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Failure of Submersed Macrophytes to Provide Cover for Rainbow Trout throughout Their First Winter in the Henrys Fork of the Snake River, Idaho

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Abstract.—Submersed aquatic plants that are abundant in some stream reaches have a potential to provide winter concealment cover for juvenile salmonids. We monitored an index of macrophyte abundance in a portion of the Henrys Fork of the Snake River during two winters that differed in severity and assessed the densities of age-0 rainbow trout *Oncorhynchus mykiss* associated with the macrophytes. The macrophyte index averaged 84–87% in November 1989 and 1992, and an average of 10–13 fish/100 m^2 were concealed there. In 1990, macrophyte cover declined to 59% in January and 46% in early February; fish density declined by about one-third by January and dropped to nearly zero in February. In 1992–1993, the macrophyte index declined to an average of 39% following anchor ice formation in December and to 32% in January. Fish density in December was reduced to about half of the November density and to about 1 fish/100 m^2 in January. Movement of marked fish in 1989–1990 was predominantly from macrophytes into cobble and boulder cover along the bank. During these 2 years, cover provided by submersed macrophytes in the study area was not adequate to hold age-0 rainbow trout throughout the winter. During winter of 1992–1993 no natural bank habitat was available because of low water flows, and we believe that none of the 1992 cohort of rainbow trout survived in the study area.

Concealment during the day in winter is a common behavioral pattern for juvenile salmonids in many stream environments. Salmonid habitat typically consists of interstitial spaces in cobble or boulder substrate (Hartman 1963; Chapman and Bjornn 1969) and in woody debris and undercut banks (Bustard and Narver 1975). Juvenile salmonids are most abundant in winter in areas containing such habitat (Bjornn 1971; McMahon and Hartman 1989; Griffith and Smith 1993) and more of them survive in such areas than they do elsewhere (Smith and Griffith 1994).

Dense beds of rooted aquatic plants (macrophytes) that are often abundant in low-gradient stream reaches have a potential to provide winter concealment for juvenile salmonids. Juveniles of several salmonid species were found in winter in rooted aquatic vegetation in a spring-fed tributary of the Credit River, Ontario (Cunjak and Power 1986, 1987), in portions of the Kenai River, Alaska (Bendock and Bingham 1988), and in a Norwegian river (Heggenes et al. 1993), but no systematic evaluation was made of use of that habitat throughout the winter. Rainbow trout *Oncorhynchus mykiss* concealed themselves in dense beds of *Chara vulgaris* at the beginning of their first winter in Silver Creek, Idaho, but rainbow trout density and *C. vulgaris* volume declined substantially through midwinter (Riehle and Griffith 1993). Schrader and Griswold (1992) noted that macrophytes in the South Fork of the Snake River, Idaho, sloughed off by midwinter and did not hold juvenile cutthroat trout *Oncorhynchus clarki* or brown trout *Salmo trutta* at that time. These observations were not quantified, and to our knowledge no previous studies have attempted to measure changes in winter macrophyte cover.

The presence of extensive growths of submersed macrophytes in depositional areas of the Henrys Fork of the Snake River, Idaho, where other forms of concealment cover were limited (Contor 1989) led us to examine whether macrophytes were used throughout the winter by age-0 rainbow trout. This study monitored an index of macrophyte abundance during two winters (1989–1990 and 1992–1993) that differed in temperature and flow (and therefore ice formation) and assessed the densities of age-0 rainbow trout associated with the macrophytes.

Study Site

The study area was the 1.8-km-long Last Chance section of the Henrys Fork of the Snake River in southeastern Idaho (44°22′N, 111°24′W). This fourth-order stream begins approximately 6 km below the Island Park Dam. Water releases from Island Park Dam (river elevation 1,896 m) are largely controlled by irrigation demands. The stream has a mean channel width of 90 m and a gradient of 0.3%. Water depth never exceeded 1 m during the study. Alluvial deposits up to 30 m thick underlie the channel (Whitehead 1978); large woody debris is uncommon, and large cobble and boulder habitat exist only along the stream banks. In summer, dense beds of aquatic macrophytes typically extend across most of the channel (Angradi and Contor 1989; Angradi 1991) and reach maximum biomass in October (Angradi 1991). Species composition was primarily water-milfoil *Myriophyllum quitense*, white water-buttercup *Ranunculus aquatilis*, fennel-leaved pondweed *Potamogeton pectinatus*, and Richardson's pondweed *Potamogeton richardsonii* (Angradi 1991). Macrophyte biomass exceeded 5 kg wet weight/m^2 in the site in October 1987 (Angradi 1991), and late fall biomass in 1989 and 1992 appeared to us to be roughly similar to that level.

