Adfluvial and fluvial life history variations and migratory patterns of a relict charr, , stock in west-central Idaho, USA

Fish stocks of the genus (Family: Salmonidae) in the Arctic charr, , and Dolly Varden, , complexes exhibit great genotypic, phenotypic and life history variation across their ranges (Behnke 1984; Taylor et al. 1999). Phylogenetic divergence has occurred extensively in these species complexes since the early-Pleistocene and has been associated with the episodic advances and retreat of glaciers (Behnke 1980; Magnan et al. 2002; Power 2002). Changing environmental conditions and habitat characteristics over geologic time, variety of life history strategies typical of charrs, including adfluvial potamodromy (migrations between lake or reservoir systems and rivers; Fraley & Shepard 1989; Olmstead et al. 2001), fluvial potamodromy (migrations between rivers; Hogen & Scarnecchia 2006), residency (Chandler et al. 2001; Nelson et al. 2002), and in a few instances, anadromy (Baker et al. 2003). Considerable research has been conducted on life history strategies and habitat use of numerous stocks during the past 15–20 years (e.g. Mackay et al. 1997; Brewin et al. 2001). However, in many localities, little is known about stock-specific life history strategies, migration patterns and habitat use.

The evolution of different migratory forms has enabled bull trout to occupy spatially diverse habitats and optimise reproductive potential by maximising growth, fecundity and survival in variable environments (Northcote 1978). Diverse life history strategies may therefore be critically important to the long-term stability and persistence of the species (Rieman & McIntyre 1993; Stowell et al. 1996; Rieman & Allendorf 2001). Continued habitat degradation, the expansion of nonnative species, and prolonged habitat fragmentation has reduced the distribution and abundance of bull trout in many localities (Rieman et al. 1997).

In the north-western United States and Canada, the range of bull trout has continued to contract and become fragmented over the last century, particularly in the more temperate southern portions (Nelson et al. 2002). Specific factors contributing to this range contraction and fragmentation include loss or alterations of critical spawning and rearing habitat (Rieman & McIntyre 1993, 1995; Rieman et al. 1997), competition with introduced nonnative species, and hybridisation and introgression with nonnative brook trout ( ).

The South Fork Salmon River (SFSR) sub-basin in central Idaho, USA, is considered a stronghold for

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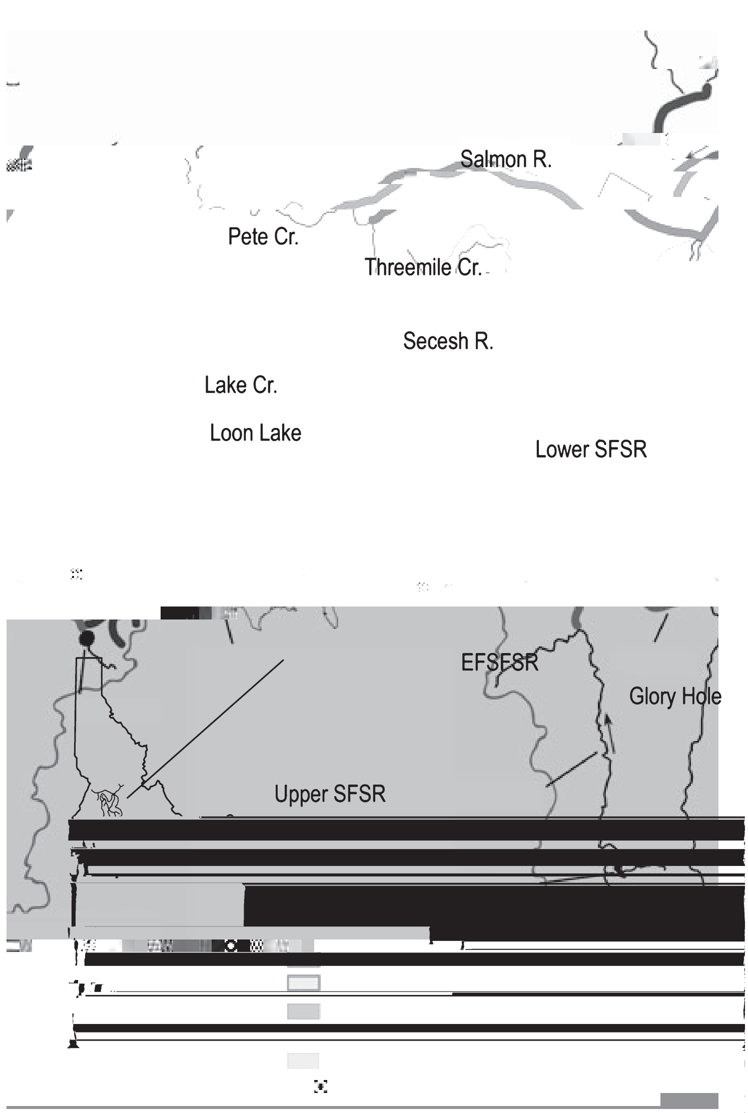

