposition, all dead organic materials would eventually end up in an anaerobic environment at the bottom of a water body, and life would cease to exist. Famed Florida limnologist Edward Deevy once wrote a brilliant essay entitled, “In Defense of Mud,” in which he extolled the importance of mud, wetlands, and smelly estuarine sediments for their role in recycling nutrients essential to the very existence of life.

Natural Ecosystems Management Issues

Atmospheric Deposition

Air pollution not only affects human health, but can also affect the quality of water in rivers, lakes, and estuaries. Air pollutants may fall as dry particles on land or water or may be deposited with rainfall. The process of deposition entails emissions of particulates and gases from air pollution sources, transport of these emissions by wind, potential chemical or physical transformations, and depositions to land and water surfaces. Deposition may be direct to the water body or indirect from runoff from the land surface.

Sources of pollutants reaching Florida may be global as well as regional and local. In Florida most air pollutants come from fossil fuel combustion, mostly from power plants and motor vehicles. Waste incineration, sulfuric acid production, cement manufacturing, pulp and paper production, and combustion of plant and animal biomass are also significant sources of air pollutants. Natural processes such as volcanic eruptions, forest fires, and suspension of eroded soil particles may contribute to air pollution.

The U.S. Environmental Protection Agency conducted a national surface water survey between 1984 and 1986 to identify the extent of acidification of lakes and streams in the United States. Of water bodies sampled in Florida, 23 percent of the lakes and 39 percent of the streams were found to be acidic. Further studies indicated that some lakes in the north central peninsula do have increased acidity due to atmospheric deposition. In most cases, however, naturally occurring organic acids are the dominant factor controlling the acidity in acidic streams. No widespread fish population losses or decreases in fish biomass have been documented because of acidic deposition in Florida.

The U.S. Environmental Protection Agency has identified eutrophication (nutrient enrichment) as one of the most serious pollution problems facing estuarine waters in the United States. Nitrogen compounds from atmospheric deposition exacerbate this problem. Eutrophication may result in oxygen depletion or reduced oxygen in the water, nuisance or toxic algae blooms, dieback of underwater plants due to reduced light penetration, and reduced populations of fish and shellfish.

In Florida coastal waters seagrasses provide shelter, and nursery and feeding habitat for many popular fish and shellfish. The quantity of seagrass is an important indicator of estuary health. In the Tampa Bay estuary, for example, seagrass losses have been attributed, in part, to reduced penetration of sunlight due to excess concentrations of phytoplankton and suspended solids in the water column. These excess concentrations are related to the increased nutrient loadings that have occurred in the past in the Tampa Bay estuary. Over the past 10 to 15 years, however, seagrass has increased by about 4,000 acres, largely as a result of improvements in sewage treatment and stormwater management. The current nitrogen loading to Tampa Bay is largely due to atmospheric deposition, either directly to the bay’s surface or transported by stormwater from the bay’s watershed. The Tampa Bay National Estuary Program has estimated that 27 percent of the bay’s nitrogen loading is due to direct deposition to the bay. Atmospherically derived nitrogen from watershed runoff could increase the total to 50 to 60 percent.

In 1989 a joint monitoring project by the Florida Game and Fresh Water Fish Commission, Florida Department of Health and Rehabilitative Services, and the Florida Department of Environmental Protection found high levels of mercury in fish from the Everglades. Mercury is known to be neurotoxic to humans, and its consumption through contaminated food has caused substantial illness and mortality in several episodes elsewhere in the world. These and subsequent findings of high mercury levels in fish led the State Health Officer to issue a series of health advisories urging fishermen not to eat some species of fish caught in the Everglades, and to sharply limit consumption of largemouth bass taken from other fresh waters in Florida.

At the time of this writing, seven years after the initial findings, we know that approximately 1 million acres of the Everglades drainage system contain fish with markedly elevated mercury burdens. Largemouth bass (*Micropterus salmoides*) average over 1.5 parts per million mercury, which exceeds all health-based standards. More than another million acres of fresh waters of Florida contain largemouth bass with elevated, but lesser, levels of mercury. When sampling is complete, mercury problems in bass are expected to be found in one-half to two-thirds of Florida's lakes and streams. Excessive mercury levels are also found in some marine fish, particularly large, long-lived predators such as shark and king mackerel (*Scomberomerus cavalla*), and certain fish from limited areas of near-shore waters.

Excessive levels of mercury found in fish today is not limited to Florida. Thirty--seven states have issued health advisories restricting consumption of fish, and similar problems arefound widely in North America, Europe, and Asia. Many lakes in Canada and Scandinavia, for example, are affected.

