Section 1

OVERWINTERING AND SPAWNING ECOLOGY OF FISHES IN COLD CLIMATES

An Annotated Bibliography

Compiled for the
Region II FRPA Riparian Management Science & Technical Committee

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SUMMARY

In South Central Alaska (Region II), rivers and streams are covered with ice and develop ice on the streambed for significant periods of the year. These conditions reduce the habitat suitability of certain portions of these systems for overwintering juvenile and resident fish species (Cunjak, 1996). Though these icing conditions prevail in primary channels, side channels and sloughs that are typical of glacial systems in Region II provide suitable habitat for overwintering fishes due to upwelling groundwater, low flow velocities, and suitable cover in the form of living and dead large woody debris and standing riparian vegetation. Lake systems that are connected to river systems also provide important overwintering habitat for resident and juvenile fish species in Alaska (Palmer, 1998, Meka et al. 2003). Of the factors that characterize suitable overwintering habitat in side sloughs and channels of large river systems, upwelling groundwater is considered the primary influence to overwintering habitat suitability in Region II Alaska (Alaska Department of Fish and Game, 1981, 1983a, 1983b). Other studies also indicate that feeding for juvenile salmonids is also very pertinent to winter survival and growth (Moles et al. 1997). In side slough habitats, overwintering fish are able to reduce energy expenditure due to low flow velocities, feed on a limited basis, avoid frazil ice, and experience higher rates of survival (Swales et al., 1986, Bustard, 1986). On rivers such as the Susitna River, resident rainbow and juvenile salmon are known to prefer side slough habitats near tributary confluences.

On large glacial river systems, high volume ground water flow paths that may extend kilometers from the main channel (Boulton et al. 1998) are thermally buffered from ambient conditions in winter. Where this groundwater upwells, it is rich in nutrients and relatively warm in winter. This key influence on juvenile salmon and resident species habitat is expressed within the context of high habitat heterogeneity to provide a wide variety of suitable habitats. The availability of these sites is restricted on smaller clear water streams that do not have the physical habitat complexity and adequate stream flow to provide adequate numbers of sites for overwintering of fish.

The complexity of side slough habitats is also critical due to the variety of species – specific microhabitat preferences. Complexity of habitat allows for the coexistence of several species in the same general location without significant competition (Cunjak 1996). For these reasons, glacial systems have been found to be extremely important to overwintering salmonids in southcentral Alaska.

Many species also show preference for sites characterized by upwelling when spawning (Baxter and McPhail, 1999, Baxter and Hauer, 2000). This is especially true for chum and sockeye salmon that prefer to spawn in side sloughs of the Susitna River. Baxter and McPhail (1999) document higher survival of bull trout embryos to the alevin stages at sites characterized by upwelling.

Because side slough habitats occupy the peripheral portions of gravel-bed floodplains, they are particularly susceptible to modification due to riparian forest practices and floodplain land developments. Access developments, for example typically require culverts or fill material when building roads to access main river channels of glacial systems. These actions can reduce the hydrologic connectivity of side slough habitats. Flood control projects that stabilize main channels also have the potential to disconnect rivers channels from its floodplain sloughs. Such modifications may also introduce sediment into the aquatic system, such as side sloughs that typically run clear throughout the year. Through experimentation, Bustard and Narver (1975) found that juvenile salmon prefer clean versus silted substratum, a preference that increased with cold water temperatures. Tschaplinski and Harman (1983) found a 63-74% decrease in abundance of overwintering juvenile fish at sites adjacent to clear cut riparian zones. Temperature is also affected by buffer strip architecture. Curry et al. (2002) report marked decreases in temperatures of surface waters at sites with no buffer strip.

Winter fish habitats are also extremely vulnerable to withdrawal of stream water for consumptive out of stream uses. Withdrawals of water that significantly reduce stream flow lead to accelerate icing characteristics that may result in disconnecting important side slough habitats and lake systems with primary channels (Cunjak, 1996). This either precludes fish from accessing their preferred habitats or strands those already occupying disconnected habitats. Because glacial systems are characterized by low flow in winter, these systems are particularly sensitive to withdrawals of water in winter.

REFERENCES

Alaska Department of Fish and Game. 1981. Juvenile anadromous fish study on the Lower Susitna River (November 1980 – October 1981). Susitna Hydro Aquatic Studies. Phase 1 final draft report. Subtask 7.10. APA Document #322

This report discusses basic data on the presence, abundance, geographical distribution, age class composition, length distribution, and smolt migration timing of juvenile salmon in the Susitna River between Cook Inlet and Devil Canyon. Field data collection took place from November 1980 – October 1981 using a variety of sampling methods. Five juvenile salmon species were captured throughout the study area. The majority of Chinook were captured during winter at slough and mainstem Susitna River. In summer the majority of Chinook were captured at tributary mouth sites. The majority of coho captured on the River below Talkeetna were found at tributary mouth sites in winter and summer. Between Talkeetna and Devil canyon occurrence of juvenile coho was greatest in Susitna side sloughs in winter and tributary mouth sites in summer. Three age classes were captured, 0+, I+, and II+. Sampling scheme bias imposed by gear types did not allow for sufficient capture of juvenile pink, chum, and sockeye.