. *1*. Secesh River and East Fork South Fork Salmon River (EFSFSR) bull trout over-wintering locations, migration corridors and spawning/rearing areas in the South Fork Salmon River (SFSR) and Salmon River drainages; determined by radio telemetry, 2003–2004 and 1999–2000 developed from Hogen & Scarnecchia (2006).

extirpated; however, relict kokanee (.) populations are still present in these lakes. Introduced, nonnative species include brook trout, mixed cutthroat trout stocks (spp.), Kamloops rainbow trout, golden trout ( ), lake trout ( ) and arctic grayling ( ). Naturally occurring hybridised species include bull trout × brook trout hybrids (hybrids) and cutthroat × rainbow trout hybrids.

Fish capture

Adult bull trout were captured in the Secesh River watershed mainly by hook and line using a combination of artificial lures, bait with circle hooks and artificial flies. This sampling method previously proved effective, with minimal harm to the fish, when collecting bull trout in the EFSFSR (Hogen & Scarnecchia 2006).

In 2003, fishing occurred almost daily between 19 June and 15 August either in the Secesh River or Lake Creek. Sampling at these particular locations and times was intended to target fish during their upstream prespawning migrations. From past observations, spawning was thought to occur after 15 August. From this sampling, 24 prespawn bull trout and one putative hybrid were selected to be radio-tagged. Putative hybrids were distinguished from bull trout and brook trout by using multiple external phenotypic traits as described in Markle (1992) and Watry (2005). In addition to these fish, 20 postspawn bull trout captured at the Nez Perce Tribe's rotary screw smolt trap on Lake Creek between 23 August and 7 September were selected for radio-tagging, for a total of 45 fish. Postspawn fish were identified by gently stripping the fish for gametes to verify gender and reproductive condition, although gender was not verified for all fish. Other indicators identifying postspawn fish included their emaciated appearance, enervated condition and late date of capture (late August

ATS R4000 receiver or a Lotek SRX400 receiver. Radio-tagged fish were tracked between July 2003 and October 2004 during periods of predetermined tag transmission. Weekly tracking was conducted from a vehicle or by foot from July through September 2003 and from June through October 2004. Aerial surveys with fixed wing aircraft were conducted on 20 September and 24 October, 2003; and on 13 June, 8 September and 1 October, 2004.

Fish locations were recorded using a Global Positioning System in the UTM NAD27CONUS coordinate system. Calculated map distances were measured from the mouth of the Secesh River beginning at river km (Rkm) 1098.6. Locations referenced as Rkm were recorded for each captured fish, and capture locations were considered the initial point of contact for each fish. Subsequent contacts were calculated as distances travelled from the initial point of contact.

When not in spawning tributaries, fish locations accurate to within approximately 50 m were deemed adequate to meet study objectives. When in spawning tributaries, triangulation helped determine precise locations to help make general observations of radio-tagged fish, particularly during the known spawning season beginning in mid-August, as identified from other studies (Shepard et al. 1984; Schill et al. 1994; Swanberg 1997; Hogen & Scarnecchia 2006). Spawning for this study was defined as any activity that demonstrated fish were participating in the spawning process, including the construction of redds, the presence of redds with fish present, the pairing of fish in small headwater tributaries during the fall spawning season, and aggressive behaviour of fish while guarding a redd. We attempted only to identify spawning areas, not to quantify spawning habitat or to detect population trends.

