SIX RIVERS NATIONAL FOREST ANADROMOUS FISH HABITAT RESTORATION AND ENHANCEMENT PROGRAM

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1978, Six Rivers National Forest developed a fisheries and watershed agement program aimed at restoring and enhancing anadromous fish populations habitat. The two objectives for the program are: 1) identify habitat tors that are limiting fish production, and 2) develop and evaluate cedures to restore or enhance chinook salmon (Oncorhynchus tshawytscha) and elhead trout (Salmo gairdneri) habitat in north coastal California streams. jects included the placement of gabion weirs, boulders, and egg incubation es to create spawning sites, rearing habitat, and fry production, respecely. Biological and hydrological monitoring is being conducted to evaluate procedures, develop guidelines and determine project cost effectiveness. ect increases in fish utilization through improved chinook salmon and elhead spawning and rearing habitat has resulted from the projects.

INTRODUCTION

anadromous fishery resource in California has experienced a two-thirds line over the last 35 years (Citizens Advisory Committee on Salmon and elhead Trout 1975). The decline has been attributed to degradation of itat due to watershed disturbances (logging, roads, mining, grazing), floods, ught, impoundments, and increased demand on the fishery. The resource line is creating severe socio-economic hardships to the north coast with ultant controversy over river, watershed and salmon management. The annual s of revenue to Northern California has been considerable. In response to declining fishery and increasing demand for the resource, management ncies have implemented policies and programs to protect existing habitat, tore lost or degraded habitat, and increase artificial propagation.

Rivers National Forest has 350 miles of anadromous salmonid habitat with an mated annual value of 11.2 million dollars (Smith 1978). The primary wning habitat for chinook salmon (Oncorhynchus tshawytscha) and steelhead ut (Salmo gairdneri) is found within the tributary streams to the main ers. Inventories have identified a variety of habitat conditions within the est, ranging from poor to high quality, and a wide range of use patterns by different fish species.

Forest fishery restoration program started in 1978 with two objectives: 1) dentify and correct habitat factors that are limiting fish production; and o develop and evaluate habitat restoration/enhancement procedures suitable Northern California streams. This paper will describe the results and edures involved in planning, implementing, and monitoring the projects.

NING. Data on Forest watersheds were compiled from stream surveys to tify possible habitat limiting factors (i.e. sediment problems, lack of

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spawning gravels, migration barriers). Based on this information, watersheds were prioritized and monitoring was initiated. Monitoring consisted of establishing "index streams" to identify fish utilization (adult spawners, redd counts, juvenile production) and the quality and quantity of habitat being utilized (i.e. spawning gravel quality, area of nursery habitat). Watershed inventories were initiated to identify continuous and potential sediment sources. Restoration/enhancement plans were then developed from the inventory data.

HABITAT LIMITING FACTORS. Habitat factors necessary for successful salmon and steelhead production have been well documented in the literature (Edmundson et al. 1968; Chapman and Bjornn 1969; McFadden 1969; Everest and Chapman 1972). Four major factors were identified which limit anadromous fish production on Six Rivers National Forest: 1) The lack of both quantity and suitability of gravels for spawning; 2) the absence of instream shelter for juvenile steelhead production; 3) the presence of fish migration barriers; and 4) the lack of adult spawners. The 1964 flood, combined with sediment-producing watershed disturbances are the primary agents responsible for the first three limiting factors.

FISH HABITAT RESTORATION / ENHANCEMENT

SPAWNING HABITAT. Spawning surveys by U.S. Forest Service biologists in Six Rivers National Forest in 1978-1979 identified specific streams where the lack of gravel accumulations were limiting chinook salmon production. The feasibility of creating gravel spawning areas by manipulating the stream channel was explored. This problem had been the subject of several investigations in Pacific Northwest streams. The Washington Department of Fisheries began experiments in 1969 to improve salmon spawning habitat through the use of gabion weirs, rock-filled wire mesh baskets (Gerke 1973). The gabion weirs were placed perpendicular to the flow across the channel. The weirs created gravel beds that were used by several salmon species (Wilson 1976). In some weirs placed perpendicularly to the flow, stress associated with peak storm flows have broken wire mesh, rolled gabions, and routed water around the bank ends of the weirs (Jackson 1974; Engels 1975).