It is generally accepted that the widespread mercury problem is caused by air pollution. Both long distance transport and localized deposition around certain types of sources may be important. Major sources to the atmosphere are metals mining and smelting, coal-fired utilities and industry, and the use and disposal of mercury in commercial products. The unusually severe problem in the Everglades has many unique features, and may be the result of a combination of other factors. Initial studies focused on the local effects of municipal incinerators and other emissions sources on the southeast coast of Florida, increased release of mercury from the soils of the Everglades Agricultural Area promoted by drainage and soil disturbance, or increased mercury mobilization from Everglades soils stemming from hydrological changes caused by the Central and South Florida Flood Control Project.

A four-year study by researchers at Florida State University and Texas A & M University funded by the U.S. Environmental Protection Agency, Florida Department of Environmental Protection, the Florida Electric Power Coordinating Group, Florida Power and Light, the Electric Power Research Institute, and the South Florida Water Management District found that mercury concentrations in rainfall increase in the summertime when rainfall is highest, whereas concentrations of other pollutants decrease. Researchers theorized that most of the air-borne mercury falling on the Everglades originates from heavy industry to the north both in the United States and abroad. Elemental mercury travels along with air currents from the U.S. east across the Atlantic until it reaches and mixes with air currents from the coast of Europe, which contain mercury not only from Europe but perhaps from Russia and China as well. The air mass now travels south where the trade winds carry it back across the Atlantic to Florida. Summer thunderstorms, with thunderheads up to 12 miles high, scour the mercury out of the upper atmosphere (Stephenson 1997).

Once mercury is in the surface water rapid geochemical transformations can occur beginning the process of bioaccumulation. Precise mechanisms are unknown, but mercury probably enters the food chain when plankton consume mercury containing bacteria. Understanding this initial step is critical because concentrations of mercury in plankton increase 10,000-fold over water concentrations (Krabbenhoft 1996). At each other trophic level the increase in concentration is 10-fold or less. The U.S. Geological Survey, the South Florida Water Management District, and the U.S. Environmental Protection Agency are co-funding a group of scientists to study mercury bioaccumulation in the Everglades. The overall objective of the study is to provide resource managers with information on the hydrologic, biologic, and geochemical processes controlling mercury cycling in the Everglades. Results of this study are expected to be available in the fall of 1999.

Loss and Degradation of Upland and Wetland Habitats

The land area of Florida supporting natural vegetation types has declined dramatically since European settlement. Florida's rapid population growth, particularly over the last 100 years, has resulted in the conversion of vast areas of the natural landscape to human uses. Today, agricultural, urban, and other uses account for 43 percent of the Florida landscape, and forests and herbaceous wetlands comprise the other 57 percent (Kautz, in press).

Most of the remaining 57 percent that is in some type of natural vegetative cover has been affected by human use to some extent. For example, nearly all forest lands in Florida have been logged at some time in the past. In 1995, 24 percent of all forest land was in densely stocked, single-species pine plantations (Kautz, in press), and wetland and upland hardwood forests increasingly are being logged for wood products. Many remaining natural areas are subject to intensive recreational uses including off-road vehicle and airboat operation. In addition, exotic species, such as melaleuca (*Melaleuca quinquenervia*) and Brazilian pepper *(Schinus terebinthefolius*), have invaded many natural areas, radically altering habitat values for native species of plants and animals.

In the course of conversion of the Florida landscape to human uses, some natural community types have been impacted more severely than others. Overall, forested lands have suffered the most with over 4.63 million acres having been cleared in the last 59 years (Kautz, in press). Of particular interest, south Florida pine rocklands have all but disappeared. Of the 375,000 acres of south Florida pine rockland habitats mapped by Davis (1967), only 6,000 acres remained (a 98 percent loss) in 1988. Large areas of herbaceous wetlands have been drained and converted to human uses. For example, herbaceous wetlands declined 51 percent between 1936 and 1995 (Kautz, in press) with over 700,000 acres having been lost in the Everglades ecosystem alone. Forested wetlands declined 17 percent between 1970 and 1987 despite aggressive wetlands protection programs (Kautz 1993).

Loss and Degradation of Riverine Habitats

The rivers throughout Florida are under stress from a number of factors. Many of the rivers have been channelized for navigation; flows have been stabilized by dams and reservoirs; floodplains have been converted to agricultural, development-related, or mining-related uses or have been destroyed by dams; and flows have been reduced due to water withdrawal for human use. These man-made alterations have resulted in loss of physical habitat and of aquatic species. For example, many species of mussels are in serious decline due to alterations of riverine habitats, siltation, deteriorating water quality, and flow stabilization throughout the United States.