No surveys were conducted during winter in 2003 and 2004 because of access problems and the inability to detect transmitter signals from the air through ice and snow. Johnson (1980) suggested the winter activity of arctic charr was negligible, and there is supporting evidence that bull trout display similar behaviour. Hogen & Scarnecchia (2006) observed that fluvial bull trout in the mainstem Salmon River and lower SFSR moved <1 km during winter. Elle et al. (1994) and Schill et al. (1994) reported negligible movements of 50–100 m within individual habitat units during winter on the mainstem Salmon River for Rapid River bull trout. In 1992, all fish reached their over-wintering destination by early October (Schill et al. 1994). In the Blackfoot River, Montana, fluvial bull trout movements during winter never exceeded 300 m (Swanberg 1997). As a result, winter movements were assumed to be tributaries, remained in the tributary between 5 and 52 days, evidently spawned, exited the tributary, moved downstream, entered Loon Creek and migrated upstream to Loon Lake (Fig. 2). One putative hybrid also displayed this general pattern, but was not observed in a tributary and apparently remained in Lake Creek for 47 days before emigrating to Loon Lake. Eleven other bull trout captured and tagged, during August and early September, at either the Lake Creek smolt trap (= 10) or by angling in Lake Creek (= 1) immediately migrated downstream following tagging, entered Loon Creek and migrated upstream to Loon Lake. In all, seven of the 10 fish captured at the Lake Creek smolt trap showed verifiable evidence of gender (three males and four females) and postspawning condition. In 2004, three bull trout captured during June in Loon Lake first moved downstream in Loon Creek from the lake before beginning their upstream migration in the Secesh River to Lake Creek and its tributaries (Fig. 3); one of these fish was not observed in a tributary. In both years, emigration out of tributaries was rapid, and occurred between mid-August and late September. Eleven of 14 bull trout exited small tributaries, evidently after spawning, by 7 September, 2003. Following emigration from the small tributaries, fish were later., October and November in Loon Lake. Mortality rates were 29% for bull trout captured by angling in Lake Creek, with 10 of 14 fish relocated in Loon Lake during June 2004. In contrast, mortality rates were 80% for fish captured at the Lake Creek trap.

In the second most common migration pattern (fluvial) 13 bull trout immediately moved downstream to the lower Secesh River (= 11) or the lower SFSR (

one of two small tributaries where spawning of nontagged fish was later observed. In each year, one fish was observed to move between spawning tributaries prior to the spawning period. In all, 27 radio-tagged bull trout were observed in spawning tributaries during 2003 (= 18) and 2004 (= 9). Only one of these fish, a female, displayed consecutive-year migrations, and utilised the same spawning tributary in each year.

Prespawn mortalities and tag recovery

Prespawn mortalities and tag recoveries were those confirmed or observed prior to 15 August in each year. In 2003, confirmed prespawn mortalities (= 2) and tag recoveries (= 1) accounted for 12% of all prespawn radio-tagged fish (= 25). During 2004, mortality signals were received from 11.5% (= 3) of all prespawn radio-tagged fish (= 26) although mortalities could not be confirmed. One other radio-tag was recovered on 18 August, 2004 in a small tributary, but the fate this fish could not be determined prior to the spawning season. The carcass and radio-tag of one consecutive-year migrant that over-wintered in Loon Lake was recovered on the Secesh River on 2 August, 2004.

Emigration from Loon Lake

Twelve radio-tagged bull trout emigrated out of Loon Lake during late June and early July 2004. Contacts with fish in Loon Creek occurred within what was assumed to be a short time after emigration from Loon Lake. As such, three fish were located either in Loon Creek or in the Secesh River at the mouth of Loon Creek on 25 June, representing the earliest observed date of emigration. These three fish were consecutive year migrants, one of which was tagged in 2004. Nine of the 12 migrants emigrated from Loon Lake by 2 July, with the latest dates of emigration occurring between 2 and 9 July. Sample sizes were too small to determine precise dates of emigration or migration rates.