The utility of rock-filled gabion weirs to hold gravel in place or to trap bedload gravel was demonstrated. However, the potential failure of such structures during peak flows prompted further experimentation in design. The "V" shaped weir design, similar to the structures developed in Oregon by Anderson and Cameron (1980), has been shown to reduce the impact of stream energy, lessening the stress on the weir and bank/structure interface.

Six Rivers National Forest began experiments with the "V" weir in 1979, placing 10 weirs in streams tributary to the Smith, Klamath, and Trinity Rivers of Northwestern California. In a detailed study of six of the weirs, single weirs placed at tails of pools were compared with pairs of weirs in series placed in riffles, for effectiveness in trapping bedload material suitable for spawning (Moreau 1981). The predicted weir effect in breaking up monotypic cobble reaches is shown in Figure 1. Weirs with splash aprons were compared to weirs without splash aprons for ability to withstand stresses from high flows in the same study. Monitoring methods included before and after topographic maps, longitudinal profiles, channel cross sections, and bed sampling by two methods

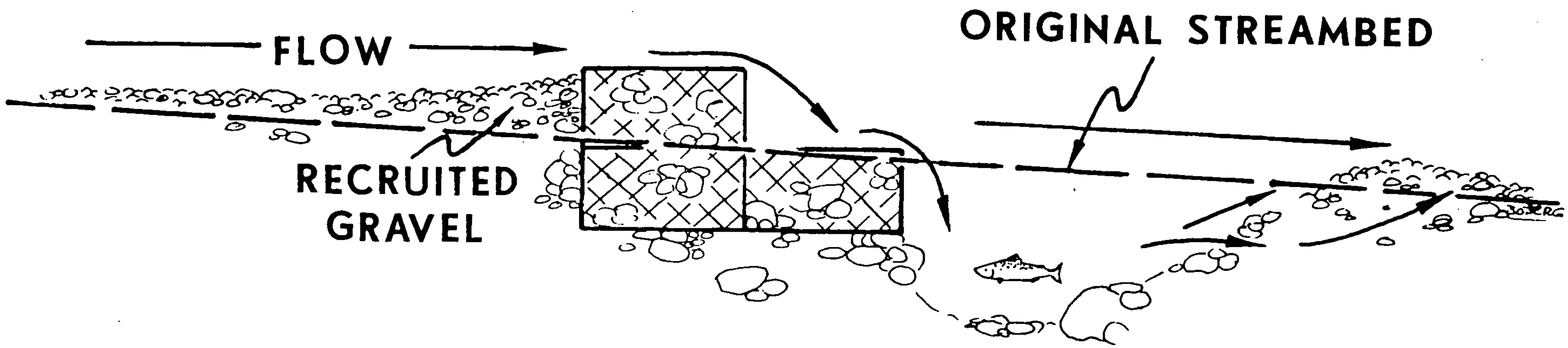

Figure 1. Cross - sectional view of gabion weir with splash apron and the observed streambed changes.

1) Use of a McNeil sampler (McNeil and Ahnell 1964); and 2) Pebble counts (Wolman 1954).

REARING HABITAT. Steelhead trout accounted for greater than six million dollars economic evaluation attributable to Six Rivers National Forest in 1977 (Smith 1978). This factor was the foremost incentive in exploring causes that may be limiting steelhead production on the Forest below optimum.

Many streams on Six Rivers were found to have a limited number of living and hiding places for age one and two year juvenile steelhead parr. This condition has lead directly to a deficient number of adult steelhead elsewhere (Narver 1976). Fry and parr stages are especially critical for steelhead because the operation of density dependent processes largely determines the strength of each year's age class and obviates the operation of other regulatory processes later in life (McFadden 1969). The purpose of this particular project was to rehabilitate rearing habitat of steelhead trout parr in Aikens Creek and Red Cap Creek, Klamath River tributaries, by the introduction of large boulders.