The Apalachicola River system is an example of a river system that has been altered by navigation, reservoir management, and potential minimum flow level requirements. The river has a congressionally authorized 106-mile navigation channel, upstream dams, and a reservoir/dam located at the Florida state line. Navigation channel maintenance has led to substantial changes in shoreline and floodplain habitats (Ager et al. 1987). The shoreline has been converted from snag and natural bank habitat to unproductive sand piles due to spoil disposal practices. The Jim Woodruff Dam at the Florida state line impedes the migration and spawning of anadromous fish species, like the threatened Gulf sturgeon and striped bass. Striped bass eggs naturally float or bounce down the river prior to hatching into fry. Prior to the dam, striped bass could swim upstream far enough that, when spawning was complete, the eggs were in no danger of reaching the injurious brackish waters of Apalachicola Bay before hatching. However, now, with the dam in place, striped bass eggs float downstream into the estuary before they can hatch, effectively precluding striped bass reproduction from the Apalachicola River. During low flow periods, the management of the upstream reservoirs and dams is altered to create short-term flow pulses for navigation. These pulses have been observed to affect the spawning behavior of fish (Charles Mesing, personal communication) and may affect the ecology of the river and bay. Upstream users also are interested in the identification of minimum flow levels for the Apalachicola River such that in-stream biological resources are protected while water use needs of Georgia residents are met (U.S. Army Corps of Engineers 1992).

If a single minimum flow level is established, the entire river and bay system ecology will change without the naturally occurring high and low flow conditions.

The introduction of non-native species has also placed riverine ecosystems under extreme stress. These species compete with the native species for habitat and food. Non-native species often will eliminate native species from their natural habitats. These introductions have occurred over the years due to intentional release by individuals, escapes from fish hatcheries, migration from upstream sources, inadvertent transport by shipping and boating interests, and escapes of ornamentals from landscaping projects. Several aquatic plants that were released into Florida’s rivers, lakes, and streams, such as hydrilla, Eurasian water milfoil (Myriophyllum spicatum), and water hyacinth, require extensive control measures in order to keep the water bodies open and not completely covered by the vegetation. Non-native fish that have escaped from fish hatcheries ortral and south Florida streams and canals. Many of these fish have established breeding populations and are eliminating native fish populations. The National Biological Survey has documented over 100 non-indigenous species and over 750 specific location occurrences in Florida water bodies. The flathead catfish (Pylodictis olivaris) and several mussel species have migrated into Florida rivers from upstream sources. The appearance of the flathead catfish in several north Florida rivers corresponds to a decline in redbreast sunfish (Lepomis auritus) populations, which are a food source for the flathead catfish (Charles Mesing, personal communication).

Loss and Degradation of Lake Habitats

The principal problems experienced by Florida lakes are: lake level stabilization, dredge and fill, eutrophication, lowered lake levels from groundwater withdrawals, and invasion by non-native aquatic plants.

In their natural condition, water levels of Florida lakes fluctuated in response to rainfall. In many areas, the very flat landscape allowed lake margins to expand or contract over a large floodplain depending on whether flood or drought conditions prevailed. As a result, many lakes were characterized by broad, productive floodplains usually supporting herbaceous wetland vegetation. Fluctuating lake levels allowed fish populations to expand and contract, and permitted shallow margins to dry out and accumulated organic sediments to decompose. However, throughout central and south Florida, lakes have been connected by canals, and water levels have been stabilized by water control structures as a flood control measure. The consequences of lake level stabilization have been that large areas of floodplain habitat are no longer available to aquatic life in many lakes, and no opportunity exists for organic sediments that accumulate on the lake bottom to decompose. Under these conditions, habitat conditions for aquatic life have deteriorated. In an effort to rejuvenate conditions for aquatic life, many lakes are drawn down and dried out on 7- to 10-year cycles to allow organic accumulations to decompose. However, lakes never have the chance to flood their natural floodplain because those areas have been converted to housing developments that would flood if lake levels were raised.

The dredging of lake bottoms to create navigation canals, the filling of lake bottoms for building construction, or the removal of shoreline vegetation for beach development have all led to loss or degradation of lake habitats. Dredging of lake bottoms typically creates a zone that is too deep for light penetration. Moreover, deep areas of lake tend to accumulate organic sediments that rob the water column of oxygen as they decompose and render those areas of the lake bottom uninhabitable to most aquatic life, including sport fishes. Filling of lake bottoms for building construction eliminates wetland and aquatic plants. Similarly, the clearing of wetlands and aquatic vegetation from the shoreline for aesthetic purposes or to create a beach destroys plants and animals.