During the first study period (November 1989 through February 1990), flow from Island Park Dam ranged from approximately 5.5 m^3/s in November to 10.4 m^3/s in January and February (USGS 1990). Flow in the study area was supplemented by a relatively constant inflow of 6.0 m^3/s from the Buffalo River (Vinson et al. 1992), which entered immediately below the dam, and by some minor inflow from springs. Water temperature in the study area was influenced by hypolimnetic (about 4°C) releases from Island Park Dam and averaged 2.5, 2.0, 2.3, and 1.4°C in November, December, January, and February, respectively, based on continuous data-logger records (Smith 1992). Surface ice formed along the banks during a few days in January and much of February 1990, but no anchor ice was observed. Conductivity was 136–140 μS/cm in November.

During the second study period (November 1992–February 1993), flow in early autumn was reduced to facilitate rotenone application to Island Park reservoir. From 26 September through 24 October, the only flow through the study area was about 6.0 m^3/s from the Buffalo River. A dam release of 3.4 m^3/s was initiated on 24 October and increased gradually to 3.8 m^3/s at the conclusion of the study period (USGS 1993). The cobble and boulder habitat along the stream banks was completely dewatered throughout that fall and winter. Water temperature, not continuously monitored between sampling dates, declined from 6°C in early November to below 1°C at midday during the last week of November and remained there until the second week of December. During that period, surface ice extended 1–2 m from the banks, and anchor ice frequently extended across as much as 70% of the channel throughout the study area. On 11 December, water temperature warmed to 2–3°C for the remainder of the study period, and the area remained free of ice.

Harriman State Park, located immediately downstream from the study area, is a major wintering location for trumpeter swans *Cygnus buccinator*, which feed on aquatic macrophytes during the winter. During early winter 1989–1990 about 750 swans were in the Harriman State Park vicinity, and one-third to one-half that number were present in winter 1992–1993 (R.E. Shea, U.S. Fish and Wildlife Service, personal communication). Geese and ducks were abundant throughout the area in 1989–1990, but were less abundant in 1992–1993; however, surface icing in 1992–1993 at Harriman State Park caused waterfowl to concentrate heavily in our study area. Avian predators, especially common mergansers *Mergus merganser*, were abundant during fall and early winter, and mink *Mustela vison* and river otters *Lutra canadensis* were observed.

Summer sampling has indicated that the density of age-0 rainbow trout is higher in the Last Chance study area than in adjacent reaches of the Henrys Fork downstream from Island Park Dam (Angradi and Contor 1989; J.S. Griffith, unpublished data). Other fish species in the study area were mountain whitefish *Prosopium williamsoni*, Utah sucker *Catostomus ardens*, redside shiner *Richardsonius balteatus*, Utah chub *Gila atraria*, and sculpin *Cottus* spp.

Methods

1989–1990

The primary study site was a 200-m length of typical habitat chosen at random. During each sample period, cables marked in 1-m intervals were stretched across the channel between permanent stakes at the top and bottom of the site. The west half of the enclosed area was not used. The east half of the enclosed area was divided by cords stretched between the two cables into eight 200-m-long sections containing macrophytes. Each section was 5-m wide and parallel to the thalweg. The macrophyte section nearest the bank began approximately 10 m from the bank to avoid the inclusion of boulder and cobble habitat. To sample cobble and boulder habitat at the site, two 100-m-long sections were established along the bank that were 2-m wide and encompassed all of that habitat present. No cobble and boulder habitat that concealed age-0 rainbow trout was present in midstream in the Last Chance study area (Contor 1989).

Cover and fish abundance were assessed in those sections on 9–11 November, 13–14 January, and 23–24 February. Electrofishing was conducted with a boat-mounted 5,000 W generator, which produced 600-V, pulsed DC at 84 Hz with a 33% duty cycle. Successive passes (a minimum of three) were made in each 5-m × 200-m section until no additional age-0 rainbow trout were captured, and the total number captured was used as the population estimate for that section. A few juvenile brook trout *Salvelinus fontinalis* and a few age-1 and older rainbow trout were captured, but they were disregarded. Age-0 rainbow trout were measured for total length to the nearest millimeter, marked with a fin clip unique to that section of river, and released at the location of their capture. Scales were taken from the larger fish for age verification. In January and February an additional 100 m upstream and downstream from each section were electrofished to search for marked fish.

