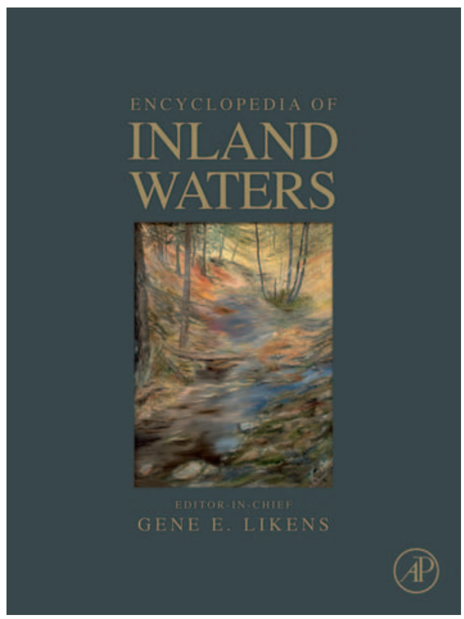

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Wetlands of Large Rivers: Flood plains

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Wetlands on Flood Plains

The term flood plain is defined by the American Geological Institute as 'the surface or strip of relatively smooth land adjacent to a river channel, constructed by the present river in its existing regime and covered with water when the river overflows it banks'. Wetlands on flood plains are important for several reasons: (1) their distribution is ubiquitous in association with streams and rivers throughout the world; (2) their total area is a substantial fraction of global wetland area; (3) often they are sites of rich biological diversity and high biological production; and (4) they perform ecosystem services of value to people and historically have been loci for the development of human societies.

The seasonally or episodically inundated land on flood plains qualifies as wetland to the extent that inundation influences the soils, vegetation, and other elements of the biota, and even brief inundation or soil saturation can be a strong ecological influence in flood plains as in other kinds of wetlands. Many flood plains contain water bodies that are permanent or semipermanent, including floodplain lakes and channels, and often have more extensive shallow wetlands that may remain wet throughout the year. From the standpoint of flood plains as wetlands, these permanently wet areas can be distinguished from land subject to temporary, albeit sometimes prolonged, inundation resulting directly or indirectly from a rise in river level. Seasonal or episodic inundation strongly affects the more permanently wet areas, often completely replacing their surface water and changing the environment for aquatic life.

Flood plains subject to riverine inundation often undergo transition into more distal wetland areas that may have been created by fluvial processes but may rarely or never be inundated directly by river water. Nonetheless, these land surfaces are often poorly drained and are generally considered as flood plains in the ecological literature, even though they tend to be distinct in their ecological characteristics from flood plains subject to riverine inundation. There may be an indirect influence of river level on the hydrology of more distal flood plains through backwater effects on surface or subsurface water levels.

The ecological features of floodplain wetlands are highly variable and many wetland classification schemes do not distinguish floodplain wetlands as a separate category, as for example in the widely used system proposed in 1979 by the U.S. Fish and Wildlife Service. Vegetation- and hydrology-based classifications typically identify wetland classes that can be found both on flood plains and in non-flood plain wetlands. For example, within a typical flood plain there may be forested swamps, marshes with emergent herbaceous plants, shallow permanent lakes, and groundwater-fed fens. Seasonal or episodic inundation may be superimposed on hydrologic regimes that are controlled by local water inputs, or the inundation may be the only source that produces wetland conditions. Permanent water bodies, as delineated during periods of isolation from the river, may expand and become merged with inundated floodplain and adjacent lakes during inundation to form a contiguous flooded area. Very narrow flood plains may be considered to be riparian zones, and there is no consistent delineation between the use of these terms in the literature.

Images and Photos of Floodplain Environments

Remotely sensed images of contrasting types of floodplain environments are included in a companion entry on Flood plains (see **Flood Plains**). In addition, photos of many of these sites appear in the online Flood plain Photo Gallery (cite web site here).