Eutrophication is the natural process of aging of lakes (and even estuaries). All lakes receive a steady supply of nutrients, particularly nitrogen and phosphorus, from rainfall and runoff. Nutrients stimulate the growth of algae and aquatic plants, which ultimately die, fall to the bottom, and decompose. Because decomposition is usually incomplete, lakes gradually fill in over long periods of time, eventually becoming wetlands. Today most Florida lakes receive excessive nutrients in stormwater runoff draining from agricultural fields, fertilized lawns, and other sources. Increased nutrient inputs have dramatically increased algal production in many Florida lakes. The higher numbers of algae not only reduce light penetration, rendering shallow habitats less suitable to submerged aquatic plants, but they also accumulate on the bottom. As a result, bottom habitats are deprived of oxygen by oxygen-demanding decomposer organisms and are rendered unsuitable for many forms of aquatic life. Although the early stages of lake eutrophication result in increased populations of sport fishes, continued inputs of nutrients accelerate the aging process, leading to poor habitat conditions and low fish populations. Examples of highly eutrophic lakes are Lake Apopka, Lake Jessup, Lake Hancock, and Lake Munson. Lake drawdowns also are used to rejuvenate eutrophic lakes, at least for 7 to 10 years, depending on nutrient input levels.

In some areas, such as the DeLand Ridge, excessive withdrawals of groundwater for human uses have dramatically lowered the level of the surficial aquifer. Since lakes typically occur where groundwater levels intersect the land surface, lowered groundwater levels have led to lowered lake levels. In some cases, lakes have dried up completely due to excessive groundwater pumping. Lakes that occur in regions of deep, sandy, excessively drained soils are especially susceptible to lowered levels in response to lowered groundwater levels.

Many Florida lakes are infested with non-native aquatic plants, the most familiar being hydrilla (*Hydrilla verticillata*) and water hyacinth (*Eichhornia crassipes*). Hydrilla, a rooted, submersed aquatic weed, is the most troublesome nuisance aquatic plant in Florida lakes (Nordlie 1990).

Hydrilla, which spreads rapidly from both underground rhizomes as well as seeds, can quickly fill the water column and form dense mats at the surface. Dense growths of hydrilla reduce fish habitat, impede navigation, and accelerate eutrophication by overloading a lake with huge quantities of dead plant materials. Water hyacinth, a free-floating aquatic plant from Brazil, can double its biomass in two weeks in nutrient rich waters. Water hyacinths can completely cover the surface of small lakes or of embayments of larger lakes. Water hyacinths prevent sunlight from penetrating the water column and reaching submersed aquatic plants. They continually rain dead plant materials on the lake bottom, overloading the decompositional capabilities of lake sediments, depleting oxygen from the water column, and rendering the water column beneath water hyacinth mats uninhabitable to most fishes and other forms of aquatic life.

Loss and Degradation of Estuarine and Marine Habitats

Loss and degradation of estuarine and marine habitat from human impact has been prevalent ever since coastal development began in Florida. Habitat loss and degradation can be categorized into five broad categories: dredge and fill, mosquito control impoundments, water quality degradation, propeller scarring, and alteration of freshwater inflows.

In Florida dredging and filling typically refers to the practice of digging or filling areas classified as wetland or submerged lands. Historically, this has been the most prevalent type of direct impact on mangrove, salt marsh, seagrasses, and tidal river habitats. Major dredge and fill impacts have been from waterfront development and navigation channel construction and maintenance. In three case studies Durako et al. (1988) found that dredge and fill accounted for salt marsh losses of 36 percent, 20 percent, and 19 percent, respectively, in the Jacksonville, St. Augustine, and Daytona Beach regions since the 1940s. Boca Ciega Bay near Tampa is an example of extreme loss (over 90 percent) of estuarine habitat. Shallow seagrass beds were dredged into massive fill areas for residential and commercial development (Haddad 1989).

Since the 1970s, loss of estuarine and marine habitat due to dredge and fill has been significantly reduced through regulation.

Mosquito control has been responsible for much of the impact to salt marshes and mangrove swamps in Florida. The salt marsh mosquito (Aedes taeniorhynchus) lays its eggs on tidally moist sediments, and small tidal pools and puddles within a marsh are necessary for successful larval hatching. One technique to control mosquitoes has been to build a dike around a marsh, cutting it off from the estuary. Salt water is then pumped into the impounded area to flood the marsh so that tidally moist sediments are not available for egg laying. In the Indian River Lagoon, over 85 percent of the salt marsh and mangrove swamp habitats have been impounded, effectively removing these habitats as functional components of the estuary. Salt marsh impoundments are no longer permitted, and active impoundment management and reconnection of the marshes to the estuary is taking place to try to reduce the extent of previous impacts.

Ditching has been the most widespread method of salt marsh mosquito habitat control. Ditches are dug to drain or to allow predatory fishes access to the small intramarsh tidal pools and puddles required for the five-day, aquatic larval stage of the salt water mosquito. Thousands of miles of ditches have been dug, crisscrossing virtually every major tidal marsh and wetland in Florida. Not only were ditches created, but also the spoil taken out of the ditch often became a dike that impeded sheet flow, altering the drainage patterns responsible for creating the marsh in the first place.

