IMPLICATIONS OF FISH HABITAT IMPROVEMENT STRUCTURES FOR OTHER STREAM VERTEBRATES[1]

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Abstract. Lack of rearing habitat for stream-dwelling juvenile steelhead (Oncorhynchus mykiss) during summer low-flow conditions is considered to be the primary factor limiting these populations in the Pacific Northwest. Fishery managers have commonly focused on changing low-complexity stream reaches into habitat more favorable to juvenile steelhead through installation of instream structures, such as deflectors. Instream structures that improve habitat for target fish species may alter habitat required by other vertebrates in stream ecosystems. Foothill yellow-legged frog (Rana boylii) eggs and tadpoles are reared in shallow stream margins, which often occur adjacent to low gradient riffles in alluvial stream reaches.

We present observations on the effects of placement of instream boulder deflectors on physical habitat, juvenile steelhead, foothill yellow-legged frogs, and western aquatic garter snakes (Thamnophis atratus) in one 30 m reach of Hurdygurdy Creek (Del Norte County, California). We also examined habitat associations of foothill yellow-legged frog egg masses throughout the lower 5 km of the creek. Steelhead utilization of instream structures was found to vary depending on season and streamflow. Foothill yellow-legged frogs utilized the 30 m reach for breeding during the three years prior to the deflector placement, but not during the three years following placement. The diet of the western aquatic garter snake appeared to differ after placement of structures. Though these shifts indicate that predators are somewhat flexible, the potential effects of changes in prey availability for the whole stream community are unknown. We recommend consideration of all members of the aquatic community in stream habitat management.

Introduction

The interactions among organisms in stream communities are complex and poorly understood (Power *et al.*, 1988). The relationships between stream organisms and stream habitat dynamics are also poorly understood (Pringle *et al.*,1988). The influence of watershed management activities on the stream environment (Hicks *et al.*,1991), on stream communities, and on individual species is difficult to ascertain. Nevertheless, a need to understand these complex relationships exists to guide future management decisions.

The U.S. Forest Service is mandated by the National Forest Management Act of 1976 to identify and use "management indices species" for monitoring environmental conditions. Anadromous salmonids are often chosen as "management indicator species" for streams where they occur because of the relatively low cost of monitoring these species compared to other stream species and because of their economic and social value. Our objective in this paper is to raise awareness of potential effects of single species management on stream community relationships.

Below we describe some basic aspects of stream habitat dynamics, fish habitat improvement activities, as well as a discussion of managing streams for the benefit of a single species. We have also included preliminary observations of the effects of fish habitat improvement work on physical habitat, steelhead (*Oncorhynchus mykiss*), foothill yellow-legged frogs (*Rana boylii*), and western aquatic garter snakes (*Thamnophis atratus*, formerly *couchii;* Collins, 1990) from one site at Hurdygurdy Creek, California.

Stream Dynamics and Aquatic Habitat

Habitat available to stream biota varies greatly on both temporal and spatial scales and is linked directly to stream channel processes (Vannote *et al.*,1980; Power *et al.*, 1988; Pringle *et al.*,1988). The form of a stream channel is a reflection of the geology, flood history, and land-use history in a watershed (Sullivan *et al.*,1987). Over time, channel form at a particular location will change as sediment is routed through the channel by the forces of water during high streamflow events (Sullivan *et al.*, 1987). Channel obstructions such as large woody material, boulders, bedrock, and vegetation cause a diversity of hydraulic gradients which can increase the complexity of velocities and depths available to stream biota (Lisle, 1981b).

Large floods during the winters of 1964-65,1972-73, and 1974-75 have had a strong influence on the morphology of stream channels in northern California. Extensive streamside landslides and gullying resulted in large sediment yields to stream channels (Lisle, 1981a). In some cases, large woody material introduced into stream channels during the flood were modified or removed in the years following the flood because the wood was believed to be potentially destructive if transported by another large flow (M. McCain, personal communication, USDA Forest Service, Smith River National Recreation Area, Gasquet, CA). Lack of large woody-material has most likely

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altered the complexity of aquatic habitat in these streams (Lisle 1981b; Sedell *et al.*,1984).