Cover availability was indexed with a modified point interception frame (Floyd and Anderson 1987), consisting of two rectangular wooden frames with inside dimensions of 50 × 100 cm. The frames were superimposed 10 cm apart with wooden dowels. Monofilament line was strung through holes drilled at 10 cm intervals in each frame to produce a double-sighting grid of 36 points. The frame was mounted on adjustable tripod legs and was leveled with bubble levels to insure vertical projection of the points. Cover sources (woody debris, aquatic macrophytes, and interstitial space between boulders and cobbles) that we judged would conceal an age-0 rainbow trout were counted if they fell under a grid point. The point interception frame was placed in 10 randomly chosen locations in each section. The cover index for a section was expressed as a percentage by dividing the total number of cover sources associated with a grid point by 360, the total number of grid points. Change in macrophyte density between sample periods was assessed with paired t-tests on arcsine transformed data after normality was verified. Change in fish density between periods was assessed with paired t-tests. A significance level of 0.05 was used throughout.

1992–1993

The general procedures used in 1989–1990 were followed, except that the west half of the channel was included and a second method of sampling fish in macrophytes was employed to verify the electrofishing results. The same 200-m primary site used in 1989–1990 was used, but study sections (four, each 5 m wide) transected rather than paralleled the channel. Four additional 5-m-wide transects were established at random within 200 m upstream and downstream of the permanent stakes.

Macrophyte and fish abundance were assessed on 7–8 November, 12–13 December, and 17–18 January along each of the eight transects and along six 100-m sections (the primary 200-m site plus 200 m on either side) of streambank on the east side of the river. Fish abundance was estimated in the same manner as in 1989–1990 by electrofishing in half of the sections chosen at random, and cover was indexed with the point interception frame at 10 locations in each section.

In the other half of the sections, a frame-net sample, modified from that used by Bendock and Bingham (1988), was used to enclose 1-m^2 habitat segments. The frame net consisted of a 1-m^3 frame of 2-cm-diameter polyvinyl chloride tubing, with 3-mm-mesh nylon netting attached on four sides and an open top and bottom. The frame net was carefully but quickly placed at each of 10 randomly selected locations per section. The point interception frame was placed inside the frame and the index of cover was calculated as in 1989–1990. Age-0 rainbow trout within the frame net were then captured by a combination of electrofishing and dipnetting until all vegetation and fish were removed. On subsequent sampling dates, care was taken to avoid resampling locations previously used.

Fish were measured for length, but not marked, and their movements were not monitored. On 1 February 1993, all habitats throughout the study area were checked for the presence of age-0 rainbow trout by 4 h of electrofishing with a backpack unit.

Fish density data collected by electrofishing through the sections were compared with data derived from the frame nets with Friedman's two-way analysis. Fish densities based on electrofishing and macrophyte densities were compared between sample periods as described for 1989–1990.

Results

November Macrophyte and Fish Abundance

Fish size at the beginning of the study period was similar between years. Length of age-0 rainbow trout captured in all sections ranged from 80 to 157 mm (N = 372, mean = 120.5 mm, SD = 22.9) in 1989 and from 77 to 155 mm (N = 132, mean = 121.2 mm, SD = 24.2) in 1992.

