Fish Habitat and Flow:

What's the Connection?

by Leroy M. Young

This article is the second in a series on the Commission's theme, "Habitat." Clean watery habitat is one thing. But how much water fish need is something else. The author explains the Commission's role in stream flow protection and how fish habitat and flow are connected.

"Habitat" is the place or type of site where a plant or animal is naturally found. That's how my dictionary defines this term. In its most basic sense, the habitat for fish is the water. That is, it's in the water where fish are naturally found. Sure, fish are typically most frequently found in specific areas in the water, like under an undercut bank or root wad, in weed beds near shore, or under or behind the larger rocks. But it is ultimately in the water that fish live and move about. Take away this most vital medium of life, and you will not have fish.

Above, Lake Wallenpaupack Dam, Pike County. The dam and hydroelectric project affect the flows of Wallenpaupack Creek and the Lackawaxen River (photo-Leroy Young). Below, a snorkeling biologist marks trout locations in Young Woman's Creek, Clinton County (cott Bollinger).

Why spend so much time on the obvious point that fish need water to live? A closely related concern that often arises for Commission biologists is not so obvious-how much water do fish need?

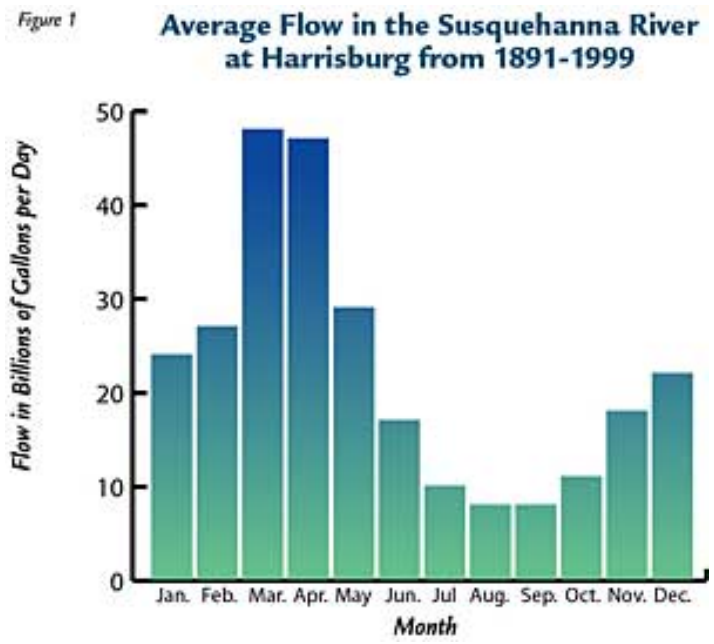
The best answer to this question is: It depends. For example, during droughts, the answer may be that they need it all. During floods, it may possibly be that they need less. And the rest of the time? I think you may be starting to get the picture.

West Fairview Access at the confluence of the Susquehanna River and Conodoguinet Creek, Cumberland County. This photograph shows the very low water conditions in the fall of 1989.

This photograph, taken from the same vantage point as the photograph above, shows the access during the flood conditions in 1993. Droughts and floods are natural conditions. Droughts create habitat conditions that can favor some fish species. In addition, streams need floods. Floods scour the stream and redistribute its bed load. photos-Art Michaels

Natural flow regime

To address this matter of how much water a fish needs, let's start at the beginning with an introduction of the term "natural flow regime." The natural flow regime is a description of how flow changes on a particular stream over time. Flows change almost daily on most streams. Over the course of time, they may range over several orders of magnitude. For example, the average flow on the Susquehanna River at Harrisburg has been continuously monitored by the United States Geological Survey since 1891. That flow ranges from 7.5 billion gallons per day (bgd) in September to 48.0 bgd in March (see Figure 1). The lowest flow ever recorded at Harrisburg was 1.1 bgd on November 29, 1930. The highest flow ever recorded was 616.3 bgd on June 24, 1972, during the Hurricane Agnes flood. Expressed another way, there were over seven million gallons of water passing Harrisburg every second on that day.



When most people think of flowing water, they probably view both floods and droughts as "bad," and most other flows as either OK or not worth thinking about at all. From a fish's perspective, all flows are important. Fish need floods, fish need droughts and fish need the flows in between. They are adapted to do just fine under these naturally changing conditions. However, when the natural flow regime is altered in some way by people, fish can get into trouble.