Many reaches lacking complexity are found in northern California streams in the lower portions of large tributaries which are of particular importance to anadromous salmonids, foothill yellow-legged frogs, and many other wildlife species (Nussbaum *et al.*,1983; Bjornn and Reiser1991). Anadromous salmonids require stream habitat for spawning and rearing of juveniles. Frogs require the instream environment for spawning, rearing of tadpoles, and cover and feeding for adults.

Fish Habitat Improvement

Anadromous salmonids have been the primary target for stream habitat improvement in northern California and special attention has been focused on steelhead because of their unique natural history and historical abundance. Steelhead spend one to four years as juveniles in the stream environment before migrating to sea (Meehan and Bjornn,1991). Their stream residency is the longest of the anadromous salmonids and thus steelhead were selected as the "management indicator species" for anadromous salmonid streams by Six Rivers National Forest (Six Rivers National Forest, 1987). Lack of suitable rearing habitat for juvenile steelhead has been of great concern to fishery managers. Steelhead spawn in mounded gravel nests known as redds during winter or fall. Newly hatched steelhead emerge from the sub-gravel environment during the spring and summer and reside in slow water areas to hold and feed. Juvenile steelhead exhibit an ontogenetic .shift in habitat utilization. As juvenile steelhead increase in size they move to deeper, faster water (Everest and Chapman, 1972). In northern California, annual summer low streamflow conditions in many streams offer limited quantities of suitable depths and velocities for larger juvenile steelhead and this has been considered an important factor limiting the population of steelhead in northern California (Overton *et al.*, 1981).

Populations of salmon and steelhead in northern California have experienced 80 to 90% declines over the past 30 to 40 years. Degradation of stream habitat, resulting from logging, road building, mining. and urbanization, has been cited as a prime cause for decline in steelhead populations because of their extended reliance on the stream environment for rearing. There is also no commercial fishery for steelhead, as there is for salmon, so over-fishing is probably not a factor in their decline (California Advisory Committee of Salmon and Steelhead Trout, 1998). Knowledge of the ocean phase of steelhead life history is limited (Pearcy *et al.*,1990).

Rising public concern over declining anadromous salmonid populations led to expenditure of public funds for stream habitat restoration (Reeves *et al.*,1991). Over the past 15 years, tens of millions of tax dollars have been spent in California to improve stream habitat for; anadromous salmonids. The most common habitat improvement method has been installation of instream structures (weirs, deflectors, boulder clusters, cover logs) in stream reaches considered lacking suitable habitat (Reeves *et al.*,1991; Frissel and Nawa,1992). Instream structures cause localized changes to channel morphology relatively quickly, making the results of the structures easy to see. Typically, some changes in channel morphology can be seen one year after the installation of instream structures given that a large streamflow event occurred over that time. The life span of instream structures averages approximately ten years (Six Rivers National Forest, 1987) which makes them short-lived relative to stream processes.

Many stream reaches in northern California that lacked suitable salmonid habits as a result of large floods and subsequent stream clearing were treated with deflectors constructed from logs or boulders. Deflectors act as channel obstructions to decrease the cross-sectional area of the channel. Deflectors have proven to be an effective technique in changing broad, shallow, low velocity reaches into narrower, deeper, and swifter reaches (Moreau,1984) which are favored by large juvenile steelhead (Bjornn and Reiser, 1991).

Deflects and other stream structures have rarely been scientifically evaluated and are almost never monitored after placement (Beschta *et al.*,1991; Reeves *et al.*,1991; Frissell and Nawa,1992). The few reported studies have focused on targeted fish species (Overton *et al.*,1981; Ward and Slaney,1981; Moreau,1984; West, 1984; House and Boehne,1985; Brock, 1986; Franklin, 1989, Fuller,1990), invertebrates (Burgess and Bider, 1980; Franklin, 1989), and rarely other wildlife species (Burgess and Bider, 1980).

