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Are There Differences in Growth and Condition between Mobile and Resident Cutthroat Trout?

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Abstract.—There is evidence that actively moving salmonids are of lower condition than the general population, and they are sometimes regarded as inferior to resident fish. However, little information exists on the permanence of this attribute. We used mark–recapture and two-way traps to determine whether there are differences in the condition and growth of mobile and resident Bonneville cutthroat trout *Oncorhynchus clarki utah* in Beaver Creek, Idaho. Actively moving fish were significantly larger than the general population, and the largest of these mobile fish were in significantly lower condition for a given size. However, mobile fish that were marked and recaptured a year later had regained condition equivalent to that of the general population upon their recapture, and the largest mobile fish had significantly greater condition than fish of equal length in the general population. In contrast, there was no relationship between growth rate and the total distance moved during the 1-year period. These results suggest that the lower condition of actively moving fish does not have permanent effects on future condition or growth in stream-resident cutthroat trout.

Much attention has recently focused on the rediscovery of mobility in stream-dwelling trout (Gowan et al. 1994; Rodriguez 2002). Whereas much work has reported on the timing and magnitude of movement, the attributes of mobile and resident fish have received little attention. Recent work has suggested that mobile salmonids have lower condition than the general population (Naslund et al. 1993; Gowan and Fausch 1996). Because many stream-dwelling trout establish territories for feeding (Chapman 1966; Jenkins 1969; Grant et al. 1989), mobility in nonmigratory populations may be a response to an energetic deficit or difficulty in procuring profitable areas for feeding (Heggenes 1988; Nakano 1995) and should result in reduced growth and condition. Alternatively, mobile individuals could move for reasons not related to competitive ability but to exploit seasonally or spatially patchy food resources and thus experience greater growth and condition.

Our objective was to determine whether the degree of mobility in individuals is associated with differences in growth or condition relative to the general population and whether any differences are transient or long term. Given the findings mentioned above, we predicted that actively moving fish would have lower condition than resident fish and that this would result in lower overall growth of mobile fish recaptured a year later. To test these predictions, we compared the condition of the general population of Bonneville cutthroat trout *Oncorhynchus clarki utah* with that of mobile fish and analyzed the growth rates and condition of mobile and resident fish recaptured 1 year after marking.

Methods

We studied the cutthroat trout population of Beaver Creek, a first-order stream in the Logan River Drainage in southeastern Idaho and northeastern Utah. A detailed description of the study stream can be found in Hilderbrand and Kershner (2000). The study location occupied the uppermost 6 km of fish-holding waters (Figure 1).

In 1995, we used two-way traps to capture mobile individuals. We constructed three traps based on the design of Riley et al. (1992; mesh diameter, 13 mm) and installed the traps at roughly 2.5-km intervals in the stream (Figure 1). Captured fish were implanted with 11-mm passive integrated transponder (PIT) tags, weighed, measured, and released at or near their point of capture and in the direction of travel. Fish from the general pop-

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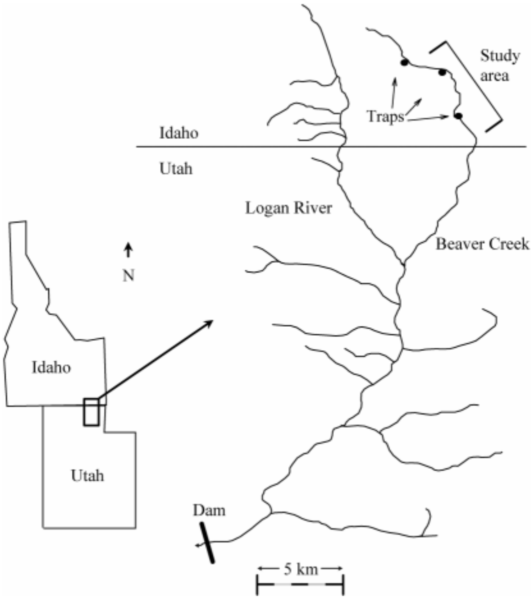

FIGURE 1.—Map showing the locations of Beaver Creek and the study area.

