effects of channelization on the aquatic life of streams

Ruth Patrick
The Academy of Natural Sciences of Philadelphia

The great growth of population and the concentration of 70 percent of that population in the coastal zone have caused rivers and their floodplains in that area to be increasingly altered for man's use. Much of the channelization has been or may be undertaken in that area. Often we forget that a river or a stream is a flowing body of water that has slowly evolved a channel and a slope that are in equilibrium with continuous inputs and outputs of water and sediments from the drainage basin. Typically a natural river overflows its channel every 1½ to 2 years onto the floodplain. The extent of the overflow is predictable for a given frequency, and the amount of overflow at various times is indicated in the floodplain by various terraces representing the extent of overflow.

CHARACTERISTICS OF FLOOD PLAINS AND SWAMPS

The floodplain is an integral part of the river, and its preservation is important because it helps to regulate the quality and the amount of water in the stream. When a river floods, a considerable amount of sediment is deposited on the floodplain. Those sediments, if they are rich in plant nutrients, fertilize the floodplain and help to maintain its high productivity. Also, considerable amounts of floodwaters seep into and recharge the underground water system. Wharton (9) emphasizes the importance of the floodplain in recharging streams in the North Carolina Piedmont.

During the period of flooding, particularly in the spring when the floodwaters are relatively high, floodplain ponds develop and remain intact after the water recedes. For example, the floodplain of the Savannah River before it was drained was well supplied with those floodplain ponds. An examination by the Academy of Natural Sciences has found that those ponds act as breeding and nursery grounds for many forms of life. Indeed, some organisms spend most of their life cycles in those ponds. With subsequent reflooding, that life enters the river. Thus, the ponds act as seeding areas for the river and increase its productivity.

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Often the floodplain bordering lower reaches of small streams that flow into larger streams are flooded throughout the year. Those areas are known as swamps. In the northeast and middle Atlantic states, swamps are usually covered with herbaceous plants, whereas in the southeastern states they are usually forested. The wetlands and the floodplain proper act as sponges or reservoirs and thus prevent flooding of adjacent land and reduce downstream flood peaks at times of high flow. Niering (8) reports that, during the 1955 flood in the Pocono Mountain area of Pennsylvania, the only highway or road bridges that survived were the ones downstream from a several-hundred-acre cranberry bog swamp. The absorptive capacity of those vegetative depressions siphoned off enough floodwaters to prevent damage. Leopold and Maddock (6) have pointed out that the overbank flow constitutes an important part of the natural valley storage during a flood. The natural storage provided by river channels and floodplains is similar to the kind of flood control provision that man attempts to build by engineering works such as dams.

The current is less in those flooded swamp areas, and sediments drop out of suspension so that as a result the water is clearer and light penetration is greater. Thus, those areas are very favorable for photosynthesis and the development of aquatic life. They are valuable as feeding, breeding, and nursery grounds for fish, invertebrates, and many species of birds. Indeed, many of the flyways of migrating birds are located across swamp areas. The relative inaccessibility of swamp areas has made them ideal for relic species and rare species to continue to live against the perturbations caused by man.

It has been well documented that plant growth in floodplains produces valuable organic detritus for downstream fisheries. The kind of species of plants is important, for the value of the detritus varies according to the types of plants present.

Swamps and marshes absorb a great deal of nutrients and thus improve water quality. We have found in studies of Tinicum Marsh (3) that a 512-acre marsh that received effluent from sewage-treatment plants absorbed phosphorus at approximately a rate of 4.9 tons per day, absorbed ammonia at the rate of 3 to 4 tons per day, and produced oxygen at the rate of 20 tons per day. Furthermore, according to Wharton (9), a survey of the Flint River showed that within 6 miles of flow through an area surrounded by marshes there was vast improvement in the bacteriological and zoological characteristics of the stream. Thus swamp areas improve water quality for aquatic life in the streams proper; act as breeding, nursery, and feeding grounds for the aquatic life and thus improve productivity; and are reservoirs for a highly diversified and sometimes unique group of species that help maintain the ecosystems of flowing waters.

CHARACTERISTICS OF THE STREAM CHANNEL

One of the obvious characteristics of water in a stream is that it does not flow in a straight line. In the headwaters we often find braided as well as sinuous channels. In areas of greater flow, the usual pattern is sinuous and results from the undulating course of flowing waters as they seek equilibrium with the channel. Thus, one edge of the channel becomes the cutting edge and the opposite is the depositing edge. In the shallow waters on the depositing side of those meanders, abundant aquatic life develops because light penetrates to the substrates; fish may be found in deep holes on the cutting side of a meander. The depositing edge is ideal for highly productive, short-generation organisms such as algae, the grasses of the aquatic world, and many kinds of invertebrates that feed on the algae. Fish come to the shallow waters to feed and spawn, and the young of each year mature there. Over time the river sometimes changes its course, breaking through a meander and creating oxbows. Most of the flow will then bypass the meander although some will continue to course through the old channel, which becomes the richest area for aquatic life. The current is slower, the silt load drops out of suspension, and the photosynthetic zone extends completely across the channel. If it were not for oxbows, the productivity of a river would be greatly decreased.