Degradation of water quality has been determined to be a significant factor in the loss of seagrass habitat and is potentially detrimental to the health of Florida’s coral reefs. Seagrass health and distribution are primarily controlled by the amount of light available for photosynthesis. By changing upland and riverine drainage and land-use patterns, increased quantities of nutrients and silts have been introduced into estuaries, the result of which has been reduced water clarity. Coupled with discharges of treated sewage and industrial effluents, reductions in water quality have significantly impacted seagrass populations. For example, it has been estimated that Tampa Bay has lost 81 percent of its seagrass beds since the 1940s, Charlotte Harbor has lost 29 percent of its seagrass beds, and Indian River Lagoon has lost 30 percent due to degraded water quality (Lewis et al. 1985, Haddad and Harris, 1985)

Water quality degradation remains the most significant threat to seagrasses statewide. A costly and successful effort to ameliorate water quality problems in Tampa Bay has resulted in an increase in water clarity and a concurrent 10 percent increase in seagrass (Lewis et al. 1991). This demonstrates that many areas that have historically lost seagrasses can recover if water quality is improved.

There is considerable concern that degradation of water quality in the Everglades has led to deteriorating habitat conditions in Florida Bay and that degraded waters from the Florida Keys are impacting Florida's precious coral reefs. Smith-Vaniz et al. (1995)
have suggested that Florida coral reefs are undergoing change due to water quality.

A phenomenon associated with the tremendous increase in the number of power boats coursing Florida's coastal waters is propeller scarring of seagrass beds. In many areas, seagrass beds are in estuarine and marine waters at depths less than 3.5 feet. When power boats move through such areas, their propellers often hit bottom, uprooting and killing seagrasses. In shallow waters that experience heavy boat traffic, seagrass beds can be badly damaged, seagrass productivity can be lowered, and the value of these waters as habitats for estuarine and marine life can be severely damaged.

Estuarine ecosystems have evolved into one of the most productive ecosystems in the world in response to naturally fluctuating, seasonal drainage patterns of freshwaters flowing to the sea. Freshwater delivers the needed nutrients and environmental conditions for sustaining habitat, and the life cycles of many of the marine species of recreational and economic importance are closely tied to natural freshwater inputs.

The flow of too much freshwater into an estuary can be catastrophic. In many areas of Florida, the practice of flood control has resulted in huge volumes of water being released into the estuarine environment over short periods of time. For example, water management practices in the upper Everglades result in excessive flood water releases into the St. Lucie estuary. The flood waters carry heavy loads of silt that have smothered some of the offshore hard bottom and reef communities in the area. Further south at the terminus of the Everglades, large volume releases of fresh water through the C-111 canal system into Barnes Sound have resulted in massive fish kills and loss of seagrass bed and other bottom habitats. Similarly, a flood control canal connecting the upper St. Johns River to the Indian River Lagoon occasionally releases huge quantities of freshwater through the Sebastian River, periodically devastating commercially cultured clams in the lagoon.

Too little freshwater can also be detrimental to estuaries. Perhaps Florida Bay at the southern tip of Florida represents the extreme results of reductions in water delivery. Since the late 1800s, the Everglades ecosystem, stretching from the Kissimmee River to Florida Bay, has been ditched and drained for farming and flood control. Now, about 80 percent of the water that formerly moved slowly through the Everglades and into southern estuaries, such as Florida Bay, today is discharged to east and west coast estuaries. As a result, conditions in the Everglades have changed in response to changes in water delivery and water quality, and reductions in freshwater inflows are believed to be a major reason for the ongoing problems with the biological systems of Florida Bay. It has been estimated that many thousands of acres of seagrass beds have been dying due to poorly understood changes in the Florida Bayas well as mangrove and sponge die-offs, have been occurring in the bay. These changes appear to be linked to the overall problems in the Everglades. Reduced freshwater inflows also allow higher salinities to extend further upstream in tidal rivers, often killing plants and animals adapted to tidal freshwater environments.

With the exception of the Caloosahatchee River, the estuaries of the Florida Gulf coast have experienced decreasing inflows of freshwater, in part for climatological and in part for cultural reasons. In order to meet the demands of a growing population for water supply, flood control, and irrigation, further declines in freshwater inflows to Gulf coast estuaries are very likely in coming decades. Some river supplies already are tapped to the maximum, as is the case with the Manatee River near Bradenton, where impoundment and diversion of water for municipal supply reduces river flow by 90 percent for 80 percent of the time. In other streams, such as the Peace River, water use permits allowing for gradual, albeit monitored, increases in flow diversions to support a regional water supply system have been issued. Like their counterparts in the Apalachicola, estuarine scientists and resource managers working in the Suwannee River are bracing for claims from south Florida residents on that river’s abundant supply of fresh water.

