

Life-History Characteristics of the Endangered Salish Sucker (*Catostomus* sp.) and Their Implications for Management

MIKE P. PEARSON AND MICHAEL C. HEALEY

We studied growth, condition, spawning period, activity patterns, and movement in the Salish Suckers of Pepin Brook in British Columbia's Fraser Valley. Radio-telemetry showed that fish were crepuscular, had home ranges averaging 170 m of linear channel, made their longest movements during the spawning period (March to early July), and rarely crossed beaver dams. Relative to closely related catostomids, Salish Suckers are small, early maturing, and have a prolonged spawning period. These characteristics are likely to impart good resilience to short-term disturbances of limited spatial scale and to facilitate successful reintroductions to suitable habitat. The chronic, large-scale disruptions that affect their habitat in Canada, however, are likely to cause further extirpations over time. Given its limited geographic distribution, management of the Salish Sucker should focus on protecting all remaining habitat and exploiting opportunities for habitat restoration and reintroduction into suitable habitats throughout their historic range.

FRESHWATER fishes are among North America's most threatened faunas (Miller et al., 1989; Moyle and Williams, 1990; Warren and Burr, 1994). Current extinction rates are estimated to be fivefold higher than those of terrestrial vertebrates and over 1000 times background rates estimated from the fossil record (Ricciardi and Ramussen, 1999). The natural history of the vast majority of threatened and endangered fishes is very poorly documented but can give important insights into extinction risk. For example, diadromy, limited geographic range, reliance on a narrow range of water body sizes, and narrow ecological specialization have been identified as important risk factors (Angermeier, 1995).

The Salish Sucker (*Catostomus* sp.) has a distribution limited to a few watersheds in British Columbia's Fraser Valley and northwestern Washington State (McPhail, 1987). It is considered to be an evolutionarily significant unit (*sensu* Waples, 1995), that evolved from a population of the common and widespread Long-nose Sucker (*Catostomus catostomus*) that became geographically isolated in Washington State's Chehalis River Valley sometime during the Pleistocene glaciations (McPhail and Taylor, 1999). The Salish Sucker is listed as endangered by the American Fisheries Society (Williams et al., 1989) and by the Committee on the Status of Endangered Species in Canada (Campbell, 2001) but not under the U.S. Endangered Species Act.

Since the 1960s, the Salish Sucker has been extirpated from at least two creeks in Canada, and much of their remaining habitat has been degraded by urbanization, agricultural drain-

age, and sedimentation from gravel mining (McPhail, 1987; MPP, unpubl.). Conservation efforts have been hampered by lack of information on distribution, habitat requirements, and life history and by low levels of public and political awareness of its plight. In this paper we report aspects of life history that have not been previously investigated for this species, including growth, movement patterns, home-range size, and spawning periods. We also discuss the implications of our findings for risk of extinction and for conservation and management.

MATERIALS AND METHODS

Study area.—This work was conducted in Pepin Brook, a second order stream in the Fraser Valley of southwestern British Columbia that is tributary to Washington State's Nooksack River (Fig. 1). Mean August discharge (base-flow) is $0.171 \pm 0.035 \text{ m}^3 \cdot \text{s}^{-1}$ (mean \pm SD). Winter discharge is not measured, but mean January flow in a similar neighboring stream (Fishtrap Creek) exceeds $1.5 \text{ m}^3 \cdot \text{s}^{-1}$ (Water Survey of Canada, Vancouver, BC). Pepin Brook is largely groundwater fed in summer (D. Johanson, British Columbia Ministry of Water, Land and Air Protection, Canada, unpubl. data) and water temperatures rarely exceed 16 C or drop below 2 C (MPP, unpubl.).

Land use within the Canadian portion of the watershed is an approximately even mix of gravel extraction, livestock farming, and parkland. The U.S. portion of the stream is confined to roadside ditches.