Floods, droughts and more

The reason why fish need floods is that streams need floods. Streams are beautifully designed to transport bed load continually. "Bed load" is the silt, sand, gravel, cobble and boulders that comprise the bottom of the stream. The shape of the stream and the composition of the bed load are critical components of fish habitat. Diverse substrate types typically favor diverse fish assemblages. The process of maintaining the substrate composition and the shape of stream channels can best be described as a dynamic equilibrium. This means that the stream is constantly changing at the fine scale, yet always staying the same at the large scale. A flood is the most important phenomenon that occurs on streams to redistribute the substrate and keep the bed load moving through the system. The need for floods was highlighted at the national level in 1996 when experiments were initiated to mimic a flood in the Grand Canyon. This natural process was interrupted since the Glen Canyon Dam was constructed on the Colorado River in 1965. Bottom substrates, particularly sand, were redistributed during this event, and the formation of sand bars, which are particularly important to that river's ecology, was significantly enhanced.

Droughts are also natural phenomena on streams and rivers. During droughts, the instream habitat conditions can actually be favored for some fish species, such as certain minnows and darters, and fry and fingerlings of larger species. Drought conditions allow these fish to compete with other fish, such as larger predators, which may be favored at higher flows. The result is a more robust and diverse fish community. An example of this phenomenon, which has been demonstrated in studies across Pennsylvania, is that smallmouth bass reproduction can be suppressed during particularly high flow conditions during their spawning period in May and early June, and enhanced with relatively low, stable flows during this same period.

Measuring the effect of flow on fish habitat

The most common method used today in Pennsylvania to determine "how much water the fish need" is called the Instream Flow Incremental Methodology (IFIM). This methodology was designed by a multidisciplinary United States Fish and Wildlife Service team of biologists, hydrologists, engineers and computer scientists working together in Colorado in the 1980s. Development of the methodology in the West makes sense when one considers the infamous "water wars" for which this relatively dry region of the country is known.

The methodology has been refined in many ways over the years, but in essence it involves the development of several computer models that are used to define the relationship between flow and fish habitat. Four basic types of models are used: A hydraulic model, a biological model, a habitat model and a water quality model.

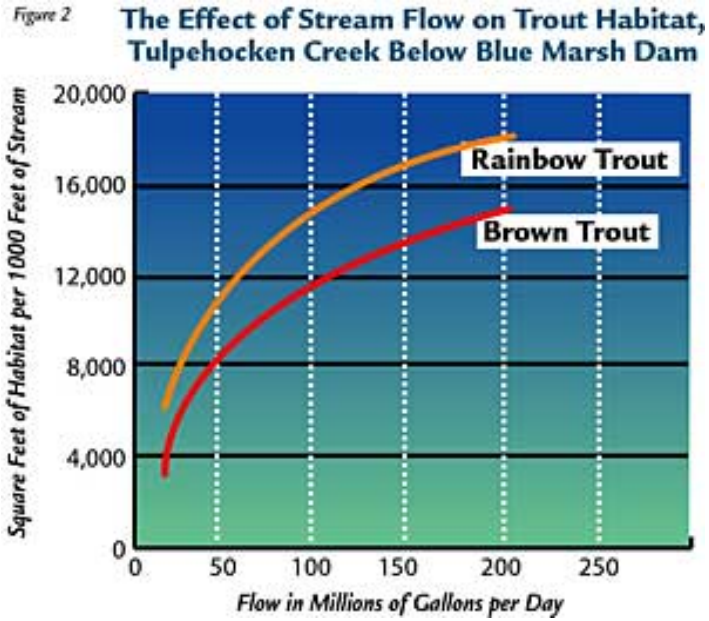
The hydraulic model is developed by measuring four critical fish habitat variables (water depth, water velocity, cover and substrate composition) at stream transects (cross sections), at various flows. This data is used to develop a computer model that can describe how these variables change with any flow the stream might experience.

The biological model is developed by observing fish in the wild and describing which depths, water velocities, cover types (such as root wads, large boulders, undercut banks or vegetation) and substrate types are most suitable for each species and life stage (spawning, fry, juvenile and adult). Snorkeling is often used to document the locations the fish prefer.

The hydraulic model and the biological model are then combined to form the habitat model, which describes how habitat-as defined by depth, velocity, substrate, and cover-changes with flow for each species and life stage.

Figure 2 shows the result of such a habitat model developed from a study we conducted on Tulpehocken Creek immediately downstream of Blue Marsh Dam, Berks County.