Ecological effects of reduced freshwater inflows are numerous and diverse, and depend on the nature of the changes. Inflow reductions promote higher salinities in estuaries. In some cases, flow reductions also can accelerate eutrophication by increasing retention times of nutrients in estuaries. In the Tampa bypass canal (formerly the Palm River), reduced flows create hypoxic (low-oxygen) zones harmful to larval and juvenile fishes. Sub-lethal harm to fisheries may result when changed inflows dislocate physiologically favorable salinity zones in rivers or estuaries from the preferred marsh, seagrass, oyster-reef, or other structural habitats preferred by particular life stages of individual species.

Some estuarine ecosystems have been or may be affected by multiple changes. In southwest Florida, for example, the connected estuaries of Faka Union, Fakahatchee, and Pumpkin bays have experienced freshwater inflow increases, decreases, changes in timing, and relocations of points of delivery, owing largely to drainage impacts caused by the Golden Gate Estates canal.

Slow progress is being made in methods for detecting ecological responses caused by inflow changes. It is clear from studies of panhandle oysters or south Florida shrimps that inflows at certain times of the year are more critical than other times. The same studies have shown that statistical relationships between flows and landings or catch-per-unit-effort must consider the maturation rate of particular species. Recent studies around the margin of Tampa Bay have shown that small changes in the riverine position of salinity zones can translate into large gains or losses of oligohaline (i.e., low salinity) habitat.

Impacts of flow alterations are worsened by the presence of instream barriers. Many Florida streams have dams, flood-control gates, salinity barriers, or other structures near, if not actually in, tidal waters. Numerous estuarine fishes historically moved far up into Florida's freshwater rivers due, in part, to the state's abundance of mineralized springs. Instream barriers prevent such movements. A single flood control structure in the tidal Sebastian River, for example, has reduced fish species diversity by 60 percent upstream of the barrier. Many valued species, such as the snook (*Centropomus undecimalis*), naturally extend into rivers. For example, some 3.4 percent of fishes at Fort Meade, 109 miles upstream of the mouth of the Peace River, are snook. However, snook no longer occur upstream of large barriers on other coastal rivers. Instream barriers that no longer serve their purpose need to be identified and either replaced by other structures or removed.

Loss of Biological Diversity

Extinction refers to the decline and eventual complete disappearance of all individuals of a species or subspecies. Extirpation refers to disappearance of all individuals of a species or subspecies from a particular region, even though the species or subspecies may persist elsewhere. Whereas extinction is forever, extirpation holds out the hope that a species or subspecies may be reintroduced into and persist in its former range.

Since the time of settlement, 12 vertebrates and 14 plants have either become extinct or have been extirpated from Florida. These species were lost as the result of wanton slaughter, over-collection, or conversion of Florida's natural ecosystems to human uses.

Another measure of the status of biological diversity in Florida is the number of species listed as endangered, threatened, and species of special concern. Species listed as endangered have population sizes so low that they are in imminent danger of extinction. Species listed as threatened have declining populations and are in jeopardy of being listed as endangered if population trends are not reversed in the near future. The species of special concern category serves as an early warning system by recognizing species that are declining.

In part due to the rich variety of life in Florida and in part due to extent of development in the state, Florida is second only to California in the number of species listed by the federal government as endangered and threatened. Florida lists 110 vertebrates, 7 invertebrates, and 413 plants as endangered, threatened, and species of special concern (Logan 1997). These endangered and imperiled species include 13 percent of freshwater fishes, 9 percent of the amphibians, 19 percent of the reptiles, 12 percent of the birds, 33 percent of the mammals, and 12 percent of the vascular plants in the state. Overall, a relatively high percentage of the state's plants and animals are in sufficient jeopardy of extinction or extirpation that they are legally recognized as in need of conservation attention.

The populations of Florida's most endangered species are perilously low. The Florida panther (Puma concolor coryi) numbers 30 to 50 adults. The key deer (Odocoileus virginiana clavium) population is estimated to include only 250 individuals. The American crocodile (Crocodylus acutus) population includes no more than 500 juveniles and adults, of which only 30 are breeding females.

Although a few Florida species are already extinct or extirpated, and although many have already been listed as endangered or potentially endangered, many more are known or suspected to have declining populations. In a survey of experts in vertebrate biology in Florida**,** Millsap et al. (1990) found that 31 fishes, 12 amphibians, 59 reptiles, 151 birds, and 43 mammals have declining populations. Overall, this survey showed that 44 percent of all Florida vertebrates are known to have, or are suspected of having, declining populations. Loss of habitat to development is usually cited as the reason for the observed declines in the populations of most of these vertebrates.

Habitat Fragmentation

One consequence of the conversion of the natural Florida landscape to agricultural, silvicultural, mining, and urban uses has the been the fragmentation of remaining habitats. As development progresses, remaining habitat patches become smaller in size and increasingly isolated from one another (Wilcove et al. 1986)**.** The inevitable consequence of habitat fragmentation is the loss of biological diversity from a region. Remaining patches of habitat grow too small to support individual plants or animals of a given species, and those species are eliminated from the patch. When many habitat patches in a region become too small to support individuals, entire populations may disappear from a region even though remaining patches appear to contain suitable habitat in all other respects.