Distribution and Extent

Floodplain wetlands tend to scale with the size of the parent river system with which they are associated, and the largest floodplain wetlands are found along the world's largest rivers, although these wetlands may be composites of riverine floodplains inundated by the parent river and its tributaries, and contiguous, poorly drained areas subject to inundation by locally derived rain and runoff. Geomorphological processes can result in exceptionally extensive flood plains relative to the discharge of the river, as for example in the Pantanal along the Paraguay River in Brazil, where neotectonic subsidence appears to have produced a vast sedimentary plain subject to seasonal inundation.

The largest flood plains have attracted academic attention, but flood plains along smaller rivers and streams add up to a sizable area as well. However as

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streams become smaller and their discharge regime more subject to short term variability, their flood plains are often inundated more irregularly, and as a result their flood plains differ markedly in ecological characteristics. As the duration of inundation decreases the floods become more of a disturbance that limits or excludes some plants and animals, rather than an ecological driver to which specialized elements of the biota can adapt.

Regimes of Flooding and Drying

Ecologists studying flood plains with predictable and protracted inundation have observed that many plants and animals are adapted to cope with and benefit from the seasonal inundation. In 1989 Wolfgang Junk and others synthesized the large body of work on the importance of inundation to articulate the Flood Pulse Concept. The Flood Pulse Concept holds that high species diversity and biological productivity of the overall river-floodplain ecosystem is explained by the seasonal inundation, which maintains a spatially and temporally variable environment with both aquatic and terrestrial characteristics. Much of the biological activity is centered on the flood plains, while the river channels provide critical interconnections among habitats and, at low water, aquatic refugia.

In addition to the frequency, duration, and amplitude of the flood pulse, its timing with respect to climatic seasonality determines its ecological roles. For example, flooding in the north temperate Mississippi River (USA) tends to occur in early Spring before the peak growing season, and flooding in the Mackenzie River delta (Canada) occurs in conjunction with ice breakup because of the northward flow direction of that river. Tropical and subtropical flood plains show the greatest biological responses because inundation occurs at warm temperatures.

Large flood plains can be inundated over vast areas, and in that case the existence and distribution of terrestrial refugia can become a limiting factor for populations of animals that cannot tolerate life in water. Larger terrestrial species of wildlife can abound in flood plains with ample refugia such as tree islands. Presumably these animals take advantage of the abundance of food on flood plains, and the reduced hunting pressure by humans can be important as well.

In some flood plains the characteristics of the isolation phase can be an important ecological driver in addition to the flood pulse of the inundation phase. Relatively small areas of permanent water can host large numbers of aquatic animals as the flooded area contracts. Suitable refugia for aquatic animals such as fishes, either in the river channel or in permanent floodplain water bodies, can enhance their populations. Depending on climate, the soil moisture may become limiting to plant growth. Wildfires are common where vegetation dies during dry periods, as for example in tropical savanna flood plains such as the Pantanal of Brazil and the Orinoco Llanos of Venezuela.

The seasonal alternation between soil saturation or inundation and soil moisture limitation can act to greatly limit the plants and animals that inhabit flood plains, although animals may migrate onto and off of the flood plain in response to changing conditions. Vertical migration of terrestrial invertebrates into forest canopies to escape flood waters has been documented in the Amazon flood plain.

Primary and Secondary Production

Floodplain wetlands commonly support high primary production, particularly in the case of tropical and semitropical floodplains where seasonal inundation often is prolonged and occurs at high temperatures.

Certain aquatic vascular plants (macrophytes) are superbly adapted to the seasonal inundation and variable water levels and attain high rates of primary productivity in spite of the constantly changing environment. Examples include the water hyacinth (*Eichhornia* spp.), water lettuce (*Pistia stratiotes*), and several grasses (e.g., *Paspalum* spp., *Echinochloa polystachya*). Many of these are native to tropical South America and have spread throughout the tropics and subtropics, causing problems in water bodies with artificially regulated water levels such as reservoirs on rivers.

Floodplain lakes can be rich in phytoplankton, particularly during periods of isolation or at least minimal through-flow of river water. In some cases algal blooms are stimulated by nutrient inputs during inundation. However, during inundation floodplain lakes often receive through-flowing river water, and this may reduce the water residence time to the point where plankton growth is suppressed by flushing (i.e., to less than a week or so). Floodplain lakes may become shallow enough over the interval between floods that sediments are resuspended by wind-induced turbulence, and then inorganic turbidity may restrict underwater light availability and limit algal growth.