Studies by Overton *et al.*, 1981; Ward and Slaney, 1981; West, 1984; Moreau, 1984; House and Boehne, 1985; Brock, 1986; and Fuller, 1990, have shown substantial increases in salmonid abundance in stream reaches modified by instream structures compared to either pre-project data or control reaches. An increase in the overall fish production of an entire stream due to the addition of structures has yet to be demonstrated. Studies by Anderson (1984) and Fuller (1990) have documented alteration in habitat available to fish species other than the target species as a result of structure placement. No large-scale study of consequences of fish habitat improvement on other stream vertebrates has been conducted and little quantitative data are available.

Observations From Hurdygurdy Creek, California

The following is preliminary data from a 30 m reach of Hurdygurdy Creek, California. Our objective was to quantify the changes in aquatic microhabitat available to both steelhead and foothill yellow-legged frogs resulting from placement of stream structures. We also examined potential secondary effects on the western aquatic garter snake, a mid-level predator in this system. Frog breeding habitat was also quantified because of the limited information available on this species. Then observations provide an example of how evaluation might be approached, though larger sample sizes and more replication would be required for statistical treatment.

Background

Hurdygurdy Creek and adjacent riparian habitats support a wide variety of fish and wildlife species and a complex food web (Figure 1). Our study focuses on steelhead and foothill yellow-legged frogs; two relatively abundant species in this aquatic system. Steelhead life history and habitat requirements were described earlier in relation to fish habitat improvement. The foothill yellow-legged frog is a medium-sized frog found primarily along permanent streams and rivers, west of the Cascade/Sierra Nevada range from central Oregon to Los Angeles County, California; sea level to 1970 m (Zweifel, 1955; Stebbins, 1985). Foothill yellow-legged frogs are generally found in association with stream riffles, having rocky substrate and partly shaded banks (Moyle, 1973; Nussbaum *et al*.,1983; Hayes and Jennings, 1988). Breeding occurs in late spring in shallow margin pools and tadpoles metamorphose in late summer (Wright and Wright, 1949; Zweifel,1955; Nussbaum *et al*., 1983). However, detailed habitat information on breeding sites is currently lacking. This species is currently listed as a state species of special concern in California (Jennings, 1987) and is a candidate for Federal listing as threatened (Federal Register, 1991) as a result of population declines and habitat loss in the southern portion of its range (Hayes and Jennings, 1986).

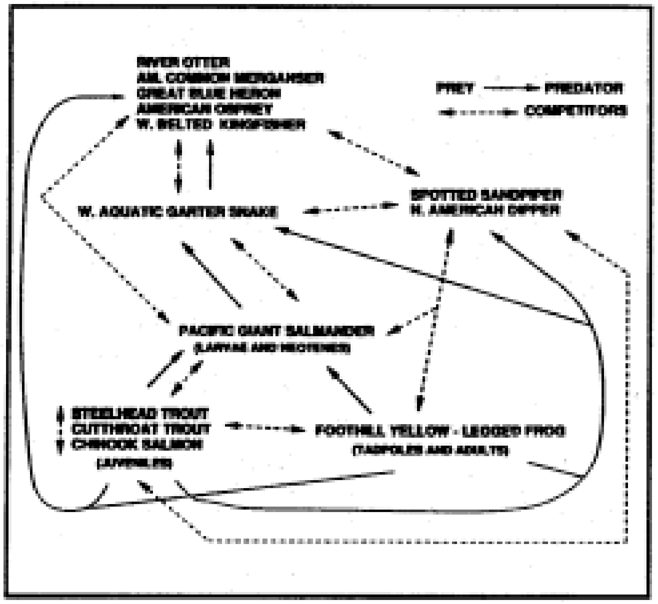


Figure 1. *Food web relationships of fish and stream-dependent wildlife species at Hurdygurdy Creek (Del Norte County. California). All species depicted were observed during 1986 through 1991 field work. Relationships shown are potential and based on field observations and a literature review. Competition may be either for food or space.*