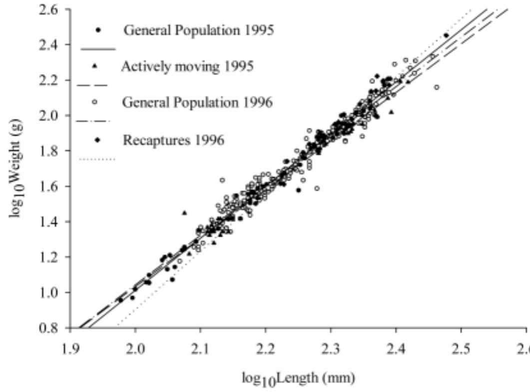

FIGURE 2.—Regressions of $\log_{10}$ transformed weight against $\log_{10}$ transformed length depicting the condition of cutthroat trout in the general population in 1995, fish actively moving through traps in 1995, the general population in 1996, and fish marked in 1995 and recaptured in 1996.

ulation were captured by hook and line and backpack electrofishing throughout the study section to provide tagged fish throughout the study reach that could be assumed to be nonmobile for study purposes. We used a global positioning system (GPS) to determine the locations of tagged fish and traps. We PIT-tagged and released 167 cutthroat trout during the summer of 1995. The following summer a 7-km reach encompassing all PIT tag releases was intensively electrofished, and we less intensively sampled an additional 6 km of stream adjacent to the study area in pursuit of tag returns. Recaptured fish were weighed, measured, released, and had their locations determined with a GPS; distances moved were later calculated in ARC/INFO (Environmental Systems Research Institute, Redlands, California). During each year, fish were collected between mid-July and early September; to control for any temporal changes in condition that might exist, fish captured in traps later in the year were not used in analyses.

We compared the condition of fish captured moving through the traps with that of the general population during the same time period; we also compared mobile and resident fish that had been PIT-tagged and recaptured 1 year after marking. Condition was analyzed by means of length-weight regressions for individual groups; the slopes and intercepts were compared by analysis of covariance (ANCOVA). For fish that had been PIT-tagged and recaptured the following year, we also examined the relationships between instantaneous growth rates using weight increment (Ricker 1975) and the degree of mobility by simple linear regression. Finally, we used analysis of variance (ANOVA) to test whether the lengths of fish caught in traps were different from those of the general population.

Results

There were significant differences in condition among moving, resident, and recaptured fish, but the magnitude of the differences depended on the size of the fish. In all but one comparison there were significant among-group differences for both the slopes ($P < 0.033$) and the intercepts ($P < 0.033$) of the length-weight ANCOVA, indicating differences not only in condition (intercepts) but also in the length-weight relationship (slopes; Figure 2). Because of the existence of nonparallel slopes, we used least-squares means to test for differences at the 25th (148 mm), 50th (175 mm), and 75th (209 mm) length percentiles. Fish caught in traps in 1995 had significantly lower condition, weighing 16% less than the general population at the overall mean fish length of 175 mm ($P = 0.022$), and the difference in condition for larger fish (209 mm) was even more statistically pronounced ($P < 0.001$). In contrast, there was no difference between the condition of smaller fish (148 mm) caught moving through traps and that of the general population in 1995 ($P = 0.22$). Population attributes, sample sizes, and the sampling time frame can be found in Table 1.

TABLE 1.—Characteristics of fish captured in Beaver Creek, Idaho, by population category.

