ARE CALIFORNIA'S NORTH COAST RIVERS REALLY "WASTING AWAY TO SEA?"

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Preface

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A growing demand for water and a decreasing supply of it in central and southern California has renewed the public's interest in the possibility of diverting more water from California's north coast rivers.

The proliferation of the concept that these rivers are "wasting away to sea" and the lack of a compendium of information on the impacts of river diversion have motivated a group of professional scientists with experience in the physical and biological systems of north coastal California watersheds to prepare this paper. Possible physical and biological impacts of a major impoundment and diversion facility on a north coast river are discussed.

By no means is this paper intended to be a complete assessment of the costs of river diversion. It is an analysis of one aspect only — the possible consequences of altering natural river flows.

Summary

Rates of erosion and sediment production from watersheds in north coastal California surpass those of any other region of comparable size in the United States. Because of this, adverse environmental and economic impacts due to diversion or impoundment of rivers in this region may be significantly different than those associated with similar projects in other parts of the country.

The existing Eel and Trinity River diversions (at Lewiston and Van Arsdale, respectively) have primarily impacted the fishery resources of these rivers. Attempts to mitigate the impacts have been complex and costly and have yet to be successful.

Analysis of the once-proposed Dos Rios Project on the Eel River provides a hypothetical example of the potential impacts of additional impoundment and diversion in the north coast region.

The most serious long term effect of the Dos Rios Project would be the reduction in sediment transport capacity of the Eel River downstream of the dam. Large volumes of sediment are contributed to the main channel from tributaries and streamside landslides. Infre-

quent, high, sediment-carrying discharges are needed to flush this sediment downstream. These high discharges would be totally eliminated by the Dos Rios diversion.

Accumulation of sediment in river channels may cause spawning gravel, pools, and coarse substrate used by adult and juvenile salmon and steelhead to fill in with fine sediment, as has occurred on the Trinity River. In the Eel River, bank erosion would become more frequent and the resultant threat to valuable streamside property from bank erosion would tend to offset the benefits of reduced flooding hazard provided by the project.

The Eel River is the chief source of sand for the stretch of beach from the mouth of Humboldt Bay southward for 13 miles. The Dos Rios project could result in beach and seacliff erosion by reducing the sand supply.

The dynamics of the Eel River estuary are poorly understood, but its importance to marine and freshwater fish and wildlife is recognized. Flow regulation and reduction could cause severe disturbances in the estuary, with harmful consequences for estuarine-dependent organisms such as salmon.

Impacts on wildlife would include inundation of habitat by the reservoir, limitation of development of a standing-water wildlife community due to fluctuati water levels, some downstream wildlife enhancem as riparian vegetation growth increases, and reducti or elimination of some 32 species of wildlife depend on salmon and steelhead for food.

The Eel River watershed ranks second statewide production of steelhead and coho (silver) salmon a third in production of chinook salmon. The Dos Ri Project would destroy the 150 miles of anadromo fishery upstream from the damsite and severely imp the downstream fishery. It would eliminate t endemic strain of summer steelhead that is federal designated as a "sensitive" species. Existing data on fi hatcheries indicates that a proposed fish hatche would not fully mitigate the loss of the anadromo fishery.

Any proposed additional diversion of north coa river water would have its own unique set of potenti impacts. The common element is the disruption of t quality, quantity and timing of river flows upon whic the biological systems depend. Unimpeded, the nor coast rivers are highly productive systems, depende on sound resource management. Water moving dow the river channels plays many valuable roles. The u diverted north coast rivers are not wasting away -the are working their way to sea.

Introduction

Water for agricultural, industrial and domestic uses in California is becoming an increasingly more valuable commodity, especially in the Central Valley and Southern California. Faced with the problem of water scarcity in portions of California, developers and politicians are turning their attention more and more to the river basins of northern California. It is commonly stated that the water in northwestern California rivers is simply "wasting away to the sea" and that it should be diverted for more beneficial uses in other parts of the state.

This paper attempts to show that the north coast rivers are not merely discharging water into the Pacific Ocean in a wasteful manner. A river basin is a complex physical and biological system supporting a variety of wildlife and a diverse fishery. The river basin responds to seasonal climatic changes with predictable hydrologic processes. The resources of these river basins are economically of great value and they can easily be harmed or destroyed by diverting and controlling stream runoff. In numerous watersheds, failures to recognize the complex physical and biological processes dependent on natural streamflow regimes have resulted in construction of storage reservoirs and diversion systems that have irreparably damaged natural resources.

Flow requirements within a river basin are fortunately gaining recognition as an essential component of river basin management. We will examine the important physical and biological processes in California north coast rivers that are sensitive to alteration of the natural streamflow. Our discussion will focus primarily on the effects of impoundment and diversion of the Middle Fork Eel River by the proposed Dos Rios Dam (fig. 1) and will also examine the impacts of two existing northern California river diversions.

The Dos Rios Project is not in the active planning process, but because of the Middle Fork Eel River's high water yield and proximity to the Central Valley, it is the project most likely to be given renewed attention if serious efforts are made to divert more water out of northwestern California. The two existing north coast water transfer projects -- the Trinity Dam on the Trinity River and the Van Arsdale-Potter Valley diversion on the Main Eel River -- are analyzed to show some of the documented impacts of altering natural streamflows.

The Potter Valley Project

The Potter Valley Project, in operation since 1903, is a modest-size water storage and diversion system located near the headwaters of the Eel River (fig. 1). Although this project is small compared to the Trinity diversion and the proposed Dos Rios Project, it provides an indication of the types of problems likely to be created by any new diversion facility in the Eel River watershed.

The project annually diverts approximately 180,000 acre-feet from the Eel River at Van Arsdale. The diverted Eel River water is used to generate power at the Potter Valley Power Plant and is used for domestic, industrial, agricultural and recreational purposes in the Russian River basin.

Several recent reports describe the adverse environmental and economic effects of this project (California Department of Fish and Game, 1975, California Department of Water Resources, 1976, U.S. Federal Energy Regulatory Commission, 1978). The most notable impact has been the decline in anadromous fish runs due to reduced spring, summer and fall streamflow. Winter flows have not been reduced enough to impact sediment transport significantly. Humboldt County has estimated that it loses $10 million annually (1977 dollars) due to reduction in sport and comercial fishing as a result of the diversion (Humboldt County, 1977).