An ongoing study of western aquatic garter snake demography, habitat use, and food habitats has demonstrated some of the complex relationships among garter snakes, steelhead, foothill yellow-legged frogs, and Pacific giant salamanders (*Dicamptodon tenebrosus*, formerly *ensatus*) (Figure 1) (Lind and Welsh, 1990; Welsh and Lind, unpublished data). Yellow-legged frog tadpoles and young-of-the-year salmonids are the primary prey of juvenile garter snakes, while larger adult snakes feed more frequently on Pacific giant salamanders (Lind, 1990). Both seasonal and ontogenetic shifts in snake food habits have been documented (Lind, 1990; Welsh and Lind, unpublished data).

Study Area

Hurdygurdy Creek is a fifth order tributary to the South Fork of the Smith River in Del Norte County and drains an area of 78 km^2 of steep terrain. It is currently under the management of the Smith River National Recreation Area of Six Rivers National Forest. Land use in the Hurdygurdy Basin has been mainly logging with associated road-building, and mining. Rainfall occurs predominantly from October through April and averages 280 cm per year (range 152-330 cm) (M. Furniss, personal communication, USDA Forest Service, Six Rivers National Forest, Eureka, CA). Measured stream discharge ranged from 0.5 cubic meters per second (cms) to peaks of 140 cms. Water temperatures range from 4 °C in winter to 21 °C in summer (USDA Forest Service, 1979).

Instream fish habitat improvement structures have been installed at various sites along the lower 7 km of Hurdygurdy Creek. Mean gradient is 1.7% and stream width ranges from 10 to 15 m. Substrate is predominantly cobbles and boulders. The stream is lined by a riparian belt ranging from 5 to 25 m wide consisting of white alders (*Alnus rhombifolia*), willows (*Salix* sp.), and big leaf maple (*Acer macrophyllum*).

We chose a 30 m reach representative of the lower 7 km of Hurdygurdy Creek to observe and document changes in stream habitat. Four boulder wing deflectors were installed in our 30 m study reach in September 1988. This reach had been part of a study of age 1 and age 2 steelhead habitat utilization in 1987 (Fuller, 1990). The reach was mapped in January. March, May, August, and October of 1987 (prior to deflects installation) and again in October 1991 (three years after structure installation).

We counted age 1 and older steelhead in this reach during January, March, May, August, and October of 1987 and during August 1990. We counted fish in a 14 m control reach during August of 1987 and August of 1990 on the same day we counted the treated reach. Fish were counted during the early afternoon by direct underwater observation using two snorkel divers working together to count fish simultaneously. We also observed young-of-the-year steelhead, and juvenile chinook salmon during our dives but we did not include that data in this report.

We documented habitat characteristics of foothill yellow-legged frog breeding sites in the spring of 1991. A total of 97 egg masses were found at 21 sites along approximately 5 km of the lower portion of the stream. We measured several biotic and abiotic variables associated with approximately 20% of egg masses found (17 egg masses at five sites). Data were recorded on egg masses by subjectively choosing masses spaced evenly throughout the site in order to represent. the range of habitat characteristics at a given site. The following habitat information was recorded: distance to shore; water temperature, depth, and flow; stream habitat type (Bisson *et al.*,1981; McCain *et a1.*,1990) and visual estimates were made for substrates in a 1-m radius circle around the egg mass. Substrates were placed in diameter size classes (mm) after Lane (1947): silt <0.063; sand 0.063-1.0; gravel 1-32; pebble 32-64; cobble 64-256; boulder >256. Only substrates that contributed an average of 1% or greater cover were included (*i.e.*, woody debris and live vegetation were omitted).

Breeding status of frogs along the 30 m study reach were documented in field notes recorded during a study of western aquatic garter snakes from 1986 to 1991 (Welsh and Lind. unpublished data). These accounts became more detailed as that study progressed, providing the most complete surveys from 1988 on. Snake abundances and food habits were documented during monthly censuses from May through September on approximately 5 km of stream that included the 30 m study reach (Welsh and Lind, unpublished data).