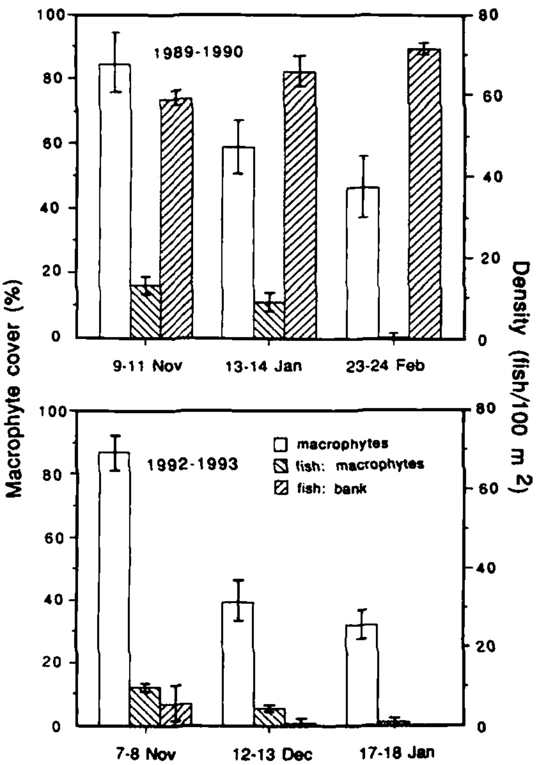

FIGURE 1.—Macrophyte cover index (%, based on point interception frames at 10 locations/section) and age-0 rainbow trout density (fish/100 m², based on three-pass electrofishing) in macrophytes and along the streambank in Last Chance study sections of the Henrys Fork of the Snake River during the winters of 1989–1990 and 1992–1993. Vertical bars denote standard errors.

The index of macrophyte cover averaged 84.3% in 1989 and 87.2% in 1992 (Figure 1). Cover within a section was less uniform across the channel (as measured in 1992) than in the sections used in 1989 that paralleled the thalweg.

An average of 13 fish/100 m² were concealed in the macrophytes in 1989 (Figure 1). In 1992–1993, fish density in macrophytes, as determined by frame-net sampling (mean = 9.7 fish/100 m², SD = 0.4), was not significantly different from density estimated by multipass electrofishing (mean = 9.8 fish/100 m², SD = 0.6).

Fish density in cobble and boulder habitat along the bank averaged 58.8 fish/100 m² in 1989 (Figure 1). In 1992, low flows dewatered the natural streambanks and an average of only 5.7 fish/100 m² were present within 2 m of the stream margin.

December–February Macrophyte and Fish Abundance

In 1989–1990, macrophyte cover declined significantly to an average of 59.0% in January and to 46.5% in early February (Figure 1). The density of fish using aquatic macrophytes for concealment declined significantly from November through February. That density declined by about one-third by January, and then dropped to nearly zero by February (Figure 1).

In 1992–1993, the macrophyte cover index declined more rapidly than in 1989, dropping significantly to an average of 39.3% in December and to 32.0% in January (Figure 1). Fish density in macrophytes in December as determined by frame-net sampling (mean = 4.7 fish/100 m², SD = 0.8) was not significantly different from that estimated by multipass electrofishing (mean = 4.6 fish/100 m², SD = 1.0), and represented a significant reduction (by about half) from that in November. Density declined further in January (Figure 1), with that determined by frame-net sampling (mean = 1.1 fish/100 m², SD = 0.4) not significantly different from that estimated by multipass electrofishing (mean = 1.0 fish/100 m², SD = 1.0). Electrofishing throughout macrophytes in the study area on 1 February 1993 captured one age-0 rainbow trout.

Density of fish in cobble and boulder habitat in 1989–1990 remained high through February, reaching over 70 fish/100 m² (Figure 1). In 1992–1993, density along the stream margin was less than 1 fish/100 m² in December (Figure 1). Electrofishing along the stream margin in and out of the study site on 1 February 1993 captured no age-0 rainbow trout.

Fish Movement

Of the 372 age-0 rainbow trout marked in November 1989, 63 (17%) were recaptured in either January or February 1990. Distance of movement averaged 62 m (range, 0–263 m). Fish marked in macrophyte sections (N = 38; average movement, 91 m; range, 40–263 m) moved significantly farther (t-test, $P < 0.05$) than did fish marked in bank habitat sections (N = 25; average movement, 30 m; range, 0–54 m). Ninety-two percent of the movement of fish marked in the macrophytes was into bank habitat areas, and 8% was into other macrophyte sections. All fish marked in bank sections in November were recovered in other bank sections; none were recovered in macrophytes.

Discussion

Electrofishing appeared to effectively sample age-0 rainbow trout concealed in macrophytes in the Henrys Fork of the Snake River. An average of 81% of the fish collected in each section in November 1992 were taken on the first electrofishing pass, and no more than two fish were ever collected on a third pass. The close correspondence between the 1992 frame-net density estimates and the multipass electrofishing population estimates further supports the validity of the electrofishing data.