Figure 2



Finally, water quality models can be used to describe how water quality variables, such as temperature, change with flow. For example, a bottom release of 2 million gallons per day (mgd) of cold water from a reservoir might cool a particular stream to a temperature suitable for trout for perhaps 2 miles. A water quality model can be used to answer the question of what happens when the release is reduced to perhaps 1 mgd or increased to 3 mgd.

Commission's role

The primary authority in Pennsylvania for regulating water withdrawals from surface waters for purposes such as municipal drinking water supplies, power plant cooling, golf course irrigation, and snow-making lies with either the Pennsylvania Department of Environmental Protection (DEP) and/or two interstate commissions-the Susquehanna River Basin Commission and the Delaware River Basin Commission. The Fish & Boat Commission acts as a consultant to these agencies on matters related to stream flow protection.

Fish & Boat Commission staff reviews water withdrawal permit applications submitted to these agencies. We then recommend stream flow protection levels or other conditions for the permits with the objective of protecting aquatic life.

A recently completed cooperative study that involved the Fish & Boat Commission as well as DEP, the Susquehanna River Basin Commission, the U.S. Army Corps of Engineers, the Maryland Department of Natural Resources, and the Chesapeake Bay Foundation resulted in the development of an instream flow computer model specific to Pennsylvania's trout streams. This million-dollar statewide study involved the development of hydraulic models at over 100 sites distributed among 72 streams in the Appalachian Plateau and Ridge and Valley physiographic provinces of Pennsylvania and the Piedmont province in Pennsylvania and Maryland. The computer model that was developed can be used to predict the effects of withdrawals by a municipality, industry or other entity on trout habitat before the withdrawal is begun. Conditions can be placed on water withdrawal permits using the information gleaned from the model to prevent degradation of instream habitat while still often permitting some level of water withdrawal.

Recently, the Fish & Boat Commission has been involved in studies to evaluate the insidious but very difficult to quantify effects of groundwater pumping on stream flows. Base flows on streams are largely supplied from groundwater aquifers. When necessary, well permits are now conditioned to protect these flows.

Another way the Fish & Boat Commission works to protect the natural flow regime of streams and rivers is through the review of hydroelectric license applications. The hydroelectric industry in the United States is regulated by the Federal Energy Regulatory Commission (FERC). We work with FERC as well as with electric utilities, private power producers, the public, local governments, non-governmental organizations such as Trout Unlimited, and other agencies such as DEP, the U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers in the license review process.

We are currently working on the relicensing of both the Wallenpaupack and Piney hydroelectric projects. The Wallenpaupack Project is located in Pike and Wayne counties on Wallenpaupack Creek. The project discharges water into the Lackawaxen River. The Piney Project is located on the Clarion River in Clarion County. The effect of peaking on aquatic life is being assessed at both of these projects. "Peaking" means holding water back in the project reservoir at night to discharge high volumes of water during the day when energy demands are greatest.

The goal of the Fish & Boat Commission in this process is to mitigate the effects of the drought/flood nature of this unnatural flow regime and restore some sense of normalcy to the flow patterns. An improved warmwater fish community should result in the Clarion River. An improved trout fishery in the Lackawaxen River is a major goal of the Fish & Boat Commission in the Wallenpaupack relicensing. IFIM studies have been conducted on both rivers to address these issues.

Municipal water supply reservoir spillway, Butler County. Reservoir water withdrawals can greatly affect stream flow. photo-Leroy Young

Low water conditions on the Susquehanna River at Middletown reveal the river's bed load-the silt, sand, gravel and rocks that comprise the waterway's bottom. photo-Art Michaels

Cold Stream, Centre County, during the 1998 drought. Droughts can actually create more robust and diverse fish communities. photo-PFBC file photo

Flowing toward the future

We believe we have made great strides in stream flow protection in recent years in Pennsylvania. The studies and work described above have placed Pennsylvania on the cutting edge of habitat protection through the process of regulating water withdrawals from streams and rivers as well as from the ground. These advances in the science of stream flow protection are critical as we face a future with ever-increasing demands on our precious water resources.

The next time you turn on your tap, flip on a light, or drink a soda, remember that the water used to make these things possibly comes from a precious resource that we all share, and that we should all respect and value. If we face future challenges to share the resource with this attitude, we will help ensure that future generations can experience the wonders of Pennsylvania's natural heritage.

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