We worked in a 1.5-km section of the stream that included a 5.8-ha marsh. The area was se-

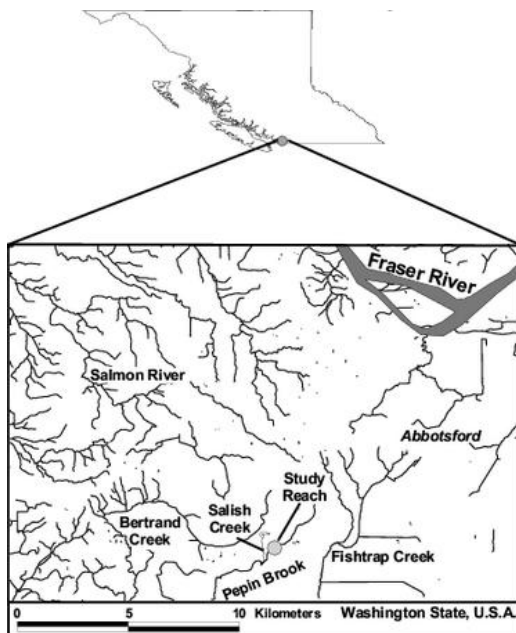


Fig. 1. Location of the study reach on Pepin Brook in British Columbia's Fraser Valley. Bertrand Creek, Pepin Brook and Fishtrap Creek flow south into Washington State's Nooksack River. The remaining drainages shown are tributaries of the Fraser River.

lected because it contains an exceptionally high concentration of Salish Suckers (MPP, unpubl. data). The marsh is a large, aging beaver pond. A single open channel meanders through an otherwise continuous cover of floating mats of reed canary grass (*Phalaris* sp.) and hummocks of cattails (*Typha latifolia*). It has an average depth of 1.2 m, width of 2 m, and current velocity of approximately $10 \text{ cm} \cdot \text{s}^{-1}$. A single open water pond (approximately $45 \times 30 \text{ m}$), thickly vegetated with submerged macrophytes, is located at its downstream end, immediately upstream of an old beaver dam. A 10–50 m wide riparian strip of mature, second-growth deciduous forest buffers the marsh from adjacent gravel pits and a blueberry farm. In addition to Salish Sucker, the marsh supports Coho Salmon (*Oncorhynchus kisutch*), Cutthroat Trout (*Oncorhynchus clarki*), Threespine Stickleback (*Gasterosteus aculeatus*), and Western Brook Lamprey (*Lampetra richardsoni*; MPP, unpubl.).

Upstream and downstream of the marsh, the creek flows through swamp. The water is also deep ($> 100 \text{ cm}$), slow moving, and periodically impounded by beaver dams; thick tree cover replaces the grass and cattails.

General methods.—Salish Suckers were captured using cylindrical double-ended funnel traps constructed from galvanized steel mesh ($60 \times 100 \text{ cm}$ with 12 mm mesh). They were baited with dry cat food in perforated canisters and set for approximately 24 h unless nocturnal hypoxia was a concern (August), in which case 6-h daytime sets were used. Catch-per-unit-effort (CPUE) was measured as the mean number of fish per trap on each sampling day. Seasonal patterns in CPUE were examined by analysis of variance with Bonferroni's multiple comparison test of log-transformed values.

Fish were anaesthetized in a solution of tri-caine methanesulfonate (MS 222, $70 \text{ mg} \cdot \text{l}^{-1}$), then weighed (nearest 0.1 g), measured (fork length, nearest millimeter) and, following recovery from sedation, released at their point of capture. Of the 4110 suckers captured during the study, 286 were individually marked with subcutaneous injections of fluorescent elastomer (Northwest Marine Technology, Inc., Shaw Island, Washington State). Water temperature was measured hourly in a shaded riffle approximately 100 m downstream of the old beaver dam using a logger (Optic-Stowaway, Onset Corporation, Pocasset, MA).

Growth and reproduction.—Growth rates were calculated from the change in fork length of marked fish between the first and final captures of the sampling season (14 May to 12 October 2000). Only fish recaptured more than seven days after marking were included. Growth rate of Salish Sucker sexes were compared using analysis of covariance with fork length at time of marking as the covariate because it was significantly and negatively correlated with growth rate for both sexes ($P < 0.001$).