After eight years of meetings and discussions between state, county and federal agencies and representatives of Pacific Gas and Electric Company, these problems are still being investigated. Humboldt County, the Dept. of Fish and Game and the Dept. of Water Resources have recommended increased flow releases to the Eel from Van Arsdale to improve downstream conditions in the Eel River (CDFG, 1975; CDWR, 1976). Restoring an increment of the Eel River's natural flow creates problems in the Russian River basin where water users have become dependent on the water supplied by diversion. The process of balancing the impacts in both watersheds is complex and costly, both environmentally and socially.

The Proposed Dos Rios Diversion and The Existing Trinity Diversion: Project Descriptions

The most current specifications for the Dos Rios Project (U.S. Army Corps of Engineers, 1968) call for a rock fill dam three miles upstream from the mouth of the Middle Fork Eel (drainage area: 753 square miles) that would be 2,100 feet in length and 730 feet high. The dam would create a reservoir of 40,000 acres and back water up into the Middle Fork Eel River Valley for approximately 36 miles. The main purpose of the project would be to store water for diversion out of the basin to the Central Valley Project; flood control would be a secondary benefit. Approximately 217,000 acre-feet (a.f.) per year would be discharged downstream from the reservoir, reduced from a historical average of over one million a.f. per year.

Trinity Dam on the Trinity River (fig. 1), a component of the Central Valley Project, was completed in 1963. Water stored behind the dam is diverted to Whiskeytown Reservoir, then released into the Sacramento River. Diverted Trinity River water ends up being used in the San Joaquin Valley and Southern California. The Trinity project substantially reduced annual discharge to the lower Trinity River, eliminated all high streamflows in the upper Trinity, destroyed the natural anadromous fishery above the dam and severely impacted the fishery of the lower Trinity.

Lewiston Dam is a small re-regulation dam directly downstream of Trinity Dam and is also operated for the benefit of the adjacent fish hatchery. The effects that the Trinity project has had on the Trinity River basin will be discussed in conjunction with the possible impacts of the proposed Dos Rios Project in the Eel River basin.

Effects of Impoundment and Diversion On Sediment Transport

The most direct effect of impoundment and diversion by the Dos Rios project would be on the capacity of the river to transport sediment. Practically all of the related effects would be due to interference with the natural capacity of the river to erode, deposit, filter, sort, flush and otherwise sculpt and modify its own channel bed. This interruption in sediment transport is all the more critical in the Eel River and neighboring basins (the Van Duzen, the Mad and the Russian) because these watersheds have the highest sediment yields for their size of any watershed in the United States (Judson and Ritter, 1964).

Impacts on downstream sediment transport in the Eel River by the Dos Rios Project would be all the more exacerbated by another proposed dam at English Ridge on the main Eel. Though this dam is less likely to be seriously considered, part of this discussion deals with the cumulative impacts of the two dams in order to further illustrate the impact of reduced flows.

As is the case with all rivers on the north coast, most of the sediment in the Eel River basin is carried during the few highest flow periods each year. For instance, the U.S. Geological Survey has determined that 50 percent of the annual suspended sediment yield is transported during a period of 2 to 9 days past stations along the Eel between Scotia and Dos Rios (Brown and Ritter, 1971). Equally important is the effect of extremely high flows, such as the December 1964 flood, on sediment transport. During the 30 day period December 23--January 23 (which includes the peak flood flows and the ensuing 3 weeks), the Eel River transported 51 percent of its entire suspended sediment discharge for the 10-year period, 1957-1967 (Brown and Ritter, 1971). This flood transport undoubtedly had a comparable effect on bedload transport (the coarser fraction of the sediment load that rolls, skips or jumps along the bottom).

In order to flush downstream the sediment carried into the main channel of the Eel River by streamside landslides and tributary streamflows, it is important to maintain these infrequent, high water discharges. Dams at Dos Rios and English Ridge would substantially reduce sediment-carrying peak flows. Presently a flow of 30,000 cubic feet per second (cfs) is equalled or exceeded an average of 4.0 days per year in the Eel River below Dos Rios. With the Dos Rios Dam this frequency would be reduced to 2.9 days, and with both dams the frequency would be reduced to 2.2 days, a decrease of 28 percent and 45 percent respectively (Dwyer et al., 1971).

Immediately downstream of a dam, a riverbed often erodes because material picked up from the bed is not replaced by material normally carried in from upstream. Moving farther downstream, more sediment