Preliminary Results

The data reported here, because of lack of spatial replication, apply only to the study reach. We are presently working on gathering more data in more study sites to test a statistically valid hypothesis.

In October 1987 our study reach was approximately 10 m wide, with a mean depth of 0.2 m, and no defined thalweg. Approximately 35% of this reach was classified as slow (water velocities < 0.4 m/s) and shallow (depth < 0.5 m). In October 1991 this reach had a width of approximately 7 m, a mean depth of 0.4 m, and a definite, meandering thalweg (Figure 2). Approximately 15-20% of this reach was classified as slow and shallow.

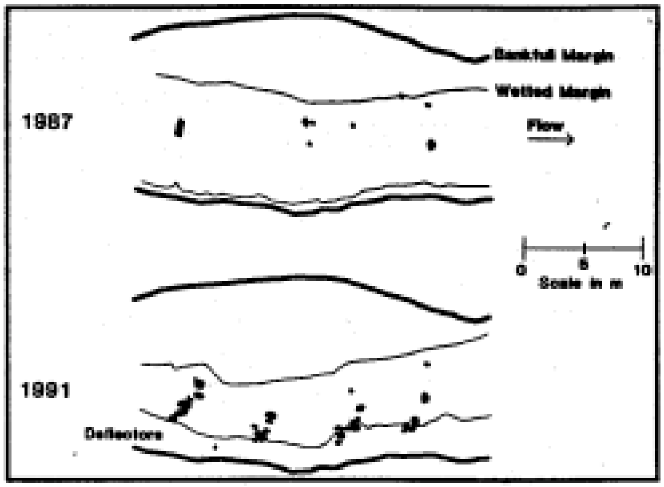
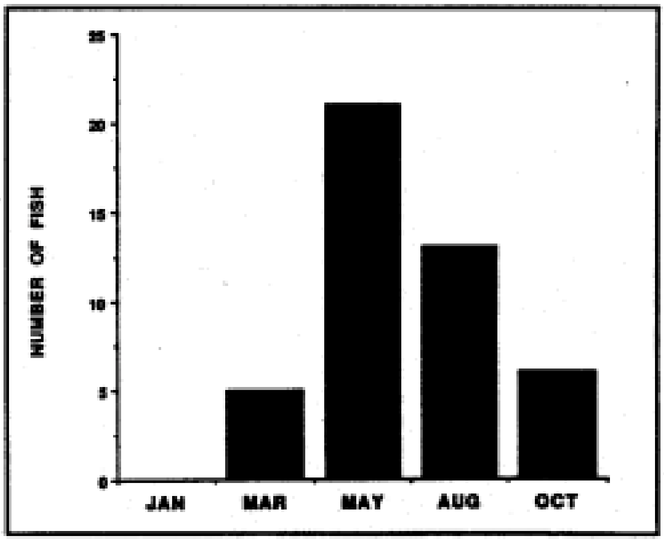


Figure 2. *Planar map of the 30 m study reach of Hurdygurdy Creek, Del Norte County, California, before structure placement (October 1987) and after structure placement (October 1991).*

The abundance of age 1 and older steelhead counted in our study reach varied with each dive throughout 1987 (Figure 3). Thirteen fish were counted in the study reach in August 1987 (prior to deflects placement) and 14 fish were counted in the study reach in August 1990 (after deflector placement). Eight fish were counted in the control reach in August 1987 and 10 fish were counted in the control reach in August 1990 (Figure 4).