Other important shallow water habitats are entrapped floating debris and trailing branches from trees with their associated leaves. One has only to visit the Savannah, the Mississippi, or the Schuylkill to appreciate the great value of those floating habitats

to deep water streams. Because floating habitats can rise and fall with the water level, they form a more or less continuous habitat. Large fish populations often congregate under floating log jams because they offer high food production and cover. The great diversity of substrate and current patterns allows many different kinds of communities to develop.

The shallow water communities are composed of many species of animals and plants. Typically those species have high predator pressure, and as a result one rarely sees a bloom or large population of a single species in the natural stream.

EFFECTS OF CHANNELIZATION

The effects of channelization depend on the type and amount of change in the stream structure that is induced by the type of channelization employed. Channelization not only affects the life in the area of the stream that is channelized but also the upstream and downstream ecosystems.

The purpose of channelization is usually to increase the rate of flow in the streams, although sometimes streams are channelized to obtain road-building materials. Snagging and removing vegetation from the banks are often considered the least harmful types of channelization, yet they produce profound change in the ecosystems of the stream. The removal of floating debris eliminates one of the most important habitats for aquatic organisms and greatly reduces the productivity of the stream. Removing overhanging branches of trees and trailing leaves also reduces the productivity of the stream. Clearing the banks of the stream often results in the death of the bank vegetation, and that causes the banks to erode and slump into the streams.

Eroded sediment reduces light penetration in the stream and as a result primary productivity is lessened. It also accumulates in unsteady berms on the river bed, and those quickly erode once the rate of flow changes and produce considerable turbidity not only in the immediate area but also downstream. Organisms that have used the substrate as a habitat are destroyed once the berms start to move. Occasionally more or less consolidated berms develop within the stream channel and become a favorable habitat for aquatic life. The spawning of fish is dependent on the availability of a suitable substrate in a desirable current, which is one that is fairly slow but predictable. Such areas are often eliminated by channelization because the diverse substrates are removed and stream velocity becomes faster and more uniform.

The destruction of the overhanging vegetation in a stream has several effects. One of the most pronounced is the increase in water temperature. We have found in studies of White Clay Creek in Pennsylvania that in an area from which the trees had been removed a rise of temperature of only a few degrees seemed to be responsible for the elimination of stone flies. Brown and Krygler (1) have shown that the maximum annual temperature increased from 57 to 87 F after clear-cut logging on a small watershed in Oregon. Terrestrial insects and other types of invertebrates falling into the water are also important food sources for stream life. The importance of leaf fall-in to the food chain of a stream has been well documented by many. Vannote has shown that tipulid larvae have certain species preferences, and their growth rates are much better when fed the type of leaves they prefer. Thus, removing the natural vegetation from the stream banks may greatly curtail not only the development of certain species of insects but also the overall productivity of the stream.

Usually channelization involves the dredging of the stream channel. The dredging homogenizes the bed structure, reduces its roughness and diversity, and destroys the diversity of the current pattern. That inevitably leads to reduction in diversity of aquatic life in the channelized area. Because the substrate suitable for many forms of aquatic life is lost or greatly reduced, productivity is likewise curtailed. For example, the spawning beds of many fish are dependent on the availability of suitable unsilted substrates in a current that is of a moderate speed but predictable.

If dredging cuts out the shoaling side of meanders and destroys the oxbows, the productivity of the stream may be almost eliminated. Usually in order to increase channel capacity, the channel is made wider and deeper. If the channel is dredged wider than necessary and the banks are clear-cut, the eroding banks will slump and build up berms within the cross section. The stream usually cuts a new meandering channel within the

dredged channel, thus defeating the purpose of channelization. Furthermore, the unstable banks may continue to erode, under bridge approaches and require the brodge to be rebuilt (2). The extent to which the channel is deepened has varying effects. The gradient or slope of a stream is one of its most conservative characteristics, and when man alters it he invariably causes erosion upstream and downstream because the flowing water seeks equilibrium with its new structure. Such erosion naturally destroys habitats of aquatic life.