Algae can be important to ecosystem-level primary production in floodplain water bodies, rivaling that of the more conspicuous floating emergent plants and floodplain forest. Stable isotope studies have shown that algae can contribute disproportionately to the support of aquatic food webs even though their biomass is small compared with that of vascular plants. In waters where flushing limits phytoplankton growth, attached algae may proliferate on submersed plant surfaces, or on sediments if the water is shallow. The importance of algae to aquatic consumers is thought to be explained by the greater nutritional value of algal cells relative to plant material containing more structural biopolymers like cellulose.

The existence of flood plains with natural flood regimes enhances the overall secondary productivity of the river-floodplain system, and this productivity extends to fisheries of cultural and economic importance. Riverine fishes include species that migrate seasonally between river channels and flood plains and others that are largely confined to floodplain waters. Water turbidity can be important in structuring fish species composition because visual feeders are limited to relatively clear waters while tactile and electrosensory feeders do well in turbid waters. When flood plains are no longer inundated in a natural fashion, or are isolated entirely from the river, riverine fish productivity and diversity tends to be diminished.

Biodiversity

Flood plains are often cited as ecosystems that harbor high biological diversity, in spite of the fact that the physical challenges imposed on the biota may well limit the suite of species that can survive and dominate in flood plains. Certainly the existence of floodplains enhances the biodiversity of a river system, and the high spatial heterogeneity typical of flood plains offers a wide range of habitats and niches. Tropical freshwater fishes, particularly in and around the Amazon basin of South America, are an especially diverse group in which many species have direct ties to floodplain environments. Flood plains can also be an important habitat for rare and endangered species that are not floodplain specialists, probably because flood plains often are less accessible to hunting, and because they may not be colonized or developed by people as easily as adjacent upland areas. Furthermore, the constant landscape change that is produced by rivers and flood plains can enhance terrestrial biodiversity by creating new areas for vegetation succession and by leaving a legacy of topographic features, soil formation, and soil drainage.

Biotic Adaptations

Many plants and animals display adaptations to seasonal inundation and, in some cases, to seasonal desiccation of floodplain environments. Most flood plains support some plants and animals that are also found on adjacent upland habitat and can persist in the flood plains despite inhospitable conditions at some times. Other floodplain species are found in wetlands in general, and still others are especially adapted to conditions on flood plains, or move between the flood plain and the river or permanent floodplain lakes for at least part of their life cycles.

Among plants, adaptations to life in floodplain habitats include rapid growth upon the arrival of flood waters, floating emergent growth habits that allow plants to rise and fall with changing water levels, and timing of flowering and seed production to take advantage of flooding for seed dispersal by water or aquatic animals including fishes. Among aquatic animals, adaptations include migration in and out of seasonally inundated areas or along an axis of inundation and drainage, timing of reproduction to match the flood pulse, and dormancy to survive dry periods. Birds, reptiles, and mammals may take advantage of the flood pulse through specific adaptations, but many species can do so opportunistically.

The high biological productivity of tropical flood plains, with much of the photosynthesis conducted by plants whose leaves are above the water surface, produces a high demand for dissolved oxygen beneath the water surface. Decomposition of organic matter and root respiration consume dissolved oxygen, and physical impediment of gas exchange by dense plant canopies reduces reaeration. Consequently, standing waters on vegetated flood plains are often depleted in oxygen to the point where its availability limits the species of aquatic life that can live there. This may be a feature common to other kinds of wetlands with high temperatures, water above the soil surface, and floating or emergent plants (oxygen depletion in water-saturated soils is characteristic of almost all kinds of wetlands).