Figurs 3. *Number of age one and older steelhead observed in the 30 m study reach at Hurdygurdy Creek, Del Norte County, California. from January to October 1997 (before structure placement).*

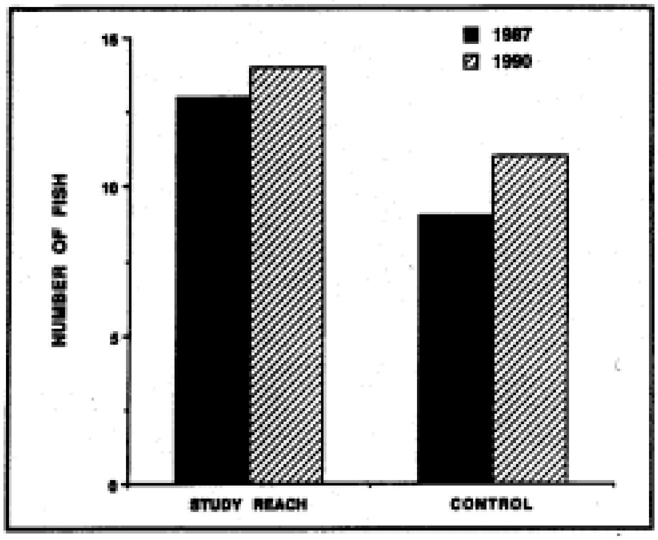


Figure 4. *Number of age l and older steelhead observed in the 30 m study reach and a 14 m control reach at Hurdygurdy Creek, Del Norte County, California. Data were recorded before structure placement (August 1987) and after structure placement (August 1990).*

We found frog egg masses in very specific habitats throughout the lower 5 km of Hurdygurdy Creek; in shallow water, with slow flows, relatively near to shore (Table 1). Dominant rocky substrates surrounding the egg masses included gravel, pebble, cobble, and boulder; and masses were most commonly attached to pebbles or cobbles. Egg masses were found primarily in glide and edgewater habitats adjacent to glide, riffle, and run habitats figure 5).

Table 1. *Habitat variables measured in association with 17 foothill yellow-legged frog egg masses at Hurdygurdy Creek, Del Norte County, California; May and June 1991.*

variable	x	SE	range
distance to :shore (m)	1.50	0.27	0.1- 4.00
water temperature °C	12.40	.47	10.3 -14.80
water depth (cm)	13.90	.99	7.0 -22.00
water flow (m/Sec)	0.03	.005	0.0- 0.06