The limiting factor for the carrying capacity of juvenile steelhead is usually physical living space (Narver 1976). This component is modified by food availability which affects, at least indirectly, the population size. Competitive, territorial behavior for space leads directly to its division, and indirectly to division of the food resource among the individuals.

The demand for greater food consumption as a steelhead fry approaches seven months of age motivates the individual to leave shallow, calm side channel habitat and venture into the main flow of a riffle. The new territorial focus is preferably behind a stable object such as a boulder, where swimming metabolic energy is minimized (Chapman and Bjornn 1969). Requirements of depth, overhead cover, and intraspecific isolation can all be met at this type location (Edmundson et al. 1968; Parkinson and Slaney 1975).

In July, 1978, a 450 foot monotypic reach in lower Aikens Creek (summer flow 2 cfs) was divided into three sections: The upper section was left as the control reach; in the middle section large boulders (2-3 ft diameter) were winched into the stream; and in the lower section a combination of boulders and log deflectors were constructed. The work was completed by the U.S.F.S. Youth Conservation Corp.

Population estimates for each section were determined in September of 1979. Each section was blocked off by nets and an electrofishing succesive-removal technique was utilizied to determine fish numbers.

The Red Cap Creek experimental design was to compare fish populations and changes in channel morphology in a stream reach before and after boulder placement, with those of an adjacent control reach of identical length and similar morphological characteristics. The reach was accessible by a front-end loader to place the boulders. The need for rearing habitat improvement resulted from a channel diversion in 1975. Boulders totalling 80 in number were placed singly and in clusters in separate sections within the treatment reach.

Planimetric maps, channel cross-sections, and longitudinal profiles provided data concerning morphological characteristics. Fish population and biomass calculations were a result of intensive electro-shocking. The sampling occurred during the same time of year for two successive years. The time chosen was when stream discharge was least, thereby determining the period minimum carrying capacity.

FRY PRODUCTION. With the ever-increasing stress placed upon natural anadromous fish production, the use of artificial propagation or stream-seeding has become imperative in fisheries management. Recently, more emphasis has been placed on the use of streamside egg incubation boxes as a relatively inexpensive, low maintenance method of fry production. Incubation boxes such as those tested by Zimmer (1964), McNeil (1968), Bams (1970), Lannen (1975), Bams and Simpson (1977), and Allen et al. (1981), have been shown to produce fry which compare favorably in size and condition to wild fry (Bams 1970; Allen et al. 1981), and are generally of greater quality than hatchery fry (Parkinson and Slaney 1975). Incubation boxes have the capability of providing an egg-to-fry survival rate five to ten times greater than natural production.

In 1980, the Six Rivers National Forest anadromous fish program was expanded to include the development of a streamside egg incubation box system which could assist in the restoration or enhancement of chinook salmon and steelhead runs on the Forest. The objectives for this element of the program are:

1. To develop a streamside egg incubation box system compatable with small north coastal streams, which typically have a high silt load and are often unstable.

2. To elevate stream production to its potential in areas where instream improvement projects have increased the quality and/or quantity of available spawning habitat.

3. To restore or enhance stream production where spawning escapement of chinook salmon or steelhead has fallen below historical or potential levels.