Small patches of habitat, particularly forests, also experience edge effects. Edge refers to a zone extending from the forest edge some distance into the interior where influencesreceive more sunlight and are more subject to winds. As a result, microclimate conditions in forest edges are hotter and drier than they are in the interior of the forest. Edge habitats are dominated by common, weedy, early successional stage species of plants, whereas forest interiors are dominated by shade-tolerant climax species. As a general rule, forest interiors also support more rare species. The animals that inhabit edge habitats are subject to increased predation and nest parasitism. Moreover, small patches of forest habitat are comprised of entirely edge species and have no species typically found in forest interiors.

Another consequence of conversion of the landscape to human uses is the loss of natural connections among remaining patches of habitat. Linkages between habitat patches benefit many species by allowing for dispersal of juveniles away from their places of birth, for movement of animals within their home ranges, and for long distance range shifts (Noss and Cooperrider 1994). Landscape linkages, such as riparian forests, may also provide habitat directly for many species. Loss of connections among habitat patches can be particularly severe in the case of wide-ranging species. The Florida black bear and Florida panther have become increasingly susceptible to collisions with automobiles as they cross busy highways trying to reach other patches of suitable habitat.

Many conservation biologists agree that the greatest hope for conserving Florida's biological heritage rests in the state's system of public lands. Lands in public ownership are less subject to development than privately owned lands, and many parcels of public land are managed specifically for the maintenance of biodiversity.

As of 1996, the system of public lands in Florida consisted of 3,020 parcels of land covering approximately 21 percent of the state. Biologists often are tempted to view public lands as islands of natural habitat surrounded by a sea of human land uses. Over two-thirds of public lands are smaller than 100 acres in size, and approximately 90 percent are smaller than 1,000 acres. The largest parcel of public land in Florida is Everglades National Park, which is 1.5 million acres in size. This large-scale picture of the system of public lands in Florida is one of many very small, poorly connected patches of habitat with all of the problems associated with small patch sizes.

Priority Conservation Lands

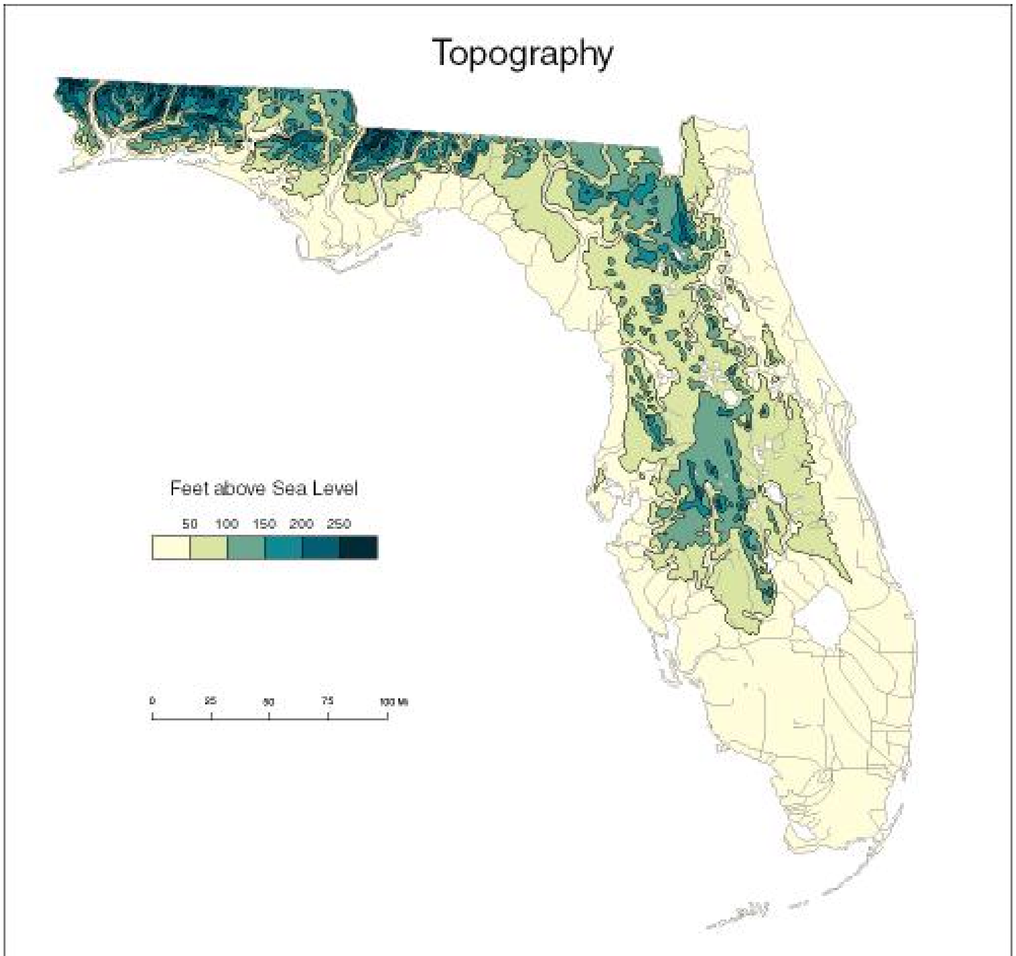
In 1994, the Florida Game and Fresh Water Fish Commission published a technical report (Cox et al. 1994) which identified a set of lands referred to as Strategic Habitat Conservation Areas (SHCA). SHCAs are 4.82 million acres of privately owned lands that should be protected from development in order to ensure the long-term persistence of most elements of Florida's biological diversity. SHCAs are built around and intended to complement biodiversity conservation efforts on the existing system of public lands.