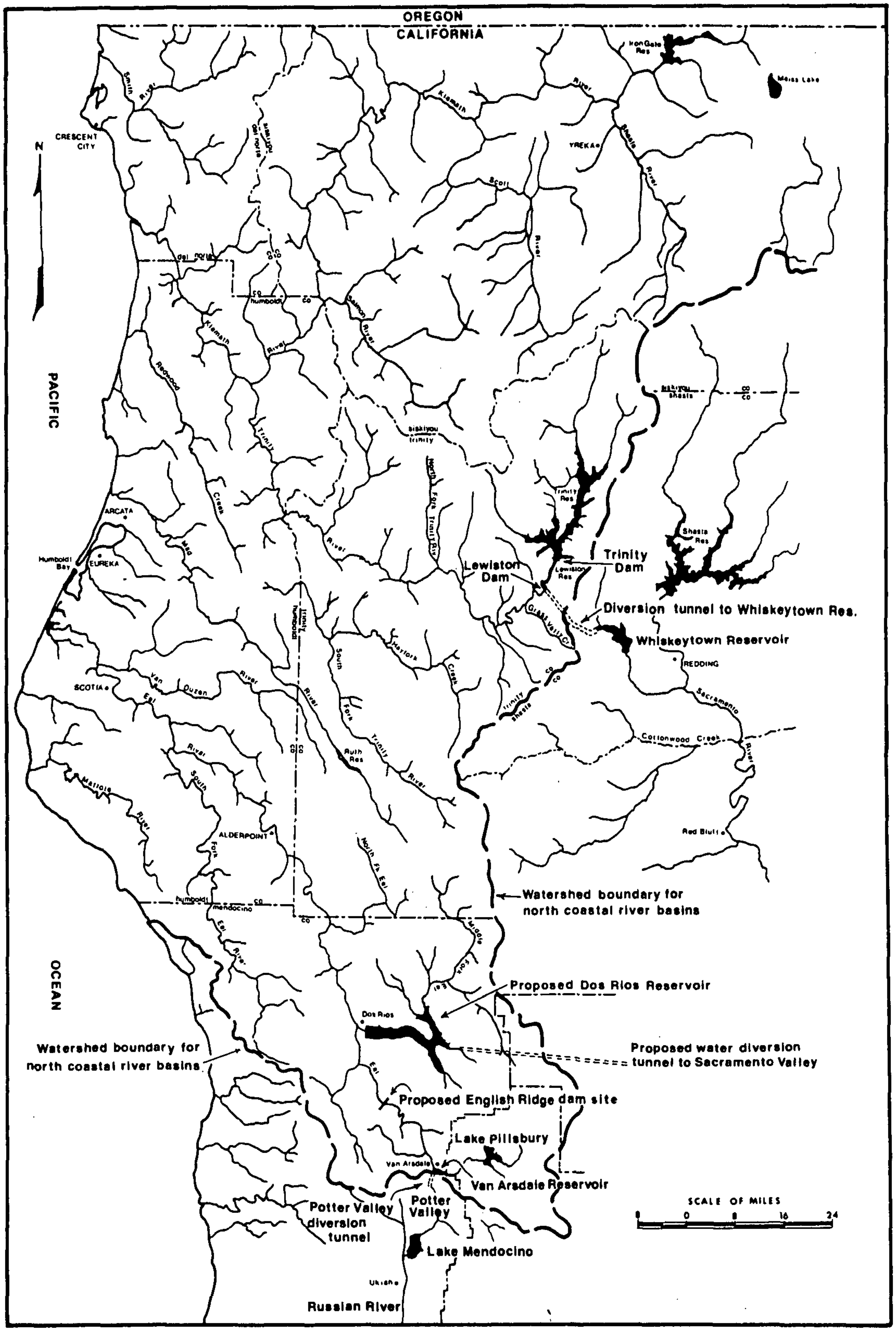

Figure 1. North Coast Rivers and Project Sites.

enters the main channel from tributaries and stream banks, and this sediment volume may soon exceed the reduced sediment transport capacity of the river. This would undoubtedly be the case with the Eel below a Dos Rios dam. In one sense the river is made smaller downstream of the dam because the high discharges of water and sediment usually are greatly reduced. Because the flows released below the dam have less capacity to transport sediment, streambed aggradation (filling in of the channel with sediment) occurs. Aggradation can be expected to be an especially severe problem in the Eel River because the Eel transports more sediment per unit drainage area than any other river in the United States (Judson and Ritter, 1964). A significant proportion of Eel River sediment (ca. 15-20 percent) is coarse material that cannot move in suspension and only moves as bedload during high streamflows Reduced high flows mean less frequent transport of coarse channel bed sediment.

The presence of abundant sediment source areas downstream of Dos Rios further support the likelihood of accumulation of coarse sediment on the bed of the

The Eel transports more sediment per unit drainage area than any other river in the United States

main Eel River.The frequency and activity of landslides along the main Eel are particularly high from Dos Rios to Alderpoint (Dwyer et al., 1971; CDWR, 1970a and 1973). Additionally, eight tributaries of especially high sediment production have been identified within this reach (Dwyer et al., 1971). The distributions of suspended sediment concentrations reflect these high source areas.

Much higher yields of suspended sediment occur in the Eel River basin below Dos Rios than occur farther upstream (Brown and Ritter, 1971). All these facts argue that reduced streamflows will result in the main Eel River channel below Dos Rios becoming progressively more choked with coarse sediment.

Downstream aggradation because of the lack of high streamflows would be therefore an anticipated effect of the Dos Rios dam. However, channel aggradation is also a naturally occurring process in the dynamic condition of river channels, and large storms like the 1964 storm triggered many landslides that delivered thousands of tons of sediment to channels, causing significant aggradation in most all major river channels (Brown and Ritter, 1971; Knott, 1971; Janda et al., 1975; Kelsey, 1977). This aggradation ranged from one foot to greater than ten feet in large stream channels. During the past fifteen years, the natural flushing action of these essentially free-flowing rivers during high flows has caused the gradual removal of the aggraded sediment. The channels of the Eel, the Van Duzen, the Mad and Redwood Creek are currently downcutting to preflood channel elevations (Lisle, 1981). A dam at Dos Rios would eliminate most of the high flows on the lower Eel that accomplish this channel downcutting and at the same time the large tributaries below the dam and the streamside landslides along the Eel will continue to sporadically fill the main channel with sediment during major storms.

A change in the size range of the channel bed material often accompanies channel aggradation. After aggradation, more fine sediment (fine sand and smaller) fills in the interstices of channel gravels. This creates a less aerated and more compacted channel bed less suitable as spawning or rearing habitat for anadromous fish.

The Trinity River below Trinity Dam offers a nearby example of the downstream effects of dams on river channels. Peak winter flow on the Trinity River at Lewiston prior to construction of the Trinity Dam often exceeded 10,000 cubic feet per second (cfs), whereas peak flow from the Lewiston re-regulation dam rarely exceeds 2,000 cfs (fig. 2). This drastic reduction in peak flows has seriously affected Trinity River sediment transport below the dam, especially in the reach between Lewiston and the North Fork Trinity River, 42 miles dowmstream. Average monthly pre-project flows and post-project releases are shown in fig. 3.

Prior to construction of the Trinity Dam, the river at the mouth of Grass Valley Creek could transport an average of 200,000 cubic yards of bedload sediment per year, while Grass Valley Creek was capable of delivering an average of 46,000 cubic yards (CDWR 1978; U.S. Bureau of Reclamation, 1979). Since the project has been completed, the transport capacity of the Trinity River has been reduced to about 10,000 cubic yards per year. The reduced capacity combined with the sediment discharge from tributaries such as Grass Valley Creek have resulted in sedimentation of pools and spawning areas in the 10-mile reach downstream of Grass Valley Creek. The present situation led the California Department of Water Resources to recommend the construction of a debris dam on Grass Valley Creek to retain sediment before it reaches the Trinity River. Engineering solutions to one major perturbation in a river system frequently involve constructing additional perturbations in the same watershed (debris basins, re-regulation dams, channelization, rip-rap, etc.).

