

ANNUAL REPORT - 1981

LARGE ORGANIC DEBRIS AND ANADROMOUS FISH HABITAT IN THE COASTAL REDWOOD ENVIRONMENT: THE HYDROLOGIC SYSTEM

E. A. KELLER, UNIVERSITY OF CALIFORNIA, SANTA BARBARA

ABSTRACT

Research on the effects of large organic debris on channel form and process relevant to anadromous fish habitat has been along three lines of inquiry. First, we have discovered a process whereby cold pools (water temperature 15°C-18°C) may develop during summer low flow in a stream in which the dominant mainstream water temperature may exceed 21°C. Cold pools develop when cool groundwater seeps into a mainstream channel in a location such that a plume of cold water is inhibited from mixing with the warmer water in the stream by barriers such as large organic debris. The discovery of cold pools is expected to have important implications for many streams in the northwestern United States that support anadromous fish and yet have summer low flows that are generally quite warm. In Redwood Creek, Redwood National Park, the distribution of fish in the stream during the summer apparently is closely related to the existence and location of cold pools. A second line of inquiry has been to develop a new way to evaluate discrete hydrologic environments such as pools, riffles, and accumulations of large organic debris. Experiments initiated in Gaylor Creek, near Tuolumne Meadows, Yosemite National Park, should provide basic data to test the model which will then be further tested in Larry Dam Creek, Redwood National Park. It is expected that results from these experiments will help managers develop design criteria to construct fish habitat in channel resortation projects. The third line of inquiry involves debris removal experiments in Larry Damm Creek, Redwood National Park. Debris was removed along a 100 m reach (pull reach) of channel during the summer of 1980 and subsequently the reach has been resurveyed and hydrologic data have been gathered. The experiments to date suggest that hydrologic variability has been lost due to removal of the debris and a fair amount of sediment stored in the channel associated with the large organic debris has moved downstream. Energy that was expended in water moving through debris accumulations in the pull reach evidently is now expended in scouring pools. Continued evaluation will help determine channel stability of the pull reach and specifically where the sediment stored by the debris has moved.

RESEARCH ACCOMPLISHMENTS

Discovery of Cold Pools in Redwood Creek

The mainstream water of Redwood Creek during the late summer may be quite warm, exceeding 21°C. Such warm temperatures are not desirable for the rearing of juvenile salmon and steelhead trout nor are desirable for adult fish migrating upstream to spawn. Fortunately, there exist cold pools, defined as pools in which the water temperature is several degrees cooler than the mainstream temperature in which young anadromous fish may live during the summer months as well as provide a holding site (or cool refuge) for mature fish as they move upstream. Several cold pools have been located in Redwood Creek and they are related to a point

source of cool groundwater that discharges into Redwood Creek near where a dry tributary enters the stream. One such cold pool near the mouth of Hayes Creek is shown on Figure 1. Springs along the right bank discharge groundwater at 12°C. Cold water collects in a small channel scoured by Hayes Creek (when it is flowing) and slowly enters into the large downstream pool which is defended by a large amount of organic debris, mostly in the forms of large redwood trunks. The cold water is inhibited from mixing with the warmer water in the main Redwood Creek by large organic debris. The plume of cold water lingers in the bottom of the pool providing temperatures several degrees cooler than the temperature found upstream and downstream of the cold pool.

During summer 1981 (detention of the debris...)

The existence of cold pools in Redwood Creek is very important in explaining the distribution of fish and the concept may prove important to many streams and rivers on the north coast of California.

Cold pools do not develop at all locations where cool groundwater flows into the stream. Favorable conditions are necessary to insure that rapid mixing of the cold water with the greater volume of warm water does not take place. Conditions favorable in Redwood Creek to the development of a cold pool are as follows: First, there must be a source of cool groundwater that enters the mainstream channel in such a way that initially it is physically separated from the main flow of the stream; and second, favorable pool morphology must exist such that slow mixing of the cold and warm water takes place. In this second part, the role of large organic debris is apparently quite important. When large trunks of woody debris exist along the stream channel and extend out into the pool, the cold water may be trapped behind the logs, inhibiting rapid mixing. This configuration is shown in Figure 1 at Hayes Creek where the cool water is primarily located, where the large organic debris is situated. Where there is no barrier protecting the cold water from the warm water of Redwood Creek, then rapid mixing takes place and cold pools do not develop. Even at the mouth of relatively large dry streams where the inflow of groundwater must be substantial, cold pools do not develop unless there is favorable pool morphology and inhibited mixing. To date, two cold pools have been found in Redwood Creek and both of these contained substantial number of juvenile salmon and steelhead trout as well as several migrating adult steelhead trout during the summer of 1981. Upstream and downstream pools in Redwood Creek contain relatively few fish compared to the cold pools. The difference is hundreds of fish in the cold pools versus tens of fish or less in the warmer pools. As more is learned about the nature and extent of cold pools, it is expected that this information will significantly impact management of anadromous fish in streams of the Pacific Northwest. We may be able to take advantage of locations where cold groundwater enters a stream and use it to enhance anadromous fish habitat. This is particularly important where rearing habitat for juvenile fish is a limiting factor in fish production.