In tropical flood plains, many aquatic animals including fishes display morphological or physiological adaptations to low oxygen availability. For example, some fish species can breathe air using the physiological equivalent of a lung, while others develop adaptations to facilitate the use of water in the thin surface layer that tends to be more oxygenated. These adaptations allow tropical floodplain fishes to thrive under conditions of low dissolved oxygen that would be lethal to many temperate fish species. However, despite these adaptations, depletion of dissolved oxygen limits the composition of the fish community and can cause fish kills in tropical floodplain waters.

Human Impacts on Floodplain Wetlands

Floodplain wetlands have been strongly altered throughout the world, often through hydrological modifications of either the parent river that inundates the flood plain or the flood plain itself. Control or exclusion of flooding has allowed colonization, agriculture, and sometimes urbanization of flood plains, as, for example, in the Yangtze (China) and lower Mississippi (USA) rivers. In some regions the flood plains are heavily populated by people even though they still undergo seasonal inundation, as, for example, in the delta of the Ganges and Brahmaputra rivers (India and Bangladesh), where much of the flood plain has been converted to rice paddies.

River regulation, mainly through construction of dams, has strongly impacted flood regimes of rivers across all spatial scales, and even many of the largest rivers of the world have been regulated to some degree. Impoundments tend to create permanently flooded reservoirs in place of seasonally flooded lands, and they usually alter the discharge regime and often the water quality and temperature well downstream. They can trap a large fraction of the suspended sediment load, leading to geomorphological destabilization of the river-floodplain system downriver of the dam. Dams operated for hydroelectric generation may impose highly unnatural, short term fluctuations in water levels, while those operated primarily for agricultural irrigation tend to change the seasonality of river flow in addition to removing water from the system.

Modification of river channels to facilitate navigation usually impacts flood plains by altering the relation between water levels and discharge; removal of barriers to navigation can enhance flow conveyance and diminish the backwater effect that produces overbank flooding. This can reduce the extent of wetland subject to inundation as well as the hydroperiod of floodplain inundation. Spoils from dredging the rivers are often placed directly on flood plains.

Flood plains have often been isolated from their parent rivers by construction of dikes, commonly with the goal of farming the land. Such land can be highly productive at first but may require costly measures to remove or control water. Over time, land subsidence, loss of fertility, and occasional incursion of flood waters can detract from agricultural sustainability. Dikes have also been constructed to maintain permanently flooded areas, sometimes for enhancing habitat for wildlife populations (e.g., waterfowl). These diked wetlands or lakes may be managed for variable water levels, but often not following a natural flood regime, and thus they are more akin to reservoirs.

The Florida Everglades (USA) provides a particularly well-studied example of how a strongly modified hydrological regime can produce negative impacts that extend to all levels of the floodplain wetland ecosystem. The hydrology of the region from the Kissimmee River through Lake Okeechobee and south across the Everglades to the southern end of the Florida peninsula originally functioned as a flood plain, even though there was no single parent river channel. During the wet season water would slowly travel from north to south across vast but shallow flooded areas. Throughout the 1900s, massive engineering works to regulate and divert water flow caused untold changes to the ecosystem, yielding a complex system of aqueducts and diked areas in which water levels have been managed for flood control and water supply. The rich soils of drained areas were developed for agriculture but are suffering from land subsidence as the organic soils oxidize and compact. A massive nutrient-enriched zone has been created downstream of the agricultural areas, changing the vegetation to favor dense stands of the cattails (*Typha* spp.). Invasive exotic species have proliferated, while native species such as wading birds that rely on a natural flood pulse have been reduced in numbers. Some coastal marine ecosystems have lost their freshwater inputs (i.e., Florida Bay) while others have experienced an unnaturally high amount of freshwater via diversion channels; both kinds of changes have strongly affected the biota. These problems have been widely acknowledged, and restoration of a more natural hydrological regime is currently being sought.

See also: Benthic Invertebrate Fauna, Wetland Ecosystems; Ecology of Wetlands; Ecology of Wetlands: Classification Systems; Floods; Flood Plains; Flow in Wetlands and Macrophyte Beds; Global Distribution of Wetlands; Riparian Zones; Wetland Ecology and Management for Birds and Mammals; Wetland Ecology and Management for Fish, Amphibians and Reptiles.

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