Encroaching riparian vegetation on the Trinity River below the dam, due to the elimination of high, flushing flows in the winter months, has substantially changed channel configuration. Riparian vegetation has constricted the channel, causing the bed to incise and eliminating shallow riffles. Incision has reduced the streambed surface area and therefore reduced the quantity of spawning and rearing habitat. Riparian vegetation now occupies three times as much channel bed area as it did before construction of Trinity Dam. Each year this vegetation grows larger with stronger, more binding root masses. This further precludes downstream transport of aggraded sediment in the event of future reservoir releases designed to flush sediment downstream (USBR, 1979).

The Trinity River and its tributaries aggraded after the 1964 flood (Hickey, 1968), but reduced flows from Trinity Dam have prevented scour of the channel fill. Tributary deltas have accumulated in the main channel, and these deltas block fish migration in some cases. Deltas of five creeks are now being considered for removal (USBR, 1979; U.S. Fish and Wildlife Service, 1979), an expensive and environmentally destructive project. Finally, the combination of aggradation and lack of flushing flows in the Trinity River has resulted in a compacted streambed surface impregnated with fine sediment and has thus eliminated much spawning area and rearing habitat. Engineering solutions to mechanically disaggregate the crust have been proposed (USBR, 1979). These solutions are both costly and have their own adverse secondary effects.

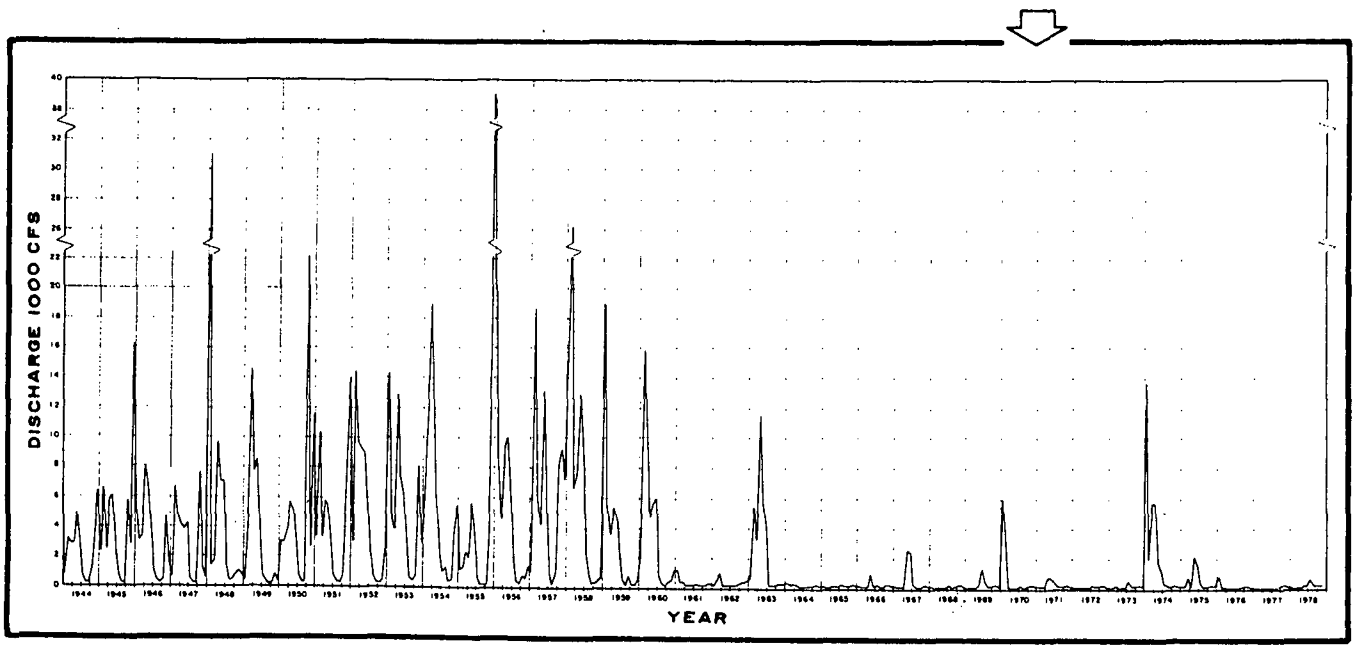

Figure 2. Peak Monthly Discharge, Trinity River at Lewiston. Source: U.S.B.R., 1979.