Year	Population	N	Dates collected	Length ± SE (mm)	Weight ± SE (g)
1995	General population	61	Jul 12–Sep 25	162.0 ± 5.21	50.3 ± 4.39
	Moving through	43	Jul 13–Sep 13	180.4 ± 6.63	62.1 ± 5.80
1996	General population	245	Jul 20–Sep 3	178.9 ± 2.34	63.0 ± 2.53
	Resident recaptures	8	Jul 30–Sep 3	192.7 ± 11.80	77.5 ± 18.56
	Nonresident recaptures	18	Jul 30–Sep 3	189.8 ± 8.86	76.1 ± 8.51

Marking and subsequent recapture did not appear to lower fish condition. Fish marked with PIT tags in 1995 and recaptured in 1996 had condition similar to that of the general population in 1996 for all three least-squares means comparisons ($P = 0.07$ at the 25th percentile; $P = 0.35$ at the 50th percentile; and $P = 0.15$ at the 75th percentile) despite differences in overall slopes and intercepts. However, fish that were known to have moved between their initial capture and recapture had significantly greater condition in 1996 than the general population (ANCOVA; $P = 0.021$), weighing nearly 8% more. Using the least-squares means comparisons, we found no temporal differences in condition within groups during the sampling season ($P > 0.09$), which might indicate that we were sampling during postspawning recovery.

Cutthroat trout caught moving through traps in 1995 were significantly longer (mean, 180.4 mm; Table 1) than the general population (mean, 162.0 mm; ANOVA: $P = 0.016$). However, there were no differences in length between fish moving upstream and those moving downstream (ANOVA; $P = 0.47$). Analysis of the growth rates of recaptured fish showed that annual growth was not associated with the distance moved between capture and recapture a year later or with mobility in general (regression slope = 0.00002; $r^2 = 0.09$; $P = 0.14$; Figure 3). More detailed analysis showed that the values for growth were similar among fish that were mobile, those that were resident (i.e., for which there was no detected movement), and those that were initially resident but moved detectable distances between release in 1995 and recapture in 1996 (ANOVA; $P = 0.58$).

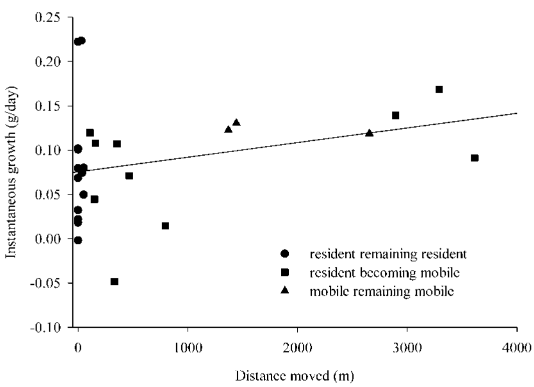

FIGURE 3.—Regression of instantaneous growth against distance moved by fish marked in 1995 and recaptured in 1996. Symbols indicate fish of different capture-recapture histories: (1) resident remaining resident = fish that were initially captured from the general population in 1995 and recaptured in the same place in 1996; (2) resident becoming mobile = fish that were initially captured from the general population in 1995 and that had moved appreciable distances upon recapture in 1996; and (3) mobile remaining mobile = fish that were initially captured moving through traps in 1995 and recaptured in 1996 at appreciable distances from their initial capture locations.

Discussion

Mobility in stream-dwelling Bonneville cutthroat trout in Beaver Creek was associated with lower condition. Large cutthroat trout caught in traps weighed substantially less than fish of a similar length in the general population. Although no information exists for other cutthroat trout subspecies, similar results have been reported for other salmonids. Naslund et al. (1993) found that lake-resident Arctic char *Salvelinus alpinus* had higher condition than those emigrating from the lake. Similarly, mobile brook trout *S. fontinalis* in Colorado streams were in poorer condition than the general population, and mobile fish were significantly longer than residents (Gowan and Fausch 1996). The mobile cutthroat trout in our study were also longer than those in the general population. Although Beaver Creek cutthroat trout are not migratory, they can be mobile during the spawning period (Hilderbrand and Kershner 2000). It is possible that the larger fish were spawned-out adults moving to more suitable foraging areas when they were caught in traps and that their low condition was due to spawning. We do not think this is the case, however, because we would expect fish in the general population also to have spawned and to be in similar condition; we found no temporal patterns to fish condition, and spawning-related movements had ceased by the time the traps were being operated.