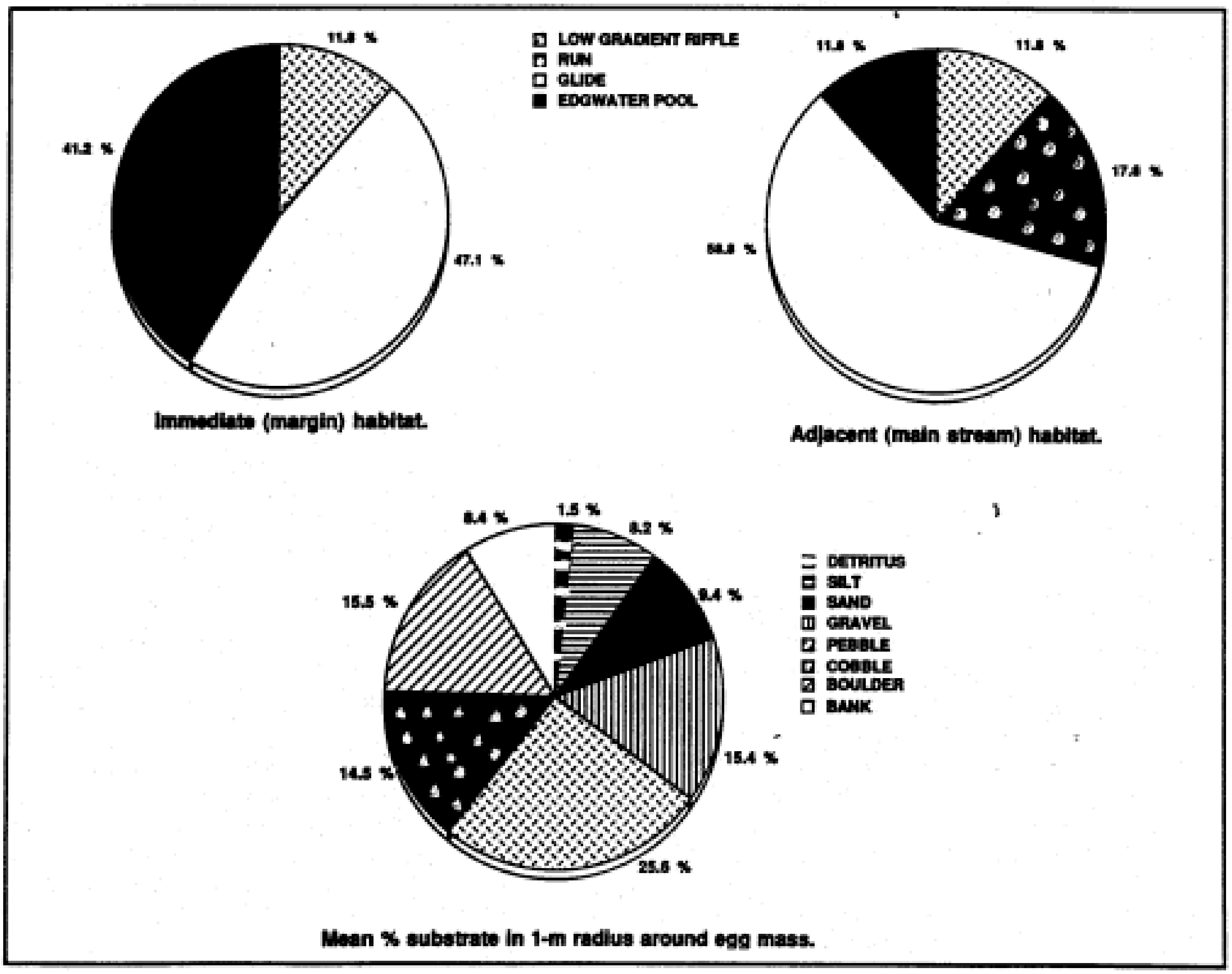


Figure 5. *Habitat characteristics of 17 foothill yellow-legged frog egg masses at Hurdygurdy Creek, Del Norte County, California in May and June 1991.*

Prior to the placement of the boulder structures (1986-1988) there was evidence that the study reach was used each year by breeding frogs. One egg mass was found in spring of 1988 and tadpoles were found in snake stomachs within the study reach in both 1986 and 1987 (Figure 6). Based on the limited movement patterns of most snakes observed (Welsh and Lind, unpublished data) we assumed that all prey items found in snake stomachs were captured in the study reach.

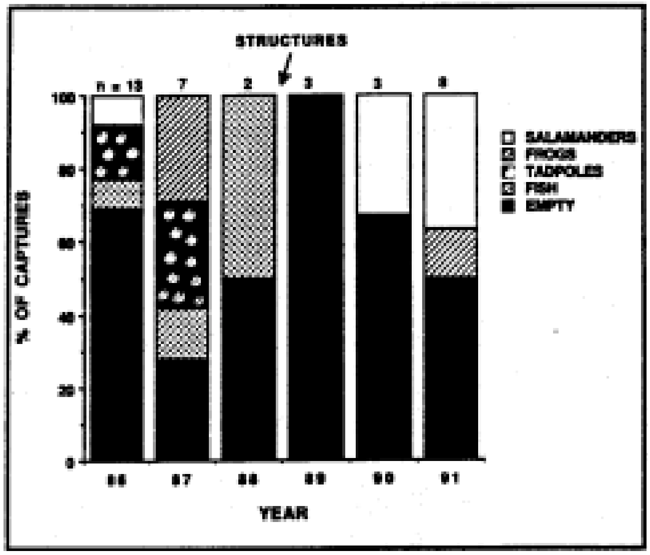


Figure 6. *Stomach contents of western aquatic garter snakes along the 30 m study reach at Hurdygurdy Creek, Del Norte County, California. from 1986 through 1991 (Welsh and Lind, unpublished data). Boulder deflector structures were placed following the last sampling period of 1988.*

In the three years following the placement of the structures, we found no evidence of foothill yellow-legged frogs breeding in the study reach. We have no evidence of effects on adult frogs, though we know that they used the study reach and were found in the diet of snakes in 1991 (Figure 6)