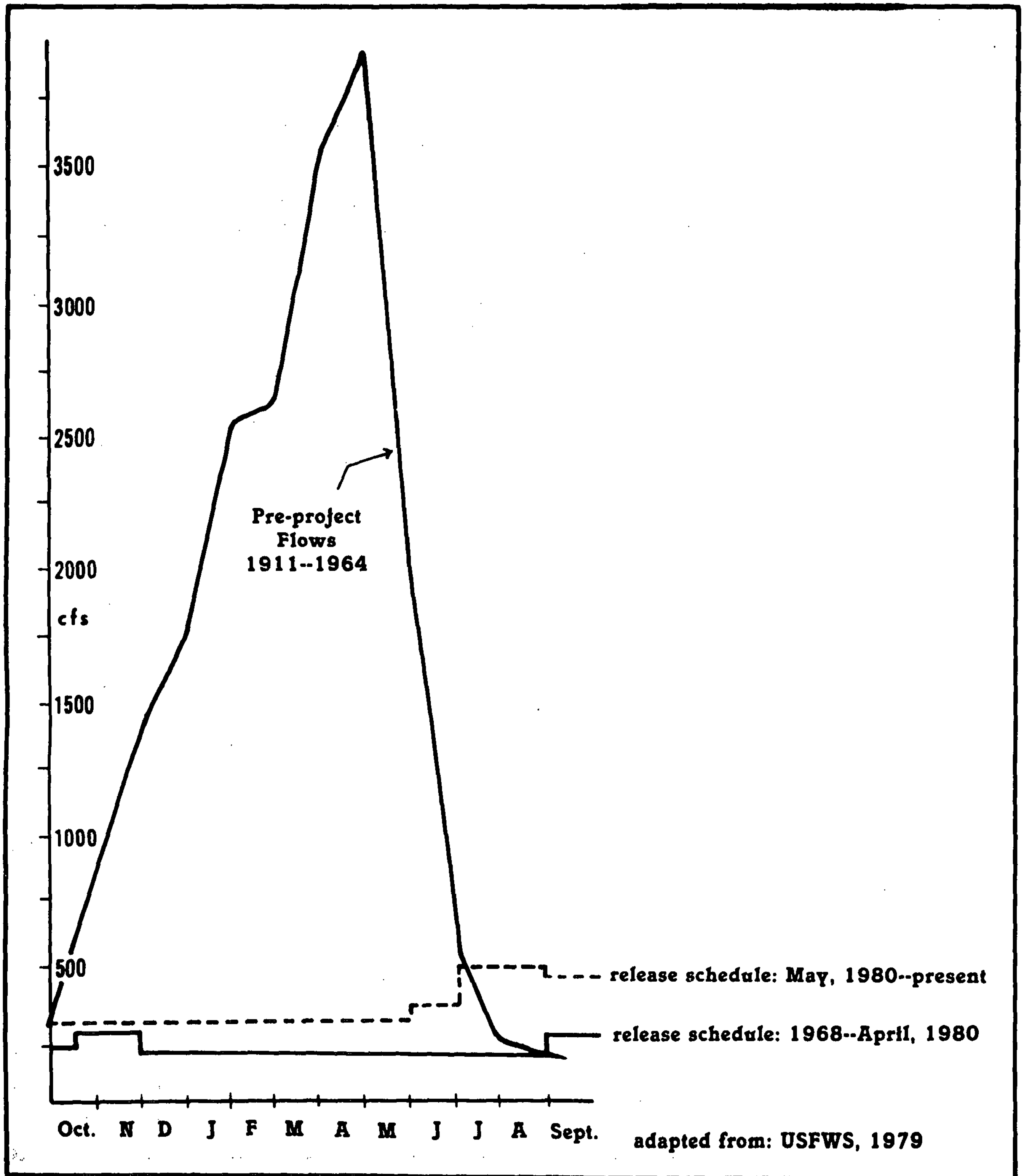

Figure 3. Pre-project flows and post-project releases.

Effects of a Dos Rios Dam On Hillslope Stability

The Eel River watershed is in large part covered by slopes that owe their present configuration to landsliding. Many of these landslides are currently active. The Dos Rios project will probably affect slope stability both in the main channel downstream of the dam and along the shoreline of the reservoir. The Middle Fork of the Eel from the damsite upstream to Round Valley passes through a canyon composed of unstable, fractured and sheared bedrock that is highly prone to slope failure (CDWR, 1967). Roughly 200 miles of shoreline would be created by the reservoir, and the saturation of lower slopes at the water's edge would likely trigger landslide movement of the slide slopes, especially with the additional effect of shoreline erosion by wind-generated waves in the reservoir. These reservoir landslides would significantly reduce water storage capacity behind the dam and shorten the reservoir's economic life.

Downstream of the dam, assuming the channel aggrades after impoundment and reduced high flows prevent channel scour, the aggraded channel will have reduced capacity to contain the higher flows within its bank (even though these "higher" flows are, in part, controlled releases from Dos Rios dam), and increased channel bank erosion and streamside slope instability may occur. These effects after channel aggradation have been documented in the neighboring Van Duzen River (Kelsey, 1977) and in Redwood Creek (Janda et al., 1975).

Indeterminate but undoubtedly negative impacts from a Dos Rios dam would also affect the Southern Pacific Railroad that runs along the edge of the main Eel. Flood control would benefit the railroad but channel aggradation in the main Eel would increase the tendency for bank erosion which would boost railroad maintenance costs. Increased bank erosion would also destroy other property, roads and possibly undermine bridges.

Effects of Impoundment and Diversion On Fishery Resources

Effects of the Trinity River Project on the Trinity River Fishery: A Case Study

The Trinity River Project provides a relevant example of the effects of a major dam on the anadromous fishery of an entire river system. The reduction of peak and average annual discharge in the Trinity River below Lewiston has had several impacts. From Lewiston to Douglas City 16 miles downstream, 28 percent of the original spawning area was lost or otherwise unusable by 1970; shorter reaches had deteriorated by as much as 80 percent. This occurred within five years of dam completion (Meacham, 1973). Additional problems created by the dam include chronic stream turbidity below the dam from turbid reservoir releases, and a reluctance or inability of juvenile salmonids to migrate downstream due to the low flow volumes released.

The Trinity River fish hatchery at Lewiston was constructed to mitigate the loss of the fishery. Problems with the Lewiston hatchery began by 1973. The temperature of the water released from the dam and used in the hatchery was too cold to allow for proper growth rates of yearling hatchery steelhead. Yearlings of insufficient size will not migrate downstream to the ocean during the normal spring season. Even though the Lewiston hatchery has facilities to produce more pounds of juvenile fish than the natural production in the area upstream of the dam ever produced, average fish production has decreased. Fall-run chinook and steelhead runs have decreased by 89 percent and 98 percent respectively since construction of the dam (Hubbell, 1973).

Hatchery fish production has been agggravated by decreased stream area and decreased water discharge below the dam. An insufficient quanity of stream habitat per juvenile steelhead released promotes premature displacement due to intraspecific competition and predation. Whenever flow releases from the dam are less than what would occur naturally, stream temperatures escalate quickly to 70 to 75° F (summer months) a few miles below the dam. The decreased water discharge cannot maintain the cold, deep-reservoir release temperature of from 48 to 52° F (Meacham, 1973).

Potential Effects of the Dos Rios Project On the Middle Fork Eel River Fishery

The Middle Fork Eel provides unusually rich anadromous fish habitat compared to other portions of the Eel River watershed. The unusual variety and potential vigor of this fishery is due in part to certain basin characteristics.

The average annual discharge from the Middle Fork is slightly greater than one million acre-feet, comprising 16 percent of the entire river basin discharge. The Middle Fork has a significantly greater quantity of streamflow discharge from snowmelt than any other major tributary of the Eel River. Reflecting this is the fact that the Middle Fork Eel normally discharges more than twice the volume of water during the months of May and June than it does during October and November (Burns, et al., 1972).