The design of the Six Rivers incubation box system [1/] accomodates the following requirements: 1) A gravity flow water system capable of supplying six to eight gpm for each incubation box, with a stilling well filtration system; 2) A portable system of simple design in an easily constructed form with readily accessible materials; 3) A capacity to incubate 40,000 chinook salmon or steelhead eggs on a gravel substrate or on incubation trays; 4) A downwelling system, capable of dealing effectively with varying amounts of silt delivered to the box during the incubation and alevin development period; and 5) A capture or live well to preclude fry escapement for monitoring.

he incubation box is constructed of 3/4 inch exterior grade plywood, eight feet ong, 16 inches wide, 21 inches deep, with 2X2 inch internal redwood reinforcing embers (Figure 2). The box is tightly covered with a 3/4 inch hinged plywood op. The interior of the box is divided by baffles into three chambers: an ncubation area; an outlet well; and a capture or live well. All seams and oints are glued and fastened with screws. The interior and exterior of the box re resin coated.

ter is diverted from an intake filter to a series of stilling wells by gravity igure 2). The water supplied from the end stilling well to the incubation box controlled by a gate valve. The flow direction is downward through the incu-

Initial Design by Dave Miller, Aquatic Biologist Simpson Timber Co.

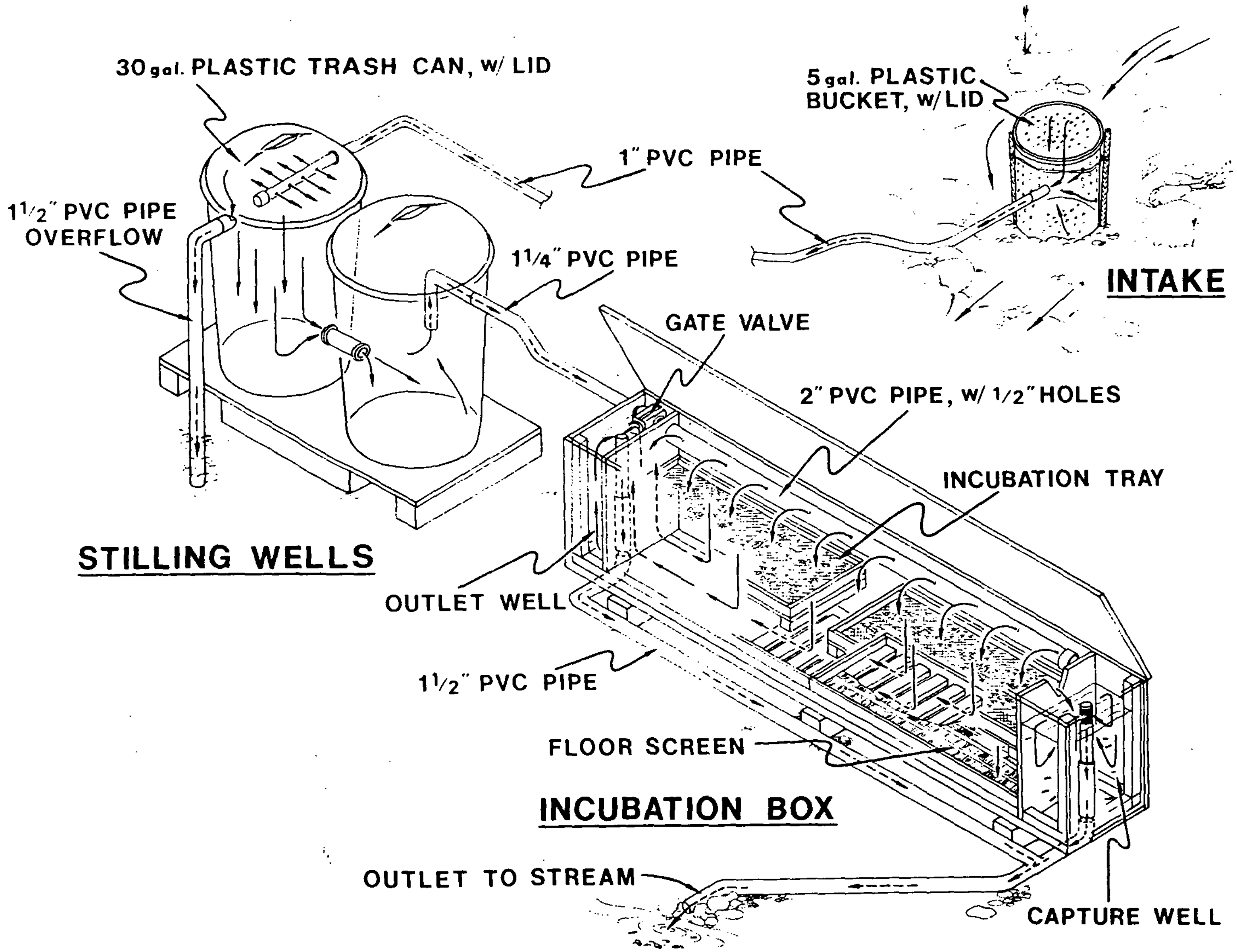

Figure [illegible]. Diagrammatic view of the salmon and steelhead egg incubation box btion area, passing through a layer of eyed eggs resting on Vexar 1/ screen rays. The flow pattern continues through the floor screen and exits through he standpipe in the outlet well. Water may also exit the system through the creened standpipe in the capture well. The screened standpipe is removable for eleasing fry.

nitially, three experimental sites were developed to assess methods, design,and ry survival rate of the proto-type downwelling incubation box. The sites ncluded Quartz Creek, tributary to the South Fork Smith River; Red Cap Creek, ributary to the Klamath River; and the upper Mad River. Because site devel-opment was initiated in late fall of 1980, steelhead eggs were all that were vailable for the preliminary assessment.

ISH MIGRATION BARRIERS. Numerous miles of suitable habitat for anadromous pawning and rearing is not accessible because of log debris jams, boulder oughs and bedrock falls. Annually, existing and potential barriers are xamined for removal or modification. Barrier assessment involves snorkel urveys, carcass counts, and habitat evaluation above and below the barrier. his information determines what will be gained in fish production by barrier emoval.