Hydraulic Geometry of Discrete Hydrologic Environments

Work has proceeded to develop a new type of hydraulic geometry (relationships between width, depth, and velocity of flow to discharge) of

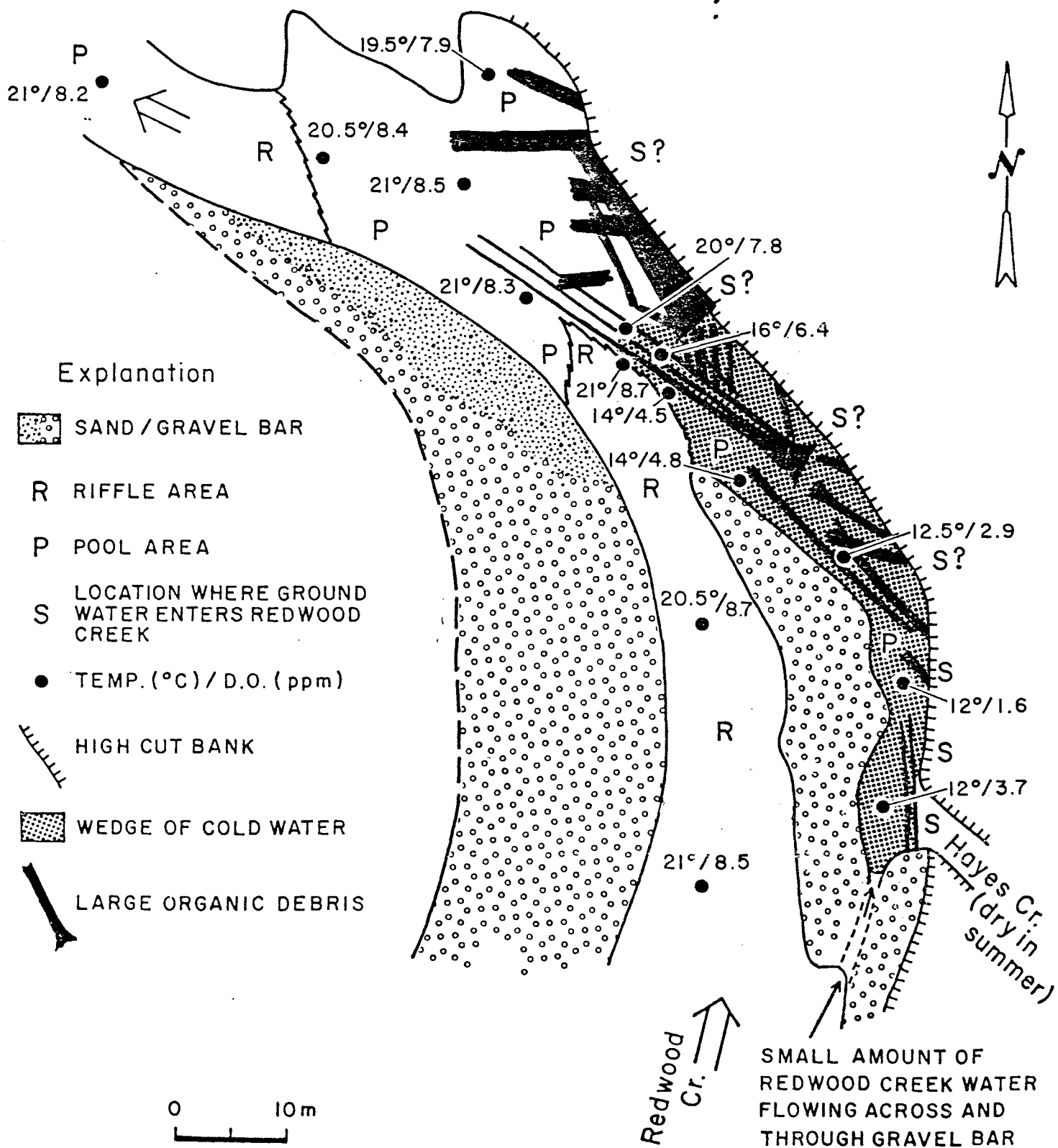


Figure 1. Map of cold pool in Redwood Creek near Orick, California. Data collected on September 1, 1981.

discrete hydrologic environments such as pools, riffles, and accumulations of large organic debris. The method being developed utilizes salinity meters and recorders to trace a slug of salt as it moves through a discrete hydrologic environment. For the first time, we may be able to characterize whole hydrologic environments in terms of changes in width, depth, and velocity of flow with discharge. If these experiments are successful, then the information learned may be helpful in designing hydrologic environments as part of fish restoration projects.