The cumulative length of streams suitable for spawning or rearing of anadromous salmonids in the Midddle Fork Eel and its accessible tributaries is 150 miles (U.S. Army Corps of Engineers 1968, U.S. Department of the Interior, Bureau of Land Management 1968). Statewide, the Eel River system ranks second in production of steelhead *(Salmo gairdneri)* and coho (silver) salmon *(Oncorhynchus tshawytscha)* (Smith, 1978). Considering miles of suitable habitat, the Eel ranks first for coho salmon and second for chinook salmon and steelhead (Lee and Baker, 1975).

Estimates of the various run sizes of these anadromous fishes entering the Middle Fork Eel are 12,000 chinook salmon (13 percent of the Eel River basin total) and 20,000 steelhead (20 percent of the basin total) (CDWR, 1972). These estimates of are very general as they are based on indirect sampling methods. Counts of adult chinook salmon and winter-run steelhead have not been conducted within the Middle Fork drainage. The estimates were derived by performing counts in tributaries near the Middle Fork, then extrapolating to equate with a drainage basin having the area of the Middle Fork. The counts and technique were applied by the California State Department of Fish and Game. The Middle Fork Eel supports approximately one-half of California's summer steelhead population. Additional information about the Middle Fork Eel

The Economic Value of the Fall-run Chinook Salmon and Winter-run Steelhead for the Middle Fork Eel River

Methods and formulas have been developed which permit assessment of the economic value of individual adult spawning salmon or steelhead (Smith, 1978). The methods account for the contribution of the ocean commercial and sport fishery, as well as the sport river fishery for steelhead and salmon. Factors necessary for the determination are dockside landing prices, angler effort and success ratios, and individual fish harvest vs. adult escapement ratios. Values for one adult king salmon and steelhead are $254 and $97.50, respectively (Smith, 1978). The values have been updated for 1981 using Consumer Price Index adjustments.

Species	Escapement	Economic Value per fish	Economic Value per species
Chinook	12,000	$254.00	$3,048,000
Steelhead	20,000	$97.90	$1,950,720
		Total:	$4,998,720

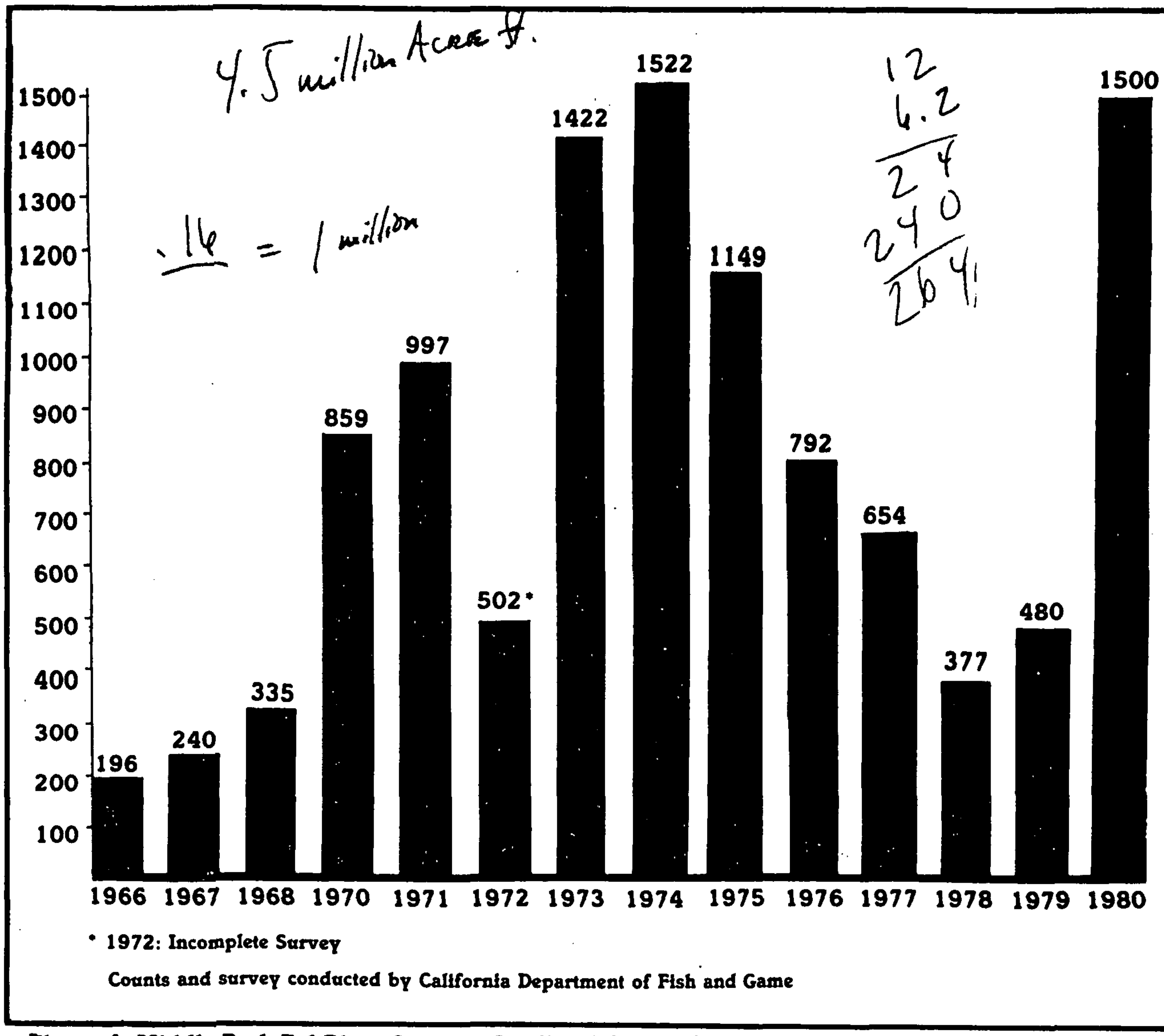

Figure 4. Middle Fork Eel River Summer Steelhead Census Survey

fisheries can be found in Smith, 1961.

A strain of fish commonly referred to as "spring-run" or "summer" steelhead inhabit the Middle Fork Eel. Adults ranging in weight from 3 to 20 pounds enter the Eel River at its mouth in the spring and migrate into the Middle Fork from April to late June. The full extent and range of this particular steelhead strain is not completely known. Specific requirements for survival and inherent vulnerability to disturbances in its habitat has prompted the U.S. Forest Service to designate it as a "sensitive species." Special management criteria are implemented by the Forest Service whenever development in a watershed occurs where a sensitive species exists. Figure 4 illustrates the variability in the annual population estimates of the summer steelhead. These estimates are based upon annual direct counts of adults in the Middle Fork Eel conducted by the California State Department of Water Resources and California State Department of Fish and Game.