While lower condition supported our predictions about mobile fish, the attribute appeared to be transient since mobile fish had condition equal to or greater than that of the general population at recapture. Higher growth or condition after moving to another site has been reported in migratory salmonids (Naslund et al. 1993; Kahler et al. 2001), but there is no long-term information on stream-resident populations. Mobility may increase as food supply decreases (Slaney and Northcote 1974; Wilzbach 1985) or fish become larger (e.g., Shetter 1968; Meyers et al. 1992; Young 1994). Mobility may also be a response of subordinate individuals to territorial interactions (Chapman 1962; Bilby and Bisson 1987; Titus 1990; Nakano 1995), but this should result in lower overall growth and condition, particularly if there are no new habitats to colonize (as is probably the case in Beaver Creek). In contrast, our results suggest that there is no penalty for being mobile in a stream-resident population and that some individuals may benefit from moving. Some fish undoubtedly are displaced by agonistic interactions, but others may follow seasonal food or habitat resources. In these cases, lower condition would be a temporary cost of movement that is recovered when a fish takes up residency elsewhere in the stream. The events causing the mobility of specific fish in our study are unknown, but there did not appear to be a long-term reduction in condition or growth.

The majority of fish sampled in this study were captured by electrofishing, but we believe that this had little effect on the results. Electrofishing can increase mortality (Hudy 1985; Habera et al. 1996) and deformities due to spinal injury (Kocovsky et al. 1997) as well as decrease growth and condition (Gatz et al. 1986; Dalby et al. 1996; Thompson et al. 1997) in salmonids. However, the data for 1995 were from fish not previously sampled with electrofishing, and the fish recaptured in 1996 had condition (at a given length) that was at least as great as that of the general population. Our 1995 sampling used single-pass electrofishing, whereas pronounced negative effects usually occur after multiple passes or multiple years of sampling. We did not track individuals for electrofishing-induced injuries or mortality, so it is possible that some of the marked fish did not survive due to electrofishing. However, the recapture rates of fish initially captured with hook and line (7%) and traps (9%) were lower than those for individuals initially collected with electrofishing (20%), which leads us to believe that mortality due to electrofishing was not substantial.

In summary, large, actively-moving fish had lower condition than the general population, but they regained condition by the following year and growth was not different between mobile and resident fish. We conclude that there is no growth penalty for moving and that we should be cautious when making inferences about the attributes of mobile fish and the profitability of such a strategy to the fitness of the individual and the population.

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References

Bilby, R. E., and P. A. Bisson. 1987. Emigration and production of hatchery coho salmon (*Oncorhynchus kisutsch*) stocked in streams draining an old-growth and a clear-cut watershed. Canadian Journal of Fisheries and Aquatic Sciences 44:1397–1407.

Chapman, D. W. 1962. Aggressive behavior of juvenile coho salmon as a cause of emigration. Journal of the Fisheries Research Board of Canada 19:1047–1080.

Chapman, D. W. 1966. Food and space as regulators of salmonid populations in streams. American Naturalist 100:343–357.

Dalby, S. R., T. E. McMahon, and W. Fredenberg. 1996. Effect of electrofishing pulse shape and electrofishing-induced spinal injury on long-term growth and survival of wild rainbow trout. North American Journal of Fisheries Management 16:560–569.

Gatz, A. J., Jr., J. M. Loar, and G. F. Cada. 1986. Effects of repeated electroshocking on instantaneous growth of trout. North American Journal of Fisheries Management 6:176–182.

Gowan, C., and K. D. Fausch. 1996. Mobile brook trout in two high-elevation Colorado streams: reevaluating the concept of restricted movement. Canadian Journal of Fisheries and Aquatic Sciences 53:1370–1381.

Gowan, C., M. K. Young, K. D. Fausch, and S. C. Riley. 1994. Restricted movement in resident stream salmonids: a paradigm lost? Canadian Journal of Fisheries and Aquatic Sciences 51:2626–2637.