In addition to these immediate effects on frog breeding habitat, there appeared to be secondary effects on the western aquatic garter snakes along the study reach: Snakes inhabiting this area showed a change in diet, possibly reflecting a change in prey availability, though sample sizes were small (Figure 6). There was also a general decrease in numbers of snakes captured in the reach after the placement of the structures (Figure 7). These changes in prey availability and the resulting feeding shifts and/or movement of snakes from the study reach probably had minor repercussions for the stream community at this scale. If such movements and shifts occurred over a wider area, predator-prey relationships could be severely disrupted.

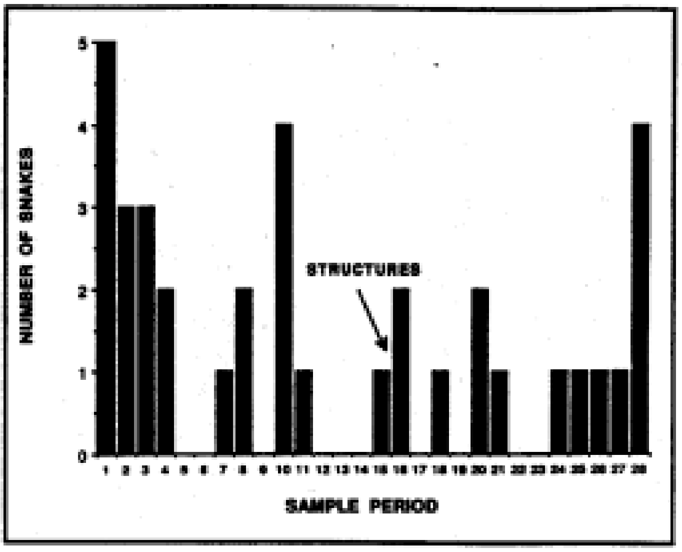


Figure 7. *Western aquatic garter snake captures along the 30 m study reach at Hurdygurdy Creek, Del Norte County, California. Sample periods 1-15 occurred prior to structure placement (1986-88) and sample periods-16 28 occurred following structure placement (1989 91).*

Conclusions

Though our results must be considered preliminary, they raise the issue of the value of single-species management The use of "management indicator species" as the target of stream habitat management activities does not allow for consideration of stream-dwelling or stream-dependent vertebrates whose habitat requirements differ from the target species. Indicator species are often chosen because they are abundant in a given habitat, they are easy to monitor, or they have some economic value (Landres *et al.*,1988). Species that exist in low numbers or are poorly known may be more sensitive to environmental perturbations. In general, the sedentary nature of most herpetofauna make them more vulnerable to small scale habitat changes than more widely ranging birds and medium-sized mammals (*e.g.*Welsh,1990). At Hurdygurdy Creek. the foothill yellow-legged frog, a species experiencing population declines due to habitat alteration in the southern portion of its range, may be negatively impacted by habitat alterations directed toward steelhead. One way to minimize these impacts would be to avoid placing instream structures in areas that are breeding "hot spots" for the frogs.

Due to the dynamic nature of stream form, the abundance of suitable habitat for any stream species can vary greatly over time. Although instream fish habitat improvement structures can radically alter the local morphology of a stream reach and thus alter the habitat available to stream-dependent species, these structures are relatively short-lived.

Given the complexity of stream ecosystem food webs (Figure 1; Power *et al.*, 1988), all species should be considered in watershed management. We and others (Reeves *et al*., 1991; Frissel and Nawa, 1992) recommend that the primary goal of land managers should be to prevent degradation of stream habitats during land management activities. Habitat damaged during these activities should be restored and instream structures can be an important tool for habitat restoration. The role of instream structures as a fishery management tool must be weighed against possible negative impacts on other stream-dependent species. Managing stream habitat and watersheds for overall stream health and community diversity rather than targeting the needs of certain life stages of a single fish species would ensure a diversity of stream habitat for a diversity of stream species.

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Report 29

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