Alaska Department of Fish and Game. 1983a. Resident and juvenile anadromous fish studies on the Susitna River below Devil Canyon, 1982. Susitna Hydro Aquatic Studies. Phase 2 basic data report. APA document #486.

Alaska Department of Fish and Game. 1983b. Synopsis of the 1982 aquatic studies and analysis of fish and habitat relationships (section 1 of 2). Susitna Hydro Aquatic Studies. Phase 2 Report. APA Document #40.

These reports discuss the distribution, abundance, adult movement and migration patterns, spawning, and juvenile rearing areas for rainbow trout, arctic grayling, burbot, Dolly Varden, and other resident species. Adult rainbow trout were found to occupy side slough habitats of the Susitna River near tributary confluences in winter.

Baxter, C.V. and F. R. Hauer. 2000. Geomorphology, hyporheic exchange, and selection of spawning habitat by bull trout (*Salvelinus confluentus*). Canadian Journal of Fisheries and Aquatic Sciences. 57: 1470-1481

The distribution and abundance of bull trout *(Salvelinus confluentus)* spawning were affected by geomorphology and hyporheic groundwater - stream water exchange across multiple spatial scales in streams of the Swan River basin, northwestern Montana. Among spawning tributary streams, the abundance of bull trout redds increased with increased area of alluvial valley segments that were longitudinally confined by geomorphic nickpoints. Among all valley segment types, bull trout redds were primarily found in these bounded alluvial valley segments, which possessed complex patterns of hyporheic exchange and extensive upwelling zones. Bull trout used stream reaches for

spawning that were strongly influenced by upwelling. However, within these selected reaches, bull trout redds were primarily located in transitional bedforms that possessed strong localized downwelling and high intragravel flow rates. The changing relationship of spawning habitat selection, in which bull trout selected upwelling zones at one spatial scale and downwelling zones at another spatial scale, emphasizes the importance of considering multiple spatial scales within a hierarchical geomorphic context when considering the ecology of this species or plans for bull trout conservation and restoration.

Baxter, J.S. and J.D. McPhail. 1999. The influence of redd site selection, groundwater upwelling, and over-winter incubation temperature on survival of bull trout (*Salvelinus confluentus*) from egg to alevin. Can. J. Zool. 77:1233-1239.

We measured survival of bull trout *(Salvelinus confluentus)* embryos to the alevin stage in areas selected and not selected by females for spawning. In this study we tested the hypotheses that (1) females are utilizing habitats influenced by discharging groundwater and that (2) there is a reproductive advantage to spawning at these selected sites. Embryo survival was assessed by placing fertilized eggs in capsules that could be retrieved once they were placed in selected and nonselected locations. The survival rate was significantly higher (88.6 vs. 76.1%) and less variable in the selected area, but alevin lengths did not differ significantly between areas. The selected areas were, on average, locations of groundwater discharge and higher water temperatures over the incubation period, while nonselected locations were in areas of surface-water recharge and lower water temperatures. The results suggest that appropriate reproductive habitats which offer the best incubation environments may be limited in bull trout systems, and that site selection by females may increase fitness and be critical for population viability.

Bustard, D.R., and Narver, D.W. 1975. Preferences of juvenile coho salmon (*Onchorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) relative to simulated alteration of winter habitat. Journal of the Fisheries Research Board of Canada. 32: 681 – 687.

This paper found through experimentation that juvenile salmonids prefer clean substrata versus silted substrata and that this preference was greatest at cold temperatures.

Bustard, D.R. 1986. Some differences between coastal and interior stream ecosystems and the implications to juvenile fish production. Canadian Technical Report of Fisheries and Aquatic Sciences 1483: 117-126.

This study demonstrated that juvenile steelhead, coho, and Chinook salmon have increased winter survival in side channel and side slough habitats that are characterized by relatively warm water due to upwelling groundwater

Craig, P.C., and Poulin, V.A. 1975. Movements and growth of Arctic grayling (*Thymallus arcticus*) and juvenile Arctic char (*Salvelinus alpinus*) in a small Arctic stream, Alaska. Journal of the Fisheries Research Board of Canada. 32: 689-697

Craig, P.C. 1978. Movements of stream resident and anadromous arctic char in a perennial spring of the Canning River, Alaska. Journal of the Fisheries Research Board of Canada. 35: 48-52

Cunjak, R.A., and Power, G. 1986. Winter habitat utilization by stream resident brook trout *(Salvelinus fontinalis)* and brown trout *(Salmo trutta)*. Canadian Journal of Fisheries and Aquatic Sciences 43: 1970 – 1981

This study proposed the important hypothesis that overwintering fishes utilize off – channel habitats in winter in part due to energetic demands in cold temperatures associated with low metabolic rates.