The Dos Rios Dam would block the existing natural populations of chinook salmon and winter and summer-run steelhead from 150 miles of anadromous fish habitat in the Middle Fork. Approximately 32,000 anadromous fish adults would be affected in each of at least the first three years following dam completion, based on best estimates available. Mitigation measures would entail the construction of a fish hatchery below the dam at updated 1979 capital cost estimates of $19.5 million (CDWR, 1967a). Annual operational costs would approach one million dollars. Artificial propogation of chinook salmon and winter-run steelhead would be conducted; duplication fo a summer steelhead run would probably not be attempted.

Potential Effects of the Dos Rios Project On the Downstream Fishery Resource Of the Eel River

The maintenance of good water quality and suitable aquatic habitat below a dam is crucial to the survival of the downstream fishery. Sediment deposition, temperature and dissolved oxygen are the physical variables of greatest importance to salmonids.

The aggradation and compaction of the river bed that would occur due to the lack of flushing flows in the Eel River channel would impact salmonids in several ways. Mortality of both eggs and young fish developing in subsurface gravels accelerates if fine sediment comprises 15 percent or more of the gravel volume (Phillips et al., 1975). Excessive fine material decreases the flow of fresh, well-oxygenated intra-gravel water, impedes the removal of metabolic wastes, and also inhibits emergence of newly hatched young (alevins). A blanket of fine surface sediment decreases aquatic insect production, the primary food source for juvenile salmonids. Fine sediment fills hiding places used by young fish and makes gravels more compact, rendering them useless by adult salmonids attempting to spawn. Aggradation fills pools important to salmonids for thermal relief and protection from predators. The accumulation of sediment at the mouths of tributaries limits access of migrating fish in and out of the tributaries.

The California State Department of Fish and Game may request provisions for occasional large volume releases in order to attempt flushing of sediment. Such a request would have a substantial effect on project economics because the increased releases would come directly from what is considered project yield (CDWR, 1972). A constant flow release is the least desirable of schedule alternatives, being conducive to the establishment of year-round resident fish populations. These resident fish may successfully compete with the remaining anadromous fish (Meacham, 1973).

Releases of cold water from a dam at Dos Rios would present the same kinds of problems to its fish hatchery as those found at the Lewiston hatchery on the Trinity River. An example of delayed maturation of juvenile salmonids already exists in the Eel River. Cold water releases from the Cape Horn Dam (part of the Potter Valley Project at Van Arsdale), upstream from the confluence with the Middle Fork, has delayed salmonid peak downstream migration from late winter until midsummer. The detrimental effects associated with such a delay involve the significantly reduced flows downstream during summer. Predation by birds and mammals becomes a serious problem, and thermal extremes may create barriers to migration or cause extensive mortality.

During summer months, altered water quality would be especially problematical for a healthy fishery. Despite cold, deep reservoir release flows, summer river temperatures may reach near-lethal extremes and these high temperatures would be associated with harmful, low dissolved oxygen levels. Thermal relief for salmonids would be futher minimized by aggradation-induced changes in channel configuration that severly limit the availability of deep pools and access to cooler tributaries. Sport fishing in the mainstream Eel near Dos Rios would be affected by released flows of turbid water from the dam. Puckett (1973) observed that no anadromous fish were caught by anglers in the Eel River when turbidity exceeded a certain low level (30 NTUs).

Proposed mitigation measures for the Eel River fishery resource affected by a dam at Dos Rios include: 1) construction of a fish hatchery below the dam; 2) multiple level intakes to the outlet from the dam to better control water quality and stream temperature; 3) a schedule of dam release flows totalling 217,000 acre-feet annually; 4) a stream habitat maintenance program which may include projects such as selected dredging at the mouths of tributaries and the placement of artificial spawning gravel in specified reaches. The limited success so far of fishery mitigation in the Trinity and Eel rivers plus the substantially greater aggradation problems that would result due to the Dos Rios diversion points to mitigation of Dos Rios impacts as an extremely formidable task.

Effects of a Dos Rios Impoundment On Wildlife

The Middle Fork courses through six general vegetation types (Kuchler, 1977) with a corresponding number of wildlife communities. The California Department of Fish and Game (1969) conducted preliminary assessments of the on-site impacts on wildlife from the proposed Dos Rios reservoir, and concluded that: 1) the reservoir would have severe impacts; 2) that preservation efforts based on game species alone would not adequately protect the overall wildlife resource; and 3) that the wildlife ecology of the Middle Fork Eel River drainage is not adequately understood to anticipate all the impacts of a Dos Rios dam.

Impacts on wildlife would extend well beyond the immediate zone of inundation by the reservoir. The high value to wildlife of the riparian vegetation and aquatic communities has been described by DeVos and Mosby (1971), McCabe (1956), the California Fish and Game Commission (1965), and documented by Marcot (1978), Bertram (1977), Sands (1977), Johnson and Jones (1977), Johnson and McCormick (1978), Anderson and Omhart (1976), and many others. Riparian zones host both greater numbers of wildlife species and greater wildlife population densities than are found in the upland environment (Marcot, 1978). Therefore, an impoundment that buries riparian vegetation and aquatic habitat will have both direct and indirect effects on all wildlife.

In the north coast area, at least 221 species (which is 72 percent of all species and includes 136 birds, 64 mammals and 23 amphibians or reptiles) breed or feed in riparian deciduous habitats, and 76 species (42 birds, 15 mammals and 19 amphibians or reptiles) are associated with aquatic habitats for breeding or feeding. Most of the riparian-associated species, and approximately 15 species which are associated with flowing water habitats, would be eliminated from the inundation zone.

After impoundment occurs, all of the habitat buried by the reservoir is irretrievable. Species which are associated with standing water, such as waterfowl, herons, grebes and gulls, may invade or increase at the site of the reservoir, but with the absence of of adequate shoreline cover, these species may occur only in low numbers. Many large-scale impoundments lack shoreline riparian vegetation that is so important to wildlife because the periodic, high fluctuations in water levels cause sterility along the shoreline, and the steepness of the littoral reach does not allow the establishment of any but a thin line of riparian or aquatic plants.