aution has to be exercised when dealing with woody debris jams. The instream ioenergy, instream shelter, and the physical make up of the channel is often overned by woody debris within the stream (Cummins 1974; Swanson 1978). Access s generally a problem as most barriers are remote. Helicopters, portable rills, explosives and man-power crews are the primary components for completing he work. Debris jams are modified to either ensure fish passage, eliminate ank erosion problems, or prevent future barriers. By cutting and/or cable nchoring of large key logs, and removing small debris, the debris jam can be tabilized and shaped to provide for fish passage, instream shelter and bank rotection.

ATERSHED RESTORATION. Several drainages have sediment yields greater than the tream's transport capabilities. This is confirmed by measurements in embed-edness, pebble counts and substrate sediment composition. Watershed restor-tion designed to reduce sediment yields to near natural levels, will result in ncreases of fish habitat and augment inchannel habitat improvement projects. nventories of entire watersheds are conducted to identify continous and po-ential sediment sources. An evaluation is conducted to determine if the source s treatable (i.e. determination of access, costeffectiveness of proposed reatments, and benefits accrued), and how it relates to other sediment sources. restoration plan is developed, all sources are prioritized and the route of unding and implementing the projects are determined. The majority of the rojects consist of structural and vegetal means of reducing sediment. Project onitoring is completed by photoregression and streambed sediment determinations bove and below the sediment source.

RESULTS AND DISCUSSION

AWNING HABITAT. All gabion weirs trapped bedload, but the suitability of the apped bedload for spawning, and the area of suitable bed material varied among e weirs. The quantity of bedload deposition appeared to be dependent on local

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hydrologic features (channel width and slope), rather than variation in weir design. Five of the six weirs trapped gravel after initial fall, 1979 storms, but a subsequent flood estimated at a five to seven year recurrence interval occurred in January, 1980. The flood apparently created beds of larger rock not optimally suited for spawning at two of the five weirs which had originally trapped suitable gravel. Chinook salmon spawning had occurred at five weirs prior to the January, 1980 flood. Weirs with splash aprons were apparently no more stable than weirs without splash aprons, but differences, if they exist, may become apparent after several years. Weirs settled in response to peak flows and leaned downstream, but no structures were destroyed. Scour channels occurred around the bank ends of two weirs which had not been adequately riprapped. After two winters, two of the weirs continue to provide significant areas of frequently utilized spawning gravel for chinook salmon and steelhead trout, while a third weir provides a small gravel area.