Reproductive condition of all fish was ranked on a qualitative scale (no evidence of reproductive activity, gravid, ripe, very ripe) based on the quantity of eggs or milt extruded from the vent following gentle abdominal squeezing. Salish Suckers larger than approximately 100 mm were sexed using the anal fin, which is dimorphic (male large and fan shaped, female rectilinear with thickened leading ray). Size at maturity of Salish Suckers was estimated from the proportion of fish in 5-mm length increments that were gravid or ripe during the peak spawning season (5 March to 15 June). Seasonal changes in fish condition were examined using relative condition factor [$K_n = (W/W')$], where W is the weight of an individual and W' is a length-specific standard weight predicted by the weight-length regression equation (Anderson and Neumann, 1996). Mean monthly K_n -values

were compared using analysis of variance and Bonferroni's multiple comparison test ($\alpha = 0.05$).

Home range and movement.—Radio transmitters (Holohil BD-2G, Carp, ON, Canada), operating in the 148–150 MHz range, were surgically implanted into the body cavities of 12 female and six male Salish Suckers. Transmitters weighed 1.95 g ($16 \times 10 \times 6$ mm) and 1.45 g ($15 \times 7 \times 4$ mm); their size limited radio tagging to the largest available individuals (tags = 1.1–3.1% of body weight). Fish were deeply anaesthetized with clove oil dissolved in creek water (Anderson et al., 1997), and sterilized transmitters were inserted through a 1–2-cm midventral incision, which was then closed with 2–4-monofilament silk or PDS sutures (3–0, Ethicon, Inc.) and sealed with tissue adhesive (3M Vetbond 1469). Gills were irrigated with a constant flow of anaesthetic during the 3–5-min procedure and with fresh creek water following surgery until spontaneous gill ventilation resumed. They were then transferred to perforated live boxes in the stream and held for 24 h. Data from the first four days after release were not used in analysis.

The marsh was mapped from bearings and distances to prominent landmarks obtained with a surveying transit and range finder. These relative locations were translated into a Cartesian coordinate system and plotted on a computerized GIS to facilitate base map production.

Fish were located using a portable receiver (Lotek SRX 400) fitted with a two-element Yagi antennae. The relatively shallow water of the marsh allowed us to locate fish precisely by maneuvering a canoe into a position where signal strength was strongest directly below the boat. Fish did not react noticeably to the presence of the boat. The ease of recovering transmitters from dead fish indicated that locational accuracy for fish at rest was within 1 m. Fish locations were either plotted directly on the map or measured using a compass and range finder to obtain distances and bearings from landmarks. Mapping precision was estimated by recording bearings and distances to two different landmarks for a subset of fish locations. The average difference in the two position estimates was 3.76 ± 0.23 m (mean \pm SEM, $n = 136$, max = 14.6).

We collected locational data at two time scales, daily and hourly. The daily time scale involved locating each fish once every 1–3 days during daylight hours, whereas the hourly time scale consisted of locating each fish once every 3–4 h over a 24-h period. Hourly data were col-

lected on 18 occasions between April and November of 2000.

Home-range sizes for each fish were estimated by calculating the minimum length of channel and the minimum area of channel containing 95% and 100% of location points on the GIS map. Three of the 18 fish were excluded from this analysis. One was located only once, and two were found dead less than 10 days after release. The remaining fish were located between 18 and 139 times over 25 to 153 days. We tested for correlation between number of position observations and estimated home-range size using the Spearman rank-order correlation coefficient (r_s) with a one-tailed test of significance (Zar, 1999).

Diel activity patterns were examined by calculating the minimum movement rate between successive locations. Each interval's movement rate was placed into the three-hour clock period (beginning at 0500 Pacific Standard Time) in which the majority of the interval occurred. Because the data failed to meet assumptions of normality and homogenous variance necessary for parametric analysis, we used the Kruskal-Wallis method to test for differences among periods and a nonparametric multiple comparison method for unequal sample sizes to identify significant differences (Zar, 1999).

Minimum daily distances traveled were estimated by summing interval distances over each 24-h session. Fish were used in the analysis only if they were located 5–8 times in the session. Over this range, number of locations had no effect on total distance ($r^2 = 0.02$, $P = 0.31$).