In order to test the new type of hydraulic geometry, it was necessary to find a stream that has a variety of discharges over a relatively short time period not characterized by complicated channel geometry. For this reason, Gaylor Creek, a tributary of the Dana Fork of the Tuolumne River in Yosemite National Park was chosen. Discharge of the stream in the spring is from snowmelt and, therefore, a variety of discharges during the melting period may be obtained. Research stations were established during the early summer on Gaylor Creek and next spring we intend to obtain additional data during the higher flows. Parallel to this, hydraulic geometry is also being gathered on Larry Damm Creek in reaches where large organic debris is abundant and in reaches where large organic debris has been removed. To date, we have insufficient data to accurately describe the hydraulic geometry of discrete hydrologic environments, but additional data is expected during the winter and summer of 1982.

Debris Removal Experiments

Debris removal experiments in Larry Damm Creek, Redwood National Park, were initiated in 1980. During the winter and summer of 1980, hydrologic data were gathered and in August of 1981, large organic debris was removed along a 100 m reach (designated the "pull reach") of Larry Damm Creek. Two 100 m reaches upstream and downstream of the pull reach were established to evaluate the effects of the experiments upstream and downstream. Although we are still gathering data on the effects of the debris removal, early evaluation suggests that the stream, following debris removal, has adjusted in such a way that several pools have developed. That is, it appears that the energy expended in water moving through debris accumulations is now expended in scouring pools. Furthermore, a fair amount of sediment stored by the large organic debris in the pull reach has apparently moved downstream. We are attempting to monitor this movement of sediment. Study of the long profile before and after debris removal suggests that there is now less hydrologic variability than before the debris was pulled, but this conclusion is tentative until additional data can be analyzed.

APPLICATION OF RESEARCH RESULTS

Research on the role of large organic debris on stream channel form and process and its role in anadromous fish habitat has been supported in part by the U.S. Forest Service (Redwood Science Laboratory) and by the Redwood National Park; both of these organizations anticipate utilizing the results of this study. In addition, the U.S. Fish and Wildlife Service, California Department of Forestry, and California Department of Fish and Game have also expressed interest in the project. Research results today have added a new awareness to many people involved with

management of streams in a forest environment. No longer is it standard operating procedure to always pull all large organic debris from stream channels. Rather, it is recognized that it is often advantageous to leave debris in the channel. Leaving large organic debris in the stream may have several benefits, including better fish habitat and saving of money that would otherwise be used for debris pulling.

It is expected that future work on the concept of cold pools will have considerable impact on the understanding of anadromous fish habitat in streams of northern California. This information in conjunction with a better understanding of the hydraulic geometry of discrete hydrologic environments may help stream managers to better design structures to restore or improve fish habitat in streams impacted by land use changes such as timber harvesting.

PUBLICATIONS

Streams in the Coastal Redwood Environment: The role of large organic debris. Edward Keller, Anne McDonald, and Taz Tally. Proceedings of the Symposium on Watershed Rehabilitation in Redwood National Park and other Coastal Areas. Center for Natural Resource Studies of the John Muir Institute in cooperation with the National Park Service, 1981, (in press).

The Effects of Geology and Large Organic Debris on Stream Channel Morphology and Process for Streams Flowing Through Old Growth Redwood Forests in Northwestern California. Taz Tally, Ph.D. Dissertation, University of California, Santa Barbara, 1981.

Development of Cold Pools During Summer Low Flow in Redwood Creek Near Orick, California and their Significance to Anadromous Fish Habitat. Edward Keller and Terry Hofstra (in preparation).

PROJECT STATUS

The research project will continue through fiscal year 1981-1982.

WORK REMAINING IN PROGRESS CONTEMPLATED DURING NEXT YEAR

Several parts of the project remain to be completed; a paired watershed study between Lost Man and Little Lost Man Creeks, continued evaluation of debris removal experiment on Larry Damm Creek, continued development of new methods of evaluating hydraulic geometry of discrete hydrologic environments, and evaluation of nature and extent of cold pools in Redwood Creek and other streams in northern California. During the first half of the 1981-82 fiscal year, research will focus on examining the effects of debris removal. During the spring and early summer of 1982, emphasis will shift to Yosemite National Park where hydrologic geometry of discrete hydrologic environments will be evaluated in Gaylor Creek. Finally, during the summer of 1982, data will again be gathered on Larry Damm Creek and in addition, we will initiate a study to evaluate in more detail the nature and extent of cold pools in Redwood Creek and their importance to anadromous fish. In addition, in the 1981-82 fiscal year, we will write at least one technical report summarizing our work to date and the Ph.D. Dissertation by Anne McDonald should also be completed.