Electrofishing probably underestimated the number of age-0 rainbow trout concealed in cobble and boulder habitat in the study area. Using the same equipment in similar habitat in the South Fork of the Snake River, Idaho, Griffith and Smith (1993) captured 83–87% of the age-0 cutthroat trout and brown trout present in enclosures with three electrofishing passes.

The persistence of macrophytes in winter would be expected to depend on factors such as water temperature, ice formation, and the extent of grazing, and species characteristics such as the natural rate of senescence. The seasonal decline in macrophytes in our study area generally was consistent between the two study periods. In 1989–1990, macrophyte loss was more gradual and resulted from sloughing and foraging by swans and other waterfowl. In December 1992, we observed macrophytes also being fragmented and uprooted by anchor ice. Angradi (1991) noted that macrophyte biomass in the study area in 1987–1988 declined to a wet weight of 2 kg/m^2 in January (about 40% of the October biomass) and reached an annual minimum in February. In both of our study years, and in 1988 (Angradi 1991), *Myriophyllum quitense* constituted nearly all of the biomass remaining in January and February. This species is the least palatable to swans in the study area (Snyder 1991). At the onset of winter, it provided cover that was denser than that provided by other macrophytes at the site, but by midwinter only widely spaced single strands remained.

During the two winters, the density of age-0 rainbow trout was correlated with the index of macrophyte cover ($r = 0.82$, $P < 0.01$). Rainbow trout entering their first winter in the study area are typically larger than their counterparts in many streams and larger than members of other salmonid species (Smith and Griffith 1994) and might require denser macrophyte cover to conceal them. Even for the smallest individuals, however, the carrying capacity of macrophytes in the study area declined to essentially zero in February of both 1990 and 1993. A contributing factor, which we did not monitor, might be oxygen depletion. Late-winter oxygen depletion apparently killed juvenile steelhead *Oncorhynchus mykiss*, coho salmon *O. kisutch*, and chinook salmon *O. tshawytscha* in side-channel pools of the Morice River, British Columbia, that were ice covered (Bustard 1986). Although no dead fish were evident, we observed the absence of rainbow trout and other fish species in portions of the study area where there was little flow through macrophytes in January 1993 after periods of surface icing.

Our results indicate differences in the importance of macrophytes for winter concealment habitat as compared with cobble and boulders. At the onset of winter 1989, macrophytes were present over more than 90% of the surface of the study area, and cobble and boulders along the bank constituted less than 5% of that area. Although the density of fish using boulders or cobble along the bank as concealment cover was about four times that of fish using macrophytes, the bulk of the population was present in the macrophytes.

As winter progressed in 1989–1990, the movement of fish from macrophytes into bank habitat was consistent with the night snorkeling observations of Contor (1989) that bank habitat was the primary environment used by rainbow trout during their first winter in the study area. We noted, as did Rimmer et al. (1983) and Cunjak and Randall (1993), that fish in areas containing suitable winter habitat tended to remain, whereas fish in habitat that became unsuitable were forced to move at a time when conditions were presumably not favorable for their survival. About 80% of the fish we marked in November 1989 were never recovered. We searched by night snorkeling and daytime electrofishing in January but found none in the 8 km of river immediately downstream from the study area, which is devoid of bank concealment habitat (Griffith, unpublished data). We did not search the area upstream from the study area.

Although macrophytes did not supply concealment for age-0 rainbow trout throughout the winter in our study, they greatly influenced the hydraulic characteristics of the channel by increasing channel roughness, which reduces water velocity and raises water level (Vinson et al. 1992). For example, water surface elevation at a staff gauge in our primary site dropped 11 cm from November 1989 to February 1990 as macrophytes declined, despite an increase in flow by nearly 50%. In an adjacent reach of the Henrys Fork, water surface elevations dropped 30–50 cm at a constant flow as macrophytes declined from fall through late winter (Vinson et al. 1992).

We believe that none of the 1992 cohort of rainbow trout survived their first winter in the study area because the natural bank habitat of cobble and boulders was dewatered by low flows released from Island Park Dam. That situation would have been ameliorated to some extent by the persistence of macrophytes that were dense enough throughout the winter to extend the wetted perimeter to the natural bank. Additional knowledge of macrophyte ecology and the winter habitat requirements of juvenile salmonids must be combined with a change in flow management to prevent the reoccurrence of such a series of events.

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