When the deepening of the channel lowers the bed of the stream below that of the aquifers with which it was formerly in equilibrium, the aquifers are drained and the floodplain dries out. Floodplain habitats suitable for muskrat, deer, many species of birds, and otters are then changed to ones suitable for rabbits and quail. Likewise water-living plant species are replaced by vegetation requiring drier conditions. In the southern part of the United States, species such as sour gum, true cypress, swamp maple, and hackberry are replaced by sweet gum, oak, and loblolly pine. In the Florida wetlands (4), alligators feed on raccoons that feed on eggs of egrets and ibis. When the wetlands were drained, the alligators moved elsewhere and the egret and ibis rookeries were eliminated by raccoons.

Underground aquifers maintain stream channels during low flows. If those are drained, there is no reservoir of water for maintenance of stream flow. As a result of channelization, streams that once were free-flowing during low water periods may become a series of isolated pools. That, of course, greatly alters the aquatic life that composes the stream ecosystems.

The straightening of the channel that often accompanies such dredging means that the water flows more quickly along its course. Slowly moving water allows streams more time to assimilate wastes and nutrients that enter them. Increasing the flow can bring about various serious consequences for downstream bodies of water. An example is Lake Okeechobee in Florida. Sewage-treatment plants discharge their effluent into tributary streams of Lake Okeechobee. Formerly those streams assimilated the mineralized wastes before the waters enter the lake. Because of the faster flow, the waters now empty more quickly into Lake Okeechobee and are causing the lake to fast become a large polishing pond for mineralized effluents.

The clearing of the floodplain of its natural forest or grassland for urbanization, agriculture, or pasture increases the erosion of sediments that clog the channel of the stream that channelization was designed to correct. Thus, continual maintenance is required if the channel is to remain clear. The nutrients entering the water are often increased depending on how the floodplain is used. The fertilizing of crops and pastures and the grazing of cattle increase the organic load. Pesticides sprayed on crops find their way into the streams where they are toxic to many forms of aquatic life. If the adjacent area and drained floodplain are urbanized, the floodplain often becomes the site for sewage-treatment plants, and their poorly treated effluents enter the stream. These increased nutrients may produce several effects. The species may change from those that are highly desirable food sources with high predator pressure to those that are undesirable food sources with little or no predator pressure; thus, nuisance growths develop. The increased nutrients also tend to develop floating and rooted aquatics that clog the channel that was channelized to increase the flow of water and intensify flooding rather than reduce it.

Another stream activity that often occurs concurrent to channelization and highway development is the taking of gravel and sand from the stream bed for road improvement. The materials are often taken without regard to the gradient of the stream and its natural bed contours. Large holes may develop in which stagnant water accumulates. Those anaerobic deep-water areas often produce toxic substances and have little or no oxygen so that aquatic life cannot survive. When a channel is straightened the banks are often riprapped with quarried stone at a vertical angle. The result is that the sun reaches the water surfaces for an insufficient period of time to support algal growths that are important as food for animals in the ecosystem. If the banks were riprapped at an angle of 30 to 45 deg with natural water-worn stones, current patterns would be produced that favor native stream organisms. As a result, the areas would be much more rapidly colonized, and the riprap would support a fairly diverse community of

aquatic organisms. If dredging is done, attempts should be made to restore the natural contour of the channel bed, for example, create pools and slackwaters in shallow streams or restore the roughness of the channel bed. That would interfere very little with the carrying capacity of the channel under flood conditions, but would greatly improve the bed habitats for species occupancy.

Man must remember that the stream and the floodplains have evolved during long periods of time and have developed a system that is best for the natural conditions at hand. He should study these conditions carefully and make sure that modification follows the dicta of nature.

SUMMARY

The stream and its floodplain are an integrated system that is well designed for moderating the effects of flooding waters and for maintaining high productivity in the stream proper. Disturbing the system inevitably results in a reduction in diversity of species and productivity. Because the functioning of the aquatic ecosystems is impaired, the ability of the stream to cleanse itself and to assimilate wastes is lessened, and the improvement of water quality is slower. The stream, instead of being one that is aesthetically pleasing and highly productive, becomes degraded and its recreational use is minimized. The chief effects of channelization are as follows:

1. Removes the natural diverse substrate materials that allow the development of many types of habitats for aquatic organisms;
2. Increases sediment load that decreases light penetration and primary production;
3. Creates a shifting bed load that is inimical to bottom-dwelling organisms;
4. Simplifies the current pattern and eliminates habitats of diverse currents;
5. Lowers the stream channel and often drains adjacent swamp areas and aquifers that help to maintain stream flow during times of low precipitation;
6. Destroys floodplain ponds that are the breeding ground for aquatic life and that act as a reservoir of species for the river proper; and
7. Reduces the stability of the banks and causes cave-in of trees and other overhanging vegetation that are an important food source for stream life and whose shade reduces high stream temperatures during the summer months.

If man is going to interfere and modify natural waterways, he should design his alterations to maintain the functioning of the aquatic ecosystem that makes possible the continuance of a stream's high water quality.

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