RESULTS

General.—Over three years we captured a total of 4110 Salish Suckers (including recaptures). The largest fish was a 287 mm female weighing 196 g. The largest male was 206 mm and weighed 107 g. Females grew to larger size; only 0.03% of males but 10% of females in the sample exceeded 200 mm in length. Modal length of females (136 mm) and males (135 mm) were nearly identical. Regression of weight on length yielded an equation of $W = 1.072 \times 10^{-5} \times L^{3.01}$ ($r^2 = 0.96$) for males and $W = 8.317 \times 10^{-6} \times L^{3.06}$ ($r^2 = 0.98$) for females. Males matured at a smaller size (50% at 125 mm, 90% at 140 mm) than females (50% at 135 mm and 90% at 155 mm). Juvenile fish, particularly young-of-the-year, were poorly represented in our samples, presumably because of sampling bias. Only 10.4% of all Salish Suckers captured were less than 120 mm in length, the approximate length of an age 2 male (McPhail, 1987).

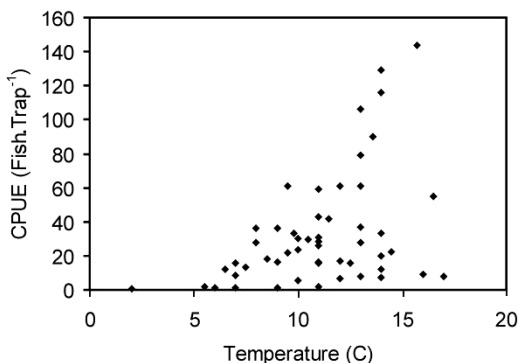


Fig. 2. Effect of water temperature on catch per unit effort (CPUE) in a Pepin Brook marsh. Each point represents the mean of three to six traps set for 24 h.

Catch per unit effort (CPUE) was strongly influenced by temperature; almost no Salish Suckers were caught when water was less than 7°C and highest catches occurred between 12 and 15°C (Fig. 2). With the exception of August, mean monthly CPUE was significantly higher between May and September than during early spring and late fall (Fig. 3).

Growth and reproduction.—Growth rates were negatively correlated with body length in both sexes ($P < 0.001$, male $r^2 = -0.64$, female $r^2 = -0.61$). Analysis of covariance revealed that when length effects were removed, male fish grew significantly more slowly (0.071 ± 0.011 mm · day⁻¹; mean \pm SEM; $n = 35$) than females (0.112 ± 0.010 mm · day⁻¹; $n = 40$) between May and October.

The spawning period of Salish Suckers appears quite protracted. In Pepin Brook, 80% of mature females (> 150 mm fork length) are visibly gravid in March. Spawning begins in early April and continues until mid-June or early July. Mature males (> 135 mm) follow a similar pattern but appear to begin gametogenesis again in late summer or early fall, as over 60% of them were producing milt during fall sampling.

Males and females showed similar seasonal changes in relative condition factor (K_n) within years, but values for both sexes differed sharply between years (Fig. 4). In all years K_n was highest in early spring (March or April), declined significantly through the spawning season, and began to increase in late summer and early fall. In 1999, following some recovery in early fall, K_n plummeted in October and November. It remained significantly lower than 1999 levels in all months of 2000. In the spring of 2001, K_n appeared to recover somewhat as peak levels

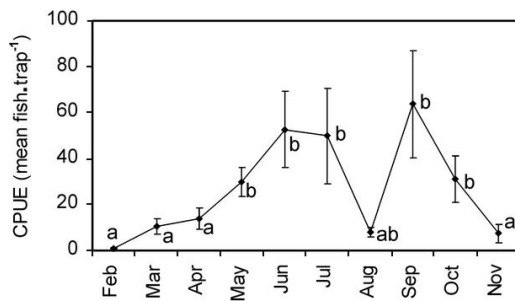


Fig. 3. Monthly mean catch per unit effort (CPUE) of Salish Suckers in Pepin Brook. Vertical bars denote SEM and months flagged with the same letter are not significantly different. Data from all years are pooled and August sets were six rather than 24 h.

(April) were significantly higher than those of 2000.