Another possible serious impact of the Dos Rios impoundment would be the inundation of a significant portion of of the winter range of the Mendocino Forest deer herd. This herd is one of the most valuable herds in the state (Larry Puckett, oral communication, April, 1980).

The downstream effects of an impoundment would differ greatly. In the short run, massive blooms of riparian vegetation would follow the disruption of usual flood cycles of the river. In turn, this would greatly enhance the riparian wildlife community, by providing a greater area and diversity of streamside vegetation. In the long term, however, riparian habitat would be lost because of the encroachment of upland plant species into the outer fringes of the riparian zone, since there would be no floods to maintain the riparian community.

Off-site effects also would probably include the reduction or elimination of some 32 species of wildlife that eat fish, insofar as the fisheries resource would decline upstream or downstream from an impoundment. Among the fish-eating species are bald eagle and peregrine falcon (Endangered Species status on Federal and State listings) and mallard, common merganser, black bear, racoon, and mink (Harvest Species on State listing). Other species, such as osprey, would also be affected.

An impoundment in the north coast area may provide additional wintering, feeding, and potential breeding habitat for bald eagles as now occurs at Ruth Lake on the Mad River.

The Eel River Estuary: A Poorly Understood But Important Link

The Eel River estuary is atypical of most estuaries because it does not exist year-round. During the rainy season, normally from October to early May, high river discharge blocks the saline tidal waters and fresh water dominates the river mouth. The estuary is renewed each spring and becomes a temporal habitat for certain estuarine organisms which are important for anadromous fish survival. This seasonal estuarine condition also exists in the Mad River and Redwood Creek basins and is highly sensitive to alteration of river discharge, water quality and river depths.

The productivity of the phytoplankton (microscopic plants which are the primary producers in the marine food chain) in the estuary is dependent on the influx of dissolved nutrients carried into the estuary by river flows. These phytoplankton in turn are consumed by specially adapted species of zooplankton (microscopic animals that graze on phytoplankton) that can tolerate the fluctuating brackish water of the estuary. Various fish, including salmonid juveniles, consume vast quantities of the estuarine zooplankton as a staple in their diet. These salmonid juveniles travel downstream to the estuary starting in the spring, and the estuary provides habitat and food for these fish from April through October or November. Some juveniles travel fairly quickly through the estuary but others take up temporary residence (Larry Puckett, oral communication, April, 1980).

The physical and chemical well-being of the estuary is crucial to the maintenance of the food chain. Sustained river flows after estuarine conditions commence in the spring supply the nutrients for phytoplankton growth and, consequently, for zooplankton development. When salmonid juveniles travel downstream to the estuary, they must reside in the estuarine environment while they metabolically adapt to the more saline environment, a process called osmoregulation. The estuarine transition must not be too abrupt (i.e., there must be a sufficient estuarine area) and there must be ample food (zooplankton) available for the juvenile fish while they osmoregulate and reside in the estuary. A healthy, undisturbed estuary fulfills both needs during most years.

The dynamics of transitory estuaries such as the Eel River estuary are not well understod, although research is in progress (Phil Buttolph, estuarine processes in the Mad River, research in Dept. of Natural Resources, Humboldt State Univ.) However, it is well understood that the estuarine transition zone from a free-flowing, fresh water river to the ocean environment is a transitory environment where populations of microscopic plants and animals annually bloom, flourish and die. In the process they feed fish, including salmonid juveniles who must temporarily reside in the estuary while they metabolically adapt prior to entering the Pacific Ocean. Estuarine area, depths, salinities, temperatures and bottom sediment are all dependent on the timing, volume and temperature of river discharge. Abrupt changes in temperature can cause mass extermination of zooplankton and irregular summer discharges or abrupt changes in discharge in the estuary can affect the reproductive cycle of zooplankton and the successful osmoregulation of anadromous fish.

If river flow is regulated by a dam on the Eel River without first thoroughly understanding the natural estuarine system, severe disruption of the estuarine habitat may occur, with devastating effects on the already dwindling anadromous fishery.

Effects of the Dos Rios Project on Sand Supply to Beaches

The Eel River empties directly into the Pacific Ocean and is the main source of sand to the beaches south of Humboldt Bay (Ritter, 1972). The Middle Fork Eel above Dos Rios contributes about 13 percent of the total sediment load of the Eel (Brown and Ritter, 1971). A dam project at Dos Rios would have an estimated sediment-trapping efficiency of at least 96 percent (Knott, 1971). This implies a potential loss of 12.5 percent of the total sand transported by the Eel, or about 561,100 tons annually. In addition, the reduced frequency of high streamflows would decrease the rate of transport of sand available below the dam.

From physical sedimentary evidence, Ritter (1972) determined that Eel River sediment is the chief source of sand for the stretch of beach from at least the Humboldt Bay entrance southward for 13 miles. Any interference with the materials transported by the Eel could lead to beach erosion in this region. Although Ritter considered that the beach materials to the north of Humboldt Bay were contributed primarily by the Mad and Little rivers, this is not certain.

A reduction in Eel River sediment output would decrease the supply of sand to beaches in a coastal region that is particularly stressed by a high incoming wave energy level (DeGraca and Eckar, 1974). Depletion of sand supply to beaches adjacent to the Eel River may be critical enough to cause beach and sea cliff erosion, though more research is needed on the local beach system before reasonable predictions can be made. A similar situation exists in Southern California where dams cut off sand supply to local beaches. The consequent loss of the beach and increased sea cliff erosion is well documented (Inman and Brush, 1973).

Conclusion

Impoundment and diversion of water from north coastal California river basins can have serious negative effects on the fish and wildlife of the river basins, on the hillslopes and downstream river channels, on the biological health of the estuaries, and may affect the stability of the coastal beaches adjacent to the river mouths. The high flows of winter, viewed as "surplus" water by some, perform some of the most important tasks of maintaining biological productivity and physical stability of the river systems.

Any proposed additional diversion of north coast river water would have its own unique set of potential impacts. The common element is the disruption of the quantity, quality and timing of river flows. Unimpeded, the north coast rivers are highly productive systems, dependent on sound resource management. Water moving down the river channels plays many valuable roles. The undiverted north coast rivers are not wasting away to the sea--they are working their way to the sea.

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