Migration periodicity

Sixteen fish tagged in 2003 were relocated in 2004, yet only six of these fish (five bull trout and one hybrid) migrated in 2004. Another bull trout that was PIT tagged and identified as a female in 2003 was recaptured and radio-tagged in Loon Lake in June 2004. Six of these seven consecutive-year migrants over-wintered in Loon Lake whereas the other fish was located in the Secesh River prior to winter in November 2004. Of the seven consecutive-year migrants in 2004, two females utilised spawning tributaries, another fish was repeatedly located in Lake Creek, but was not observed in a spawning tributary, and one fish was a prespawn mortality. Incomplete data for three other fish made it impossible to assess their true migratory periodicity.

Spawning activity

No radio-tagged fish were observed spawning in either tributary (i.e. Pete Creek or Threemile Creek) located in the upper Secesh River watershed, although a few did display spawning behaviours such as pairing and chasing. Spawning locations and period were conditional upon locations of radio-tagged fish relative to observations of nontagged fish. Redds were observed independent of radio-tagged fish locations in both years.

The first paired fish were observed on 18 August, 2003 and 27 July, 2004. In all, 11 redds were positively identified between 24 August and 21 September, 2003 and three redds were positively identified between 17 August and 1 September, 2004. Radio-tagged fish remained in spawning tributaries until at least 23 and 26 August, 2003 and 2004 respectively. In 2003, one radio-tagged fish remained in a spawning tributary until at least 21 September, the latest such observation in both years.

Postspawning movements and mortalities

In 2003, 37 of 39 fish were contacted in Loon Lake (= 20), the Secesh River (= 11), Loon Creek (= 3) and the SFSR (= 3). In all, 24 (57%) postspawning migrants were transmitting mortality signals in November 2003. In 2004, six of 12 migrant fish survived postspawning migrations. Four of these six surviving fish were captured and tagged in Loon Lake, two of which returned to Loon Lake by 8 September displaying over-wintering site fidelity. The other two of these four fish were located in the Secesh River by 15 September. Two other migratory fish that were initially captured in Lake Creek were located in the Secesh River on 8 September. One of these two fish made the single longest individual migration of any radio-tagged fish, travelling a total distance of 113.3 km and was last located near the mouth of the SFSR (Fig. 6). Two consecutive-year migrants which over-wintered in Loon Lake were relocated in Loon Lake during September; both transmitted mortality signals in October 2004.

Over-wintering

Radio-tagged bull trout over-wintered in Loon Lake, Loon Lake in June 2004; the one radio-tagged hybrid also evidently over-wintered in Loon Lake. Fourteen of these fish survived in Loon Lake until at least June 2004. Two consecutive-year migrants demonstrated over-wintering site fidelity by returning to Loon Lake in September 2004. In 2004, 17 of 22 mechanisms of exploration that favour migration as a means to opportunistically exploit available resources (Northcote 1978; Power 2002). Exploratory migrations can also help organisms maintain spatial diversity by extending their range beyond the limits of

In contrast to the unusual adfluvial migratory pattern observed for Secesh River bull trout, results of several other aspects of this study were consistent with results reported elsewhere. For example, the low incidence of prespawn mortalities (7%) and tag loss (3%) were similar to those observed in other studies (Schill et al. 1994; Swanberg 1997), as were the high (49%) overall mortality rates (Schill et al. 1994; Chandler et al. 2001; Hogen & Scarnecchia 2006). Similarly, average water temperatures in spawning tributaries during the spawning period (<9 °C) were consistent with those reported for the species. Spawning typically occurs at temperatures <9 °C (McPhail & Murray 1979; Shepard et al. 1984; Fraley & Shepard

conference proceedings. Calgary, Alberta: Trout Unlimited Canada, pp. 167–172.