Home range and movement.—Of the 18 fish we tracked, two were still being followed when the study was terminated, batteries expired in four (two of these were recaptured and appeared healthy the following spring), and two were assumed predated. The transmitters from both of these fish were recovered with no sign of a carcass; one badly chewed and one in very shallow water (< 10 cm) far from its home range. Three other tagged fish were found dead of unknown

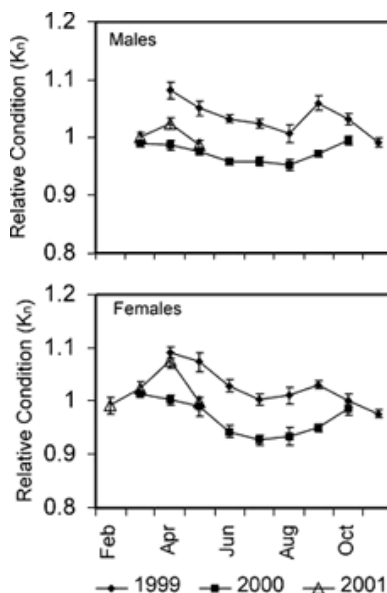


Fig. 4. Changes in relative condition factor (K_n) of Pepin Brook Salish Suckers between April 1999 and May 2001. Vertical bars denote standard errors of means.

causes. The fates of the remaining seven are unknown.

Home-range size (95%) of the 15 fish used in the analysis ranged from 42–307 m of linear channel and covered between 212 and 1704 m² of area (Table 1). One hundred percent ranges were much more variable because of a small number of very large movements. Home-range size was not correlated with sample size in our dataset ($r_s < 0.25$, $P > 0.1$). Of the 730 locations in the telemetry dataset, all but three were upstream of the old beaver dam, the area in which all fish were initially captured.

Minimum daily distances moved ranged from 1–376 m (mean 120, SEM 13.9, median 90). All fish that were followed on multiple occasions showed high variation in distance moved between days, most spanning more than an order of magnitude.

Movement rates of radiotracked Salish Suckers were highest at dawn and dusk, greater than between 0800 and 1700 Pacific Standard Time (Fig. 5). Median movement rates were lower at night than during dawn and dusk, but the difference was not statistically significant. During the night, fish were obviously moving and visible (by flashlight) much more frequently than during the day.

Daytime resting positions were usually in heavy cover, often among thick emergent vegetation adjacent to the open channel. Adult Salish Suckers showed some fidelity to resting areas. Fish were found at rest within 10 m of their previous days resting location on 50% of occasions. On five of the 80 times individuals were tracked over 24 h, fish moved from daytime resting positions near the upstream end of the study area to spend the night in the pond more than 200 m downstream, and then returned to spend the next day within 2 m of their original location.

Eight of 265 Salish Suckers that were marked in the marsh in October 1999 and two of 103 marked in March 2000 were captured in a weir-trap on Salish Creek, a tributary to Pepin Brook located 1020 m downstream of the study reach. Of the 10 fish (fork lengths 135–222 mm), five were female and three were male. Gender of the other two was not recorded. Six of them, including all the males, were in reproductive condition. Seven of the 10 were subsequently recaptured in Salish Creek at least once during spring or summer 2000. All were found 450–600 m upstream of the weir trap in the largest, deepest pools available. None left Salish Creek by March 2001 when the weir trap was removed (Tyese Patton, University of British Columbia, Canada, unpubl. data).

DISCUSSION

Life-history strategy.—Salish Suckers are small, short lived (McPhail, 1987), and early maturing relative to most populations of *C. catostomus*. The latter are notoriously variable for these traits. Individuals in some populations exceed 500 mm in length and 19 yr of age, (Scott and Crossman, 1973), whereas individuals in “dwarf” populations mature at much smaller size. Among the 1284 records of occurrence for *C. catostomus* in the University of British Columbia Fish Museum, the smallest recorded mature individual is 106 mm (fork length; male, Hart Lake, Peace River drainage, British Columbia, Canada; J. D. McPhail, University of British Columbia, Canada, pers. comm.). This is slightly larger than our smallest recorded Salish Sucker, a 96 mm mature male.