Cunjack, R.A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53: 267-282.

This paper reviews studies on winter fish habitat and the negative impacts of certain land use activities on overwintering fish habitat. In particular this paper discusses the adverse impacts to fish habitat due to inadequate riparian forest practices that result in substratum embeddedness and inadequate cover. This paper also discusses the negative impacts associated with water withdrawal during winter months. Inadequate streamflow results in increases in ice formation that results in stranding of fish and dewatering of off channel habitats as well as the excluding fish from important channel margin habitat that is utilized for feeding and cover.

Cunjack, R.A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53: 267-282.

This review paper discusses a large body of literature focusing on winter habitat relationships for juvenile and adult life stages of fish. This very important review discusses the use of side channel (off channel) habitats by overwintering fish and the importance of upwelling groundwater in these habitats. Due to energetic constraints associated with reduced metabolic activity fish seek aquatic habitats characterized by relatively warm water that is flowing slowly. Due to upwelling groundwater these habitats are key to survival in winter when deep pools in main channels develop frazil ice and become unsuitable to occupy. This paper also discussed the importance of habitat complexity for overwintering fishes due to species-specific habitat requirements or preferences. This paper also discusses the importance of beaver ponds and large wood debris to overwintering salmonids. Both beaver ponds and large wood create deep pools in off channel habitats that are very important winter habitat to fish, especially those species sensitive to light in winter.

Curry, R.A., D.A. Scruton, and K.D. Clarke. 2002. The thermal regimes of brook trout incubation habitats and evidence of changes during forestry operations. Canadian Journal of Forest Research 32: 1200-1207.

The thermal regimes in streambed substrates used by brook trout, *Salvelinus fontinalis* Mitchell, for incubation of embryos were examined in reference and treatment (0- and 20-m riparian buffer strips) streams in a clear-cut harvested, northern temperate forest of western Newfoundland. In these streams, incubation habitats (redds) were primarily composed of downwelling surface waters with variable but minor mixing of upwelling groundwater. The resulting incubation temperatures were cold (<1°C) and surface water temperatures were accurate predictors of redd temperatures. Both treatment streams displayed evidence of warming in the fall and spring of the 2 years beginning the year of initial harvesting. The increase was most pronounced in the stream without a riparian buffer strip. Clear-cut harvesting with and without a riparian buffer strip altered the thermal regime of surface water and the hyporheic zone in this northern temperate forest where, in addition to salmonid incubation, many biological processes take place. The potential for impacts on stream ecosystems is estimated to be high for the managed forests of this region. Future studies should strive to enhance our understanding of the hydrological connections between forests and streams on this landscape to determine the full effects of timber harvesting on the hydrology and biology of a watershed and its streams.

Jackson, D.A., P.R. Peres-Neto, and J.D. Olden. 2001. What controls who is where in freshwater fish communities – the roles of biotic, abiotic, and spatial factors. Canadian Journal of Fisheries and Aquatic Sciences. 58: 157-170

We examine evidence for the structuring of fish communities from stream and lake systems and the roles of biotic, abiotic, and spatial factors in determining the species composition. Piscivory by fish is a dominant factor in both stream and lake systems whereas evidence for the importance of competition appears less convincing. Within small streams or lakes, the impact of predation may exclude other species, thereby leading to mutually exclusive distributions and strong differences in community composition. Within a geographic region, abiotic effects frequently dictate the relative importance of piscivory, thereby indirectly influencing the composition of prey species present. The spatial scale of studies influences our perceived importance of biotic versus abiotic factors, with small-scale studies indicating a greater importance of competition and large-scale studies emphasizing abiotic controls. The scale of the individual sites considered is critical because smaller systems have higher variability and wider extremes of conditions than larger lakes and rivers. The stability of physical systems and degree of spatial connectivity contribute to increased diversity in both larger stream and larger lake systems. We identify challenges and needs that must be addressed both to advance the field of fish community ecology and to face the problems associated with human-induced changes.

Meka, J.M., E.E. Knudson, D.C. Douglas, and R.B. Benter. 2003. Variable migratory patterns of different adult rainbow life history types in a Southwest Alaska watershed. Transactions of the American Fisheries Society 132:717-732.