Clayton, T.B. 2001. Movements and status of bull trout ( ) in the Belly River, Alberta and Montana. In: Brewin, M.K., Paul, A.J. & Monita, M., eds. Bull trout II conference proceedings. Calgary, Alberta: Trout Unlimited Canada, pp. 141–145.

Dunham, J., Rieman, B. & Davis, K. 2001. Sources and magnitude of sampling error in redd counts for bull trout. North American Journal of Fisheries Management 21: 343–352.

Elle, S., Thurow, R. & Lamansky, T. 1994. Rivers and streams investigations. Boise, ID: Idaho Department of Fish and Game, Job Performance Report, Project: F-73-R-16, Subproject II, Study IV.

Fraley, J.J. & Shepard, B.B. 1989. Life history, ecology, and population status of migratory bull trout ( ) in the Flathead Lake and River system, Montana. Northwest Science 63: 133–143.

Gross, M.R. 1987. Evolution of diadromy in fishes. Bethesda, MD: American Fisheries Society Symposium, 1: 14–25.

Gulseth, O.A. & Nilssen, K.J. 2001. Life-history traits of charr, , from a high arctic watercourse on Svalbard. Arctic 54: 1–11.

Haas, G.R. & McPhail, J.D. 1991. Systematics and distributions of Dolly Varden ( ) and bull trout ( ) in North America. Canadian Journal of Fisheries and Aquatic Sciences 48: 2191–2211.

Hanski, I.A. 1991. Single species metapopulation dynamics: concepts, models, and observations. Biological Journal of the Linnean Society 42: 17–38.

Hanski, I.A. & Gilpin, M.E. 1997. Metapopulation biology: ecology, genetics, and evolution. San Diego, CA: Academic Press.

Herman, S.J. 1997. A unique bull trout spawning population of Pinto Lake, Alberta. In: Mackay, W.C., Brewin, M.K. & Monita, M., eds. Friends of the bull trout conference proceedings. Calgary, Alberta: Bull trout Task Force, c/o Trout Unlimited Canada, pp. 217–226.

Hindar, K. & Jonsson, B. 1993. Ecological polymorphism in arctic charr. Biological Journal of the Linnean Society 48: 63–74.

Hogen, D.M. & Scarnecchia, D.L. 2006. Distinct fluvial and adfluvial migration patterns of a relict charr, , stock in a mountainous watershed, Idaho, USA. Ecology of Freshwater Fish 15: 376–387.

Howell, P.J. & Buchanan, D.V. 1992. Proceedings of the Gearhart Mountain bull trout workshop. Corvallis, OR: Oregon Chapter of the American Fisheries Society.

Hvenegaard, P.J. & Thera, T.M. 2001. Monitoring the bull trout ( ) spawning run in Lynx Creek, a tributary to the Kakwa River, West Central Alberta. In: Brewin, M.K., Paul, A.J. & Monita, M., eds. Bull trout II conference proceedings. Calgary, Alberta: Trout Unlimited Canada, pp. 147–151.

Johnson, L. 1980. The Arctic charr, . In: Balon, E.K., ed. Charrs: Salmonid fishes of the genus Salvelinus. Hague, The Netherlands: Dr. W. Junk Publishers, pp. 15–98.

Klamt, R.R. 1976. The effects of coarse granitic sediment on the distribution and abundance of salmonids in the central Idaho batholith. Master of Science Thesis. Moscow, ID: University of Idaho.

Mackay, W.C., Brewin, M.K. & Monita, M. 1997. Friends of the bull trout conference proceedings. Calgary, Alberta: Bull Trout Task Force, c/o Trout Unlimited Canada.

Power, G. 2002. Charrs, glaciations, and seasonal ice. Environmental Biology of Fishes 64: 17–35.
Reist, J.D. 1989. Genetic structuring of allopatric populations and sympatric life history types of charr, / , in the western Arctic, Canada. Physiological Ecology, Japan 1: 405–420.
Rieman, B.E. & Allendorf, F.W. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21: 756–764.
Rieman, B.E. & McIntyre, J.D. 1993. Demographic and habitat