With knowledge gained from the first series of treatments, a spawning riffle utilizing a pair of "V" weirs with splash aprons was created in August and September, 1980. Approximately 220 cubic yards of graded gravel were placed at the site. After the gravel had rearranged from winter flows, the majority of it was between the two weirs. The total gravel area was then approximately 2,500 square feet. Chinook salmon and steelhead trout were observed using this area for spawning from November, 1980 to March, 1981. Table 1 describes the observed spawning benefits and project costs for Patricks Creek.

The projects of 1979 and 1980 have demonstrated that the "V" -shaped gabion weir is a useful management tool for providing spawning gravel. Monitoring of these completed projects will continue to determine the life span of the structures. Additional gabion and boulder weir projects are currently in the planning stage, and will be installed in selected streams on the National Forest.

Table 1. Project costs, observed spawning and monitary benefits are listed for the Patricks Creek spawning restoration projects.

YEAR	Structures Built	Cost	Observed Spawning	First Year Benefit*	Second Year Benefit
1979	Three Gabion Weirs	$5,000	7 Salmon Redds	$2,800	
			7 Steelhead Redds	$1,400	
			7 Salmon Redds		$2,800
			12 Steelhead Redds	$2,400	
1980	Two Gabion Weirs Graded Gravels	$18,000	8 Salmon Redds	$3,200	
			18 Steelhead Redds	$3,600	

Total Cost = $23,000
Total Benefit to Date = $16,200

* The above benefit figures are based on 1980 net economic values of approximately $200.00 for a chinook salmon spawner and $100.00 for a steelhead spawner (Smith 1978 values modified to reflect 1980 values).

REARING HABITAT. The Aikens Creek project resulted in a two-fold and a four-fold increase in juvenile steelhead numbers in the boulder-only section and the boulder-log section, respectively. There was a marked increase in age 1+ steelhead trout in the treated section.

Table 2 describes the results of the Red Cap Creek project. Stream surface area increased 7% and stream flow volume decreased 20% during the year in the control reach for a discharge of 26 cfs, as the channel became wider by 5% and shallower by 25%. The treatment reach uniformly increased 18% in surface area due to lateral erosion. Streamflow volume increased by 75% in the treated section where boulders were placed in clusters. The increase in pool stilling area averaged $1.10 m^3$ per boulder.

able 2. Production of Steelhead Parr (age 1+ years), and stream morphology characteristics of Red Cap Creek. Data is per 100 feet (30.5 meters) section of respective reach. Data for boulder cluster section is used for treatment reach.

	Stream Morphology		Fish Production			
	Surface Area	Volume	Relative Biomass		Absolute Biomass	Population Estimate
ontrol each	m^2	m^3	g/m^2	g/m^2	grams	
ept. 979 Q= 26 cfs)	284	85	2.18	7.26	610	20 (17-23)
ept. 980)= 26 cfs)	297	65	1.28	5.69	381	13 (11-15)
r-cent ange	5%	-24%	-41%	-22%	-38%	-35%
eatment ach						
pt. 79 = 26 cfs)	326	65	0.77	3.80	254	9 (+0)
pt. 80 = 26 cfs)	384	114	2.74	9.27	1,054	27 (25-29)
-cent nge	18%	75%	256%	143%	315%	300%

The control reach population of steelhead parr (age 1+) in 1980 was 35% less than in 1979. The section with boulder clusters in the treatment reach exhibited a 300% increase in number of parr comparing 1980 to 1979.

The control reach decrease in relative biomass of age 1+ parr of 41% per surface area and 22% per volume, are similar to the decrease of 38% in absolute biomass. The increase in absolute biomass of 315% in treatment reach parr, boulder cluster section, was greater than the 256% and 143% increase in relative biomass per surface area and volume, respectively.