In most populations, *C. catostomus* do not spawn before age 5 (Scott and Crossman, 1973), whereas Salish Suckers spawn at the end of their second year (McPhail, 1987). The Salish Sucker spawning period is also very protracted (6–8 weeks), relative to Longnose Sucker (2–3 weeks: Scott and Crossman, 1973; Barton, 1980; Schlosser, 1990).

These characteristics suggest that the Salish Sucker has evolved an opportunistic life-history strategy (sensu Winemiller and Rose, 1992). Protracted or multiple spawning periods increases fecundity in species otherwise limited by small female body size (Blueweiss et al., 1978; Burt et al., 1988). This, especially when combined with early maturation, promotes resilience to frequent disturbance by facilitating rapid population growth and fast recolonization of habitat over short spatial distances (Schlosser, 1990). Small body size and multiple spawnings are common in species inhabiting headwater areas, which commonly experience higher rates of disturbance than downstream reaches (Schlosser, 1995a). Unfortunately, these traits provide little resilience to large-scale or chronic disturbances (Winemiller and Rose, 1992), especially in species that have very limited geographic ranges (Moyle and Williams, 1990; Angermeier, 1995).

Sexual size dimorphism with larger females is common among fishes and reflects different equilibrium points for the sexes between opposing selective pressures favoring large and small body size (Shine, 1989; Blanckenhorn, 2000). The major forces favoring large size in most poikilotherms are increased fecundity in females and sexual selection in males (Shine, 1989). Selective pressures favoring smaller body size are more varied (for review, see Blanckenhorn,

TABLE 1. CHARACTERISTICS, TRACKING DETAILS, AND HOME-RANGE SIZES OF THE 15 SALISH SUCKERS USED IN THE RADIOTELEMETRY STUDY. Fish are sorted by increasing length and sex.

| Fish | Length (mm) | Weight (g) | Sex | Start date | Days tracked | Sightings | Linear home range (m) | | Home-range area (m ²) | |
|--------|-------------|------------|-----|------------|--------------|-----------|-----------------------|------|-----------------------------------|-------|
| | | | | | | | 95% | 100% | 95% | 100% |
| 19 | 191 | 74.4 | F | 9/23/00 | 56 | 30 | 42 | 216 | 212 | 830 |
| 120 | 195 | 72.0 | F | 9/23/00 | 62 | 33 | 148 | 167 | 1238 | 1302 |
| 40 | 197 | 80.3 | F | 9/23/00 | 62 | 30 | 101 | 155 | 930 | 1317 |
| 839 | 197 | 90.1 | F | 4/10/00 | 27 | 37 | 240 | 497 | 1316 | 7008 |
| 740 | 200 | 83.0 | F | 5/7/00 | 117 | 95 | 218 | 350 | 1419 | 1938 |
| 141 | 203 | 103.3 | F | 5/6/00 | 77 | 74 | 307 | 328 | 1653 | 1692 |
| 962 | 205 | 88.5 | F | 8/5/00 | 50 | 29 | 164 | 180 | 1202 | 1210 |
| 860 | 209 | 115.2 | F | 4/10/00 | 153 | 139 | 113 | 151 | 1222 | 1587 |
| 800 | 214 | 107.5 | F | 8/5/00 | 33 | 28 | 307 | 334 | 1736 | 1801 |
| 840 | 231 | 148.7 | F | 9/23/00 | 30 | 18 | 251 | 260 | 1640 | 1598 |
| 819 | 243 | 155.3 | F | 7/26/00 | 31 | 21 | 289 | 351 | 1634 | 1777 |
| 940 | 166 | | M | 4/11/00 | 58 | 65 | 90 | 160 | 1138 | 1423 |
| 119 | 167 | 55.0 | M | 5/6/00 | 39 | 46 | 221 | 250 | 1703 | 1991 |
| 18 | 175 | 61.2 | M | 5/7/00 | 29 | 34 | 72 | 81 | 1064 | 1142 |
| 822 | 203 | 83.5 | M | 8/4/00 | 34 | 29 | 92 | 93 | 995 | 1006 |
| Mean | | | | | | | 177 | 238 | 1273 | 1841 |
| (SEM) | | | | | | | (24) | (32) | (107) | (407) |
| Median | | | | | | | 164 | 216 | 1238 | 1587 |