The lands identified as SHCAs include (1) the minimum area of habitat needed to maintain viable populations of 30vertebrates inadequately protected by the current system of public lands, (2) known high quality examples of four rare community types including pine rocklands, tropical hardwood hammocks, sandhills, and scrubs, (3) wetlands important to the continued nesting success of wading birds, (4) lands needed to protect significant bat caves, and (5) lands important to the conservation of 105 globally rare species of plants. The SHCA maps were developed as a guide to decision makers involved in public land acquisition, land use planning, development regulation, and private landowner conservation initiatives.

As a part of the Florida Game and Fresh Water Fish Commission project to map Strategic Habitat Conservation Areas, Cox et al. (1994) also mapped lands they referred to as Biodiversity Hot Spots. This map depicts patterns of species richness for 54 focal species of vertebrates selected as indicators of biological diversity in Florida. The criteria used to select the 54 focal species were: species listed by the state of Florida as endangered, threatened, or species of special concern that are jeopardized by habitat loss; wide-ranging species whose protection would also protect habitats for many species with smaller area requirements; species that are indicators of rare community types; and keystone species whose activities allow other species also to be present. Separate habitat distribution maps were created for each of the 54 focal species using a map of Florida vegetation derived from Landsat satellite imagery, records of known occurrences for each species, and information on the habitat requirements of each species. Then, the 54 individual species maps were overlaid and ranked to produce the Biodiversity Hot Spots map. The importance of large public land holdings to many focal species is clearly apparent from the map. Areas appearing in gray on the map generally indicate relatively large tracts of forested lands utilized by bobcat and wild turkey (*Melagris gallopavo*). Although these two focal species are not currently in jeopardy in Florida, their presence usually indicates habitat conditions suitable for a variety of native species.

Among the vertebrates listed by the state of Florida as endangered, threatened, or species of special concern, 33 are wetland-dependent. That is, these species inhabit only wetlands, or they require wetlands during some time in their lives to survive (e.g., breeding, feeding, roosting).

Kautz et al. (1994) mapped and ranked Florida wetlands based on the number of wetland-dependent listed species likely to use each wetlands. The map was created by first developing a distribution map for each species using habitat maps and known occurrence information, and then overlaying the 33 separate species maps and ranking wetlands based on species use. The extensive wetlands ecosystems of south Florida, particularly in the regions of the Everglades and Big Cypress Swamp, provide habitat to the largest number of wetland-dependent listed species. Other notable wetlands include the marshes of Lake Okeechobee, the marshes of the upper St. Johns River, coastal wetlands around Pine Island in Charlotte Harbor, the wet prairies south of Gainesville, forested and shrub swamp wetlands in Dixie and Lafayette counties, and forested wetlands around Osceola National Forest. Also mapped by Kautz et al. (1994) were upland habitats used by some of the wetland-dependent listed species. The most extensive areas of upland use are the pine flatwoods ecosystems of north Florida lands that provide habitat for the Florida black bear.


Topography
Feet above Sea Level
50
100
150
200
250


Wetlands Prior to Development
Wetlands

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Study Questions

1. What is a hydrological cycle?

2. What is a hydroperiod?

3. What is a controlled burn? Scientifically, what time of year should it be done in Florida?

4. Define eutrophication? What are the problems associated with this phenomenon?

5. Look up Melaleuca quinquenervia and Brazilian pepper (Schinus terebinthefolius) on the internet? What are the problems each of these species present to the ecosyustems of Florida?

6. Write a short paragraph about Hydrilla verticillata and water hyacinth (Eichhomia crassipes). Include their origin, introduction, and problems they create in Florida lakes.

7. What effect does freshwater have on an esturine ecosystem?

8. What is biodiversity? Why is it important? What is happening to biodiversity in Florida?

9. What are Strategic Habitat Conservation Areas (SHCA)? What are they for? What types of lands are involved?