Grant, J. W. A., D. L. G. Noakes, and K. M. Jonas. 1989. Spatial distribution of defence and foraging in young-of-the-year brook charr, *Salvelinus fontinalis*. Journal of Animal Ecology 58:773–784.

Habera, J. W., R. J. Strange, B. D. Carter, and S. E. Moore. 1996. Short-term mortality and injury of rainbow trout caused by three-pass AC electrofishing in a southern Appalachian stream. North American Journal of Fisheries Management 16:192–200.

Heggenes, J. 1988. Effects of short-term flow fluctuations on displacement of, and habitat use by, brown trout in a small stream. Transactions of the American Fisheries Society 117:336–344.

Hilderbrand, R. H., and J. L. Kershner. 2000. Movement patterns of stream-resident cutthroat trout in Beaver Creek, Idaho-Utah. Transactions of the American Fisheries Society 129:1160–1170.

Hudy, M. 1985. Rainbow trout and brook trout mortality from high voltage electrofishing in a controlled environment. North American Journal of Fisheries Management 5:475–479.

Jenkins, T. M., Jr. 1969. Social structure, position choice, and microdistribution of two trout species (*Salmo trutta* and *S. gairdneri*) resident in mountain streams. Animal Behaviour Monographs 2:57–124.

Kahler, T. H., P. Roni, and T. P. Quinn. 2001. Summer movement and growth of juvenile anadromous salmonids in small western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:1947–1956.

Kocovsky, P. M., C. Gowan, K. D. Fausch, and S. C. Riley. 1997. Spinal injury rates in three wild populations in Colorado after eight years of backpack electrofishing. North American Journal of Fisheries Management 17:308–313.

Meyers, L. S., T. F. Thuemler, and G. W. Kornely. 1992. Seasonal movements of brown trout in northeast Wisconsin. North American Journal of Fisheries Management 12:433–441.

Nakano, S. 1995. Individual differences in resource use, growth, and emigration under the influence of a dominance hierarchy in fluvial red-spotted masu salmon in a natural habitat. Journal of Animal Ecology 64:75–84.

Naslund, I., G. Milbrink, O. Eriksson, and S. Holmgren. 1993. Importance of habitat productivity differences, competition, and predation for the migratory behaviour of Arctic charr. Oikos 66:538–546.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Riley, S. C., K. D. Fausch, and C. Gowan. 1992. Movement of brook trout (*Salvelinus fontinalis*) in four small subalpine streams in northern Colorado. Ecology of Freshwater Fishes 1:112–122.

Rodriguez, M. A. 2002. Restricted movement of stream fish: the paradigm is incomplete, not lost. Ecology 83:1–13.

Shetter, D. S. 1968. Observations on movements of wild trout in two Michigan stream drainages. Transactions of the American Fisheries Society 97:472–480.

Slaney, P. A., and T. G. Northcote. 1974. Effects of prey abundance on density and territorial behaviour of young rainbow trout (*Salmo gairdneri*) in laboratory stream channels. Journal of the Fisheries Research Board of Canada 31:1201–1209.

Thompson, K. G., E. P. Bergersen, R. B. Nehring, and D. C. Bowden. 1997. Long-term effects of electrofishing on growth and body condition of brown trout and rainbow trout. North American Journal of Fisheries Management 17:154–159.

Titus, R. G. 1990. Territorial behavior and its role in populations of young brown trout (*Salmo trutta*): new perspectives. Annales Zoologici Fennici 27: 119–130.

Wilzbach, M. A. 1985. Relative roles of food abundance and cover in determining the habitat distribution of stream-dwelling cutthroat trout (*Salmo clarki*). Canadian Journal of Fisheries and Aquatic Sciences 42:1668–1672.

Young, M. K. 1994. Mobility of brown trout in south-central Wyoming streams. Canadian Journal of Zoology 72:2078–2083.