Two sections where boulders were placed singly failed to produce desirable results the first year. Boulders were removed from one section and buried in channel aggradation in the other. The buried boulders were uncovered in the 1980-81 winter flows and are now providing rearing habitat.

Expenditures for the entire projects summed to $2,305. A benefit-cost analysis was calculated using a procedure developed by Ward and Slaney (1979). The analysis was calculated for the successful boulder cluster section. The initial cost must be included, and monetary values for returning adults and repeat spawners were derived by methods determined by Everest (1977). Beginning with four year old spawners, a benefit cost analysis (values discounted at 10%) after 10 and 20 years was 0.92 and 2.11, respectively.

FRY PRODUCTION. The egg incubation box systems at all three sites functioned favorably. Two of the systems experienced only minor problems, while the other suffered no difficulties. Approximately 1,800 mortalities were incurred at the Quartz Creek site due to a fungal infestation. From the 7,000 eggs placed in the Quartz Creek box, approximately 4,950 fry were produced and released, an egg-to-fry survival rate of 71%. The only difficulty at the Mad River site was the reduction of the outlet flow, due to a partially blocked pipe. The restriction of the outlet caused the box to over flow, losing approximately 900 fry. Approximately 8,850 fry were produced and released at the Mad River site from 10,051 eyed eggs stocked, yielding 88% survival. From 10,085 eyed steelhead eggs stocked in the Red Cap Creek box, 9,875 fry were produced and released -- a survival rate of 98%.

The preliminary assessment of the Six Rivers incubation box appears favorable with regard to cost, functional design and egg-to-fry survival. An initial investment of approximately $2,500 was incurred for each incubation box system, including site development, monitoring and maintenance. Each system has the capacity of producing 30,000+ fry annually. With the initial cost pro-rated over a probable life expectancy of five years, the cost per fry produced is approximately $0.02. The initial design of the downwelling system appears functional and easily maintained. The water supply system proved to be stable and handles fairly high silt loads adequately. Much of the research into fry production using incubation boxes maintains that a rugose substrate is a necessity for the development of high quality fry. However, most of these investigations have dealt with pink, chum or sockeye salmon fry production. McNeil and Bailey (1975) point out that there are indications that chinook salmon alevins may be better adapted to conditions in smooth substrate incubators. This may also be true with steelhead alevins. This preliminary study did not deal with size or quality of fry produced, only survival. A comparative study of the effects of a rugose versus smooth substrate on chinook salmon and steelhead fry quality will be initiated in the fall, 1981.

FISH BARRIERS. The removal of two fish barriers by the use of an Alaskan Steepass fish ladder and the blasting of a side channel around boulder roughs has resulted in an additional 60 miles of habitat made available for steelhead trout. Modification of 35 debris jams eliminated bank erosion problems and potential barriers; while creating rearing habitat by adjusting and stabilizing log debris to form instream shelter and pools. Thorough evaluation of each barrier or debris jam must be completed to ensure that long-term channel damage does not occur from jam removal.

WATERSHED RESTORATION. Watershed restoration projects to date have resulted in revegetating approximately 200 acres of bare erodible soils. The work has consisted of reducing sediment production from two major landslides and several road fill slopes. The Forest has currently inventoried 150,000 acres in search of problem sediment sources, with a continuing annual objective of 60,000 acres.

Benefits accrued from these projects have resulted not only in reduction of sediment delivered to the channel, but also include benefits to wildlife, timber, and soil productivity.

SUMMARY. The goal of Six Rivers National Forest is to increase anadromous fish habitat by 25% over the next five years, as well as improve the quality of water produced within Forest watersheds. The pilot projects discussed above have demonstrated that procedures do exist for restoring and enhancing habitat. These procedures are currently being utilized to develop total watershed plans to restore and enhance anadromous fish habitat and populations.

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