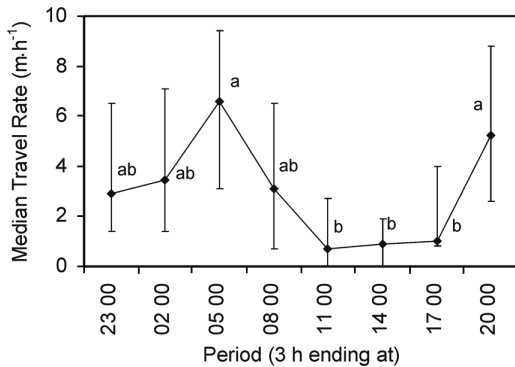


Fig. 5. Movement behavior of Salish Suckers at different times of day. Values are medians of distance traveled between successive captures with 95% confidence intervals. Those marked with the same letter are not significantly different.

horn, 2000). Among those likely to be important in Salish Sucker life history are reduced mortality risk caused by shorter maturation time and advantages associated with greater agility, including improved predator avoidance and possibly sexual selection. Some, but not all, populations of Longnose Sucker also show sex-related size differences (Scott and Crossman, 1973). The resumption of milt production in male Salish Suckers in the fall is unusual but known to occur in some temperate fishes adapted to early spring spawning (J. D. McPhail, University of British Columbia, pers. comm.).

Condition.—The seasonal pattern of condition factor was undoubtedly associated with energy loss during spawning and subsequent recovery. The cause of the sharp decline in condition in the fall of 1999 that continued throughout 2000 was presumably related to poor feeding conditions of unknown cause. Some recovery was apparent in the spring of 2001.

Home range and movement.—The home-range sizes we found for Salish Suckers were an order of magnitude larger than those of other lotic species reviewed by Minns (1995). All but one of these, however, was studied using mark-recapture rather than telemetry, the former being strongly biased toward finding small home-range sizes (Gowan et al., 1994). Home ranges of Salish Suckers were comparable in scale (tens to a few hundreds of meters of channel) to those of the few other small stream fishes studied by telemetry (Matthews, 1996; Young, 1996; Roberge, 2000). Fish in larger rivers seem to travel much farther (Tyus and Karp, 1990; Matheney and Rabeni, 1995; Swanberg, 1997),

although this may be confounded with body size.

The reluctance of radio-tagged fish to cross the beaver dam suggests that Salish Sucker distribution and home-range size will be strongly influenced by shallow water features like dams and riffles. Salish Suckers tend to be associated with long continuous areas of deep pool habitat (MPP, unpubl.), and their distributions may be constrained by modest barriers like beaver dams. Schlosser (1995b) found that beaver dams had a major influence on the structure of a small stream fish community in Minnesota by limiting dispersal and colonization processes. Fish crossed dams only when discharge exceeded a threshold during critical life-history stages.

Salish Suckers were capable of crossing the dam. Radio-tagged fish did on three occasions, and the marked fish captured in the Salish Creek weir-trap had traveled more than 1 km downstream crossing the study reach dam and two others en route. These movements occurred during the spring of 2000, and most of the fish were in reproductive condition, suggesting that spawning was the motivation. Salish Creek is a diversion constructed in 1999 to enhance habitat. Fish density within it was still quite low in 2000, and Salish Suckers there grew significantly faster than those in the marsh (T. Patton, University of British Columbia, Canada, unpubl.), suggesting that it was attractive habitat, which may explain why none left after the spawning season.

Diel activity.—Movement rates of Salish Suckers were highest around dawn and dusk. High crepuscular activity rates have been recorded in many species and are usually related to travel between diurnal and nocturnal areas of activity and resting (Bohl, 1980; Helfman, 1981; Matheney and Rabeni, 1995) or to high food availability at these times (Ovidio et al., 2002).