Radiotelemetry was used to document population structure in adult rainbow trout *Oncorhynchus mykiss* from the Alagnak River, southwest Alaska. Rainbow trout (N = 134) longer than 440 mm were implanted with radio transmitters and tracked for varying periods from July 1997 to April 1999. Fifty-eight radio-tagged fish were tracked for sufficient duration (at least 11 months) to allow description of seasonal migratory patterns. Unique seasonal movements of fish suggested discrete, within-basin population structure. Telemetry data documented the existence of multiple migratory and nonmigratory groups of rainbow trout, indicating unique life history patterns. The observed groups consisted of what we defined as a lake-resident ecotype, a lake–river ecotype, and a riverine ecotype; the riverine ecotype demonstrated both highly migratory and nonmigratory movement behavior. Considerable variation in movement patterns was found within both the lake–river group and the river migratory group. Radio-tagged trout did not migrate between the two Alagnak watershed lakes in either year of the study, suggesting lake fidelity in the population structure. Alagnak River rainbow trout may have evolved the observed seasonal movement patterns to optimize winter thermal refugia and summer food availability of salmon eggs and carcasses.

Moles, A. Korn, S., and Rice, S. 1997. Effects of low temperatures and starvation on resistance to stress in presmolt coho salmon. American Fisheries Society Symposium 19: 148 – 154.

Arctic winter conditions in Alaska can cause a decline in juvenile salmonid overwintering survival. Through controlled experimentation, the authors subjected juvenile coho to temperature and feeding treatments. Fish that were starved were more susceptible to disease, reduced tolerance to salinity and swimming stamina. They did not grow and deteriorated in general throughout the experiment. In contrast, fish that were fed grew at all temperatures, even at 0.2 degrees Celsius. Although food was found to be important, it was considered of lesser importance to arctic fish than for temperate fish due to lower metabolic rates associated with cold water temperatures.

Palmer, D.E. 1998. Migratory behavior and seasonal distribution of radio-tagged rainbow trout in the Kenai River, Alaska. U S Fish and Wildlife Service, Alaska Fisheries Technical Report Number 46, Kenai, Alaska.

Radio telemetry was used to monitor seasonal movements of large rainbow trout in the Kenai River. Rainbow trout began movements to overwintering areas in late September and ceased migration by mid-December. Rainbow trout tagged above Skilak Lake selected overwintering areas in Skilak Lake (64%), Kenai Lake (18%), and river locations between Skilak and Kenai Lakes (18%). Rainbow trout radio tagged below Skilak Lake selected Skilak Lake (72%) and river locations below the lake (28%) for overwintering. Most fish showed high fidelity for overwintering locations from year to year (1995 – 1996).

Riis, J.C. and Friese, N.C. 1978. Fisheries and habitat investigations of the Susitna River – a preliminary study of the potential impacts of the Devils Canyon and Watana Hydroelectric projects. Alaska Department of Fish and Game Division of Sport and Commercial Fish.

This report documents the use of the Susitna River and its side sloughs by rearing salmonids that were incubated in clearwater tributaries of the Susitna such as Montana Creek. This report also documents that juvenile salmonids use side sloughs of the Susitna from Portage Creek down to the Chulitna confluence for rearing habitat. The predominant rearing species captured for this study were Chinook and coho.

Swales, S., Lauzier, R.B., and Levings, C.D. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. Canadian Journal of Zoology. 64: 1506-1514.

This study documents that Juvenile coho preferred off-channel habitats influenced by warmer water temperatures due to upwelling groundwater and characterized by low flow velocities.

West, R.L., M.W. Smith, W.E. Barber, J.B. Reynolds, and H. Hop. 1992. Autumn Migration and Overwintering of Arctic Grayling in Coastal Streams of the Arctic National Wildlife Refuge, Alaska *Transactions of the American Fisheries Society*: Vol. 121, No. 6, pp. 709–715.

During 1984 and 1985, 67 adult Arctic grayling *Thymallus arcticus* with surgically implanted radio transmitters were released at their summer feeding areas in three river systems of the Arctic National Wildlife Refuge, Alaska. We tracked the fish from aircraft to determine patterns of autumn migration to overwintering locations. During August or September in each area, fish left the small tundra streams where they were tagged and migrated into larger streams. Migration rates peaked at 5–6 km/d about 1 September and averaged 1 km/d. Fish in two river systems moved into adjacent rivers after passage through estuarine waters. Migration distances from spawning or summer feeding areas to overwintering sites were as great as 101 km. Potential overwintering areas determined from transmitter relocations included deep pools, spring-fed areas, and lakes. Management problems associated with these extensive seasonal migrations may include the maintenance of the species migratory circuit in a region that may face future development.

Tschaplinski, P.J., and Harman, G.F. 1983. Winter distribution of juvenile coho salmon (*Onchorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Canadian Journal of Fisheries and Aquatic Sciences 40: 452 – 461.

This paper notes a 63 – 74% decrease in abundance of overwintering juveniles adjacent to inadequate forest buffer strip management, such as clear-cutting the riparian zone.