Although some activity was recorded at all times of day, fish were most often actively moving when located at night. Some other catostomids are nocturnal. Longnose and White Suckers (*C. commersoni*) feed continuously by night in the shallow waters of lakes, resting in deeper areas by day (Carlander and Cleary, 1949; Campbell, 1971; Emery, 1973), but Northern Hog Suckers (*Hypentelium nigricans*) appear diurnal (Matheney and Rabeni, 1995). For most species, nocturnal activity is attributed to predator avoidance (Hall et al., 1979; Adam et al., 1988; Naud and Magnan, 1988), but diurnal predation risk for adult suckers appears very low. In the deep, heavily vegetated marsh habitat, avian predators present little threat, and no

coexisting predatory fish are large enough to consume them. Mink (*Mustela vison*), which are common in the study area and are known to prey on Salish Suckers (MPP, pers. obs.), are also nocturnal or crepuscular (Nowak and Paradiso, 1983).

The fidelity to resting areas observed in radio-tagged Salish Suckers occurs among many fishes and is thought to improve predator avoidance though familiarity with the local environment (Helfman, 1993). The combination of nocturnal activity and fidelity to daytime resting areas suggests that predation risk may be higher for this species than it appears.

Seasonal activity.—Salish Suckers were active at temperatures down to 7 C. Water temperatures in the marsh were above this threshold for at least part of 245 days during 2000. In other systems, Salish Suckers are often found in water exceeding 20 C (MPP, unpubl. data). Longnose Suckers are similarly eurythermal, often spawning in temperatures of 5 C (Scott and Crossman, 1973) but tolerating temperatures well above 20 C (Black, 1953). CPUE was highest from May to September, when water temperatures were above 10 C. CPUE was very low in August, likely because of the shorter (6 vs 24 h), daytime-only sets we used in that month to avoid asphyxiating fish overnight. Hypoxic conditions also may have reduced CPUE directly. The relationship between catch rate and temperature was complex with the highest, but also the most variable, catch rates occurring at high temperatures.

Management implications.—The Salish Sucker has been in decline in British Columbia since at least the 1970s (McPhail, 1987) and perhaps much longer. The habitats of their native streams have been dramatically altered by human settlement over the past 150 yr. In this period approximately 75% of forest land and 62% of wetland in the Fraser Valley has been lost, largely to urban and agricultural land uses (Healey et al., 1999). Agricultural and storm drainage combined with irrigation withdrawals have reduced summer low flows, whereas forest removal, dredging, and channelization have reduced habitat complexity (Boyle et al., 1997), and nutrient loading has reduced water quality (Vizcarra et al., 1997). The risk of Salish Sucker extirpation or extinction depends upon the extent and severity of future disturbances to their habitat and on their resilience to and ability to recover from those disturbances.

Local populations of Salish Sucker appear confined to relatively small reaches of stream

that include deep pools but also shallow riffles suitable for spawning. Some individuals do explore more widely, however, and are able to colonize unoccupied suitable habitat, as shown by the suckers that invaded Salish Creek. Their rapid growth, early maturation, and relatively high fecundity suggest that Salish Suckers are capable of recovering from disturbances to their habitat provided the local population is not wiped out. If local populations are extirpated, the area may be recolonized by fish from other local populations, provided the habitat remains suitable. These factors suggest that conservation of this species can be accomplished by maintaining a number of healthy local populations within a stream system. Such populations would likely be quite resilient to short-term local disturbances. Furthermore, the characteristics of the species suggest that reintroduction to stream systems from which they have been eliminated, such as Little Campbell River, is likely feasible provided habitat characteristics are suitable. The species is not likely to survive continued large-scale degradation of its habitat, such as through the extensive urbanization that is now occurring as metropolitan Vancouver expands eastward. Provided water flow and water quality can be maintained, however, the stream and riparian habitat that must be set aside to maintain healthy sucker populations is relatively small.

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- INSTITUTE FOR RESOURCES, ENVIRONMENT, AND SUSTAINABILITY, UNIVERSITY OF BRITISH COLUMBIA, 2206 EAST MALL, VANCOUVER, BRITISH COLUMBIA, V6T 1Z3 CANADA. E-mail: (MPP) mpearson@portal.ca; and (MCH) healey@interchange.ubc.ca. Send reprint requests to MPP. Submitted: 30 Oct. 2002. Accepted: 23 April 2003. Section editor: D. G. Buth.