RESOURCE PARTITIONING AND BEHAVIORAL INTERACTIONS AMONG YOUNG-OF-THE-YEAR SALMONIDS, CHENA RIVER, ALASKA

A

THESIS

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By

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ABSTRACT

The partitioning of habitat and food and the behavioral interactions of young-of-the-year Arctic grayling (Thymallus arcticus), chinook salmon (Oncorhynchus tshawytscha), and round whitefish (Prosopium cylindraceum) were studied in the laboratory and in their natural habitat. Individuals of all three species defended territories. Arctic grayling were the most aggressive of the three and appear to displace round whitefish from their preferred habitat. In sympatry, there is a segregation of habitat use between Arctic grayling and chinook salmon. Stomach content analysis showed an overlap in diet among the three species.

Larvae of the three species emerged at different times and sizes, resulting in a size divergence among coexisting species during their first summer. The three species were found to inhabit faster moving and deeper water as they grew, resulting in a spatial separation of the species and a reduced probability of interactions and competition among them.

STUDY SPECIES

Arctic Grayling

The Arctic grayling, *Thymallus arcticus*, is found throughout Alaska and northern Canada. Its range extends as far south as Montana, where a small population is found in the headwaters of the Missouri River. In Asia, it is found from the upper Yalu River and northern Mongolia in the south and west to the Kara and Ob rivers in Siberia (Morrow 1980).

Arctic grayling spawn in the spring. In Alaska, the spawning period is from mid-May to mid-June (Schallock 1966; Tack 1974; Bendock 1979). A water temperature of about 4 C appears to initiate spawning in interior Alaska (Tack 1974). Spawning takes place in rivers, intermittent streams, and lakes, especially near the mouths of inlet streams (Warner 1957; Tack 1971). A variety of substrates are used for spawning. Spawning frequently occurs over gravel or rubble (Nelson 1954; Tack 1971). Spawning over mud (Reed 1964), silt (Bendock 1979), and organic matter (Tack 1980) has also been reported. Eggs hatch soon after deposition. Wojcik (1955) reported hatching in 18 days at 8 C and in 8 days at 15.5 C. The fry emerge from the gravel in 3 to 4 days (Kratt 1977).

The Arctic grayling is a popular sport fish. In Alaska, the 1980 sport harvest was estimated at 170,137 fish (Mills 1981). The grayling's popularity in Canada is large, with it being one of the few fish in the northern part of the country that provides fly fishing

(Scott and Crossman 1973). The Arctic grayling also contributes to the subsistence fishery in parts of Alaska and Canada (Scott and Crossman 1973; Morrow 1980).

Chinook Salmon

The chinook salmon, *Oncorhynchus tshawytscha*, ranges in Alaska from southeast Alaska north to Point Hope. Outside of Alaska, its range extends as far south as the Ventura River, California. In Asia, it is found from Hokkaido, Japan in the south to the Anadyr River, Siberia in the north (Morrow 1980).

It is an anadromous species, entering fresh water to spawn. In the Yukon River, there is a single run that enters the Yukon River in June. Those fish returning to the Chena River reach their destination from July to August (F. Andersen, Commercial Fisheries Division, Alaska Department of Fish and Game, Fairbanks, pers. comm.).

Spawning occurs in large rivers as well as tributaries, generally near riffles (Scott and Crossman 1973). The eggs overwinter under the ice and hatch in the spring. Emergence from the gravel occurs after the yolk sac has been absorbed, about 2 to 3 weeks after hatching (Scott and Crossman 1973). The young stay in fresh water for as long as 1 to 2 years in the Yukon River drainage or as little as 3 months in the Puget Sound, Washington area (Morrow 1980). In the Chena River, most chinook salmon smolts begin their migration to the sea in the spring just after ice breakup, almost 1 year after hatching.

Fish were observed using small sand drifts as velocity barriers, moving from drift to drift, staying close to the substrate. Regardless of water depth, round whitefish larvae were found within 5 to 20 mm off the substrate. Cover, in the form of vegetation, was sometimes present but was not utilized.

Larval Arctic grayling were seen in shallow shoreline areas of little or no velocity. They were also found in small side pools, sometimes getting stranded when pools became isolated as the river level dropped. In areas where a water current was present, larval grayling used sand drifts and rocks as velocity barriers. They were found within 10 to 20 mm off the substrate in association with silt and sand substrates. Rocks and debris were present in some areas but were not used as cover.

Juvenile Habitat Evaluation

Habitat use by young-of-the-year Arctic grayling, chinook salmon, and round whitefish was determined by evaluating fish densities in various habitats and associations with habitat variables such as depth, velocity, and substrate type. The mean fork lengths and size ranges of fish captured at each sampling site are included in Tables 3-8. Association with temperature was not evaluated. Arctic grayling were found in temperatures ranging from 5 to 17 C. Round whitefish were captured in temperatures in the 6 to 17 C range and chinook salmon were in temperatures ranging from 5 to 15 C.

Qualitative observations were made on the use of cover by all three species. Chinook salmon frequently used logs and debris for cover when frightened. The use of logs, debris, or vegetation for cover was not observed in Arctic grayling or round whitefish. When frightened, they would flee and in instances when cover was available, it was not utilized.

Fish density.--The densities of fish varied among habitat types. All three species were found in the highest densities in habitats of slow-moving water, shallow depth, and substrates of sand or silt. Arctic grayling were most abundant in areas with silt substrates and velocities of zero (Figure 2). These areas were found to accommodate approximately 6.2 fish per square meter. The depth of water with the highest density of grayling was 300 to 450 mm. Round whitefish were found in the highest density over a silt substrate and in a velocity of zero to 0.2 m/sec (Figure 3). The depths of water with the highest densities of whitefish were 300 to 450 mm and zero to 150 mm. Chinook salmon communities were high in density in habitats with sand substrates, water velocities of zero, and depths of 150 to 300 mm (Figure 4).

Fish length versus depth and velocity.--Fishes were found to inhabit deeper and faster water as they increased in length. Early in the season, all three species were seen and captured close to shore, in backwater areas, in pools, or in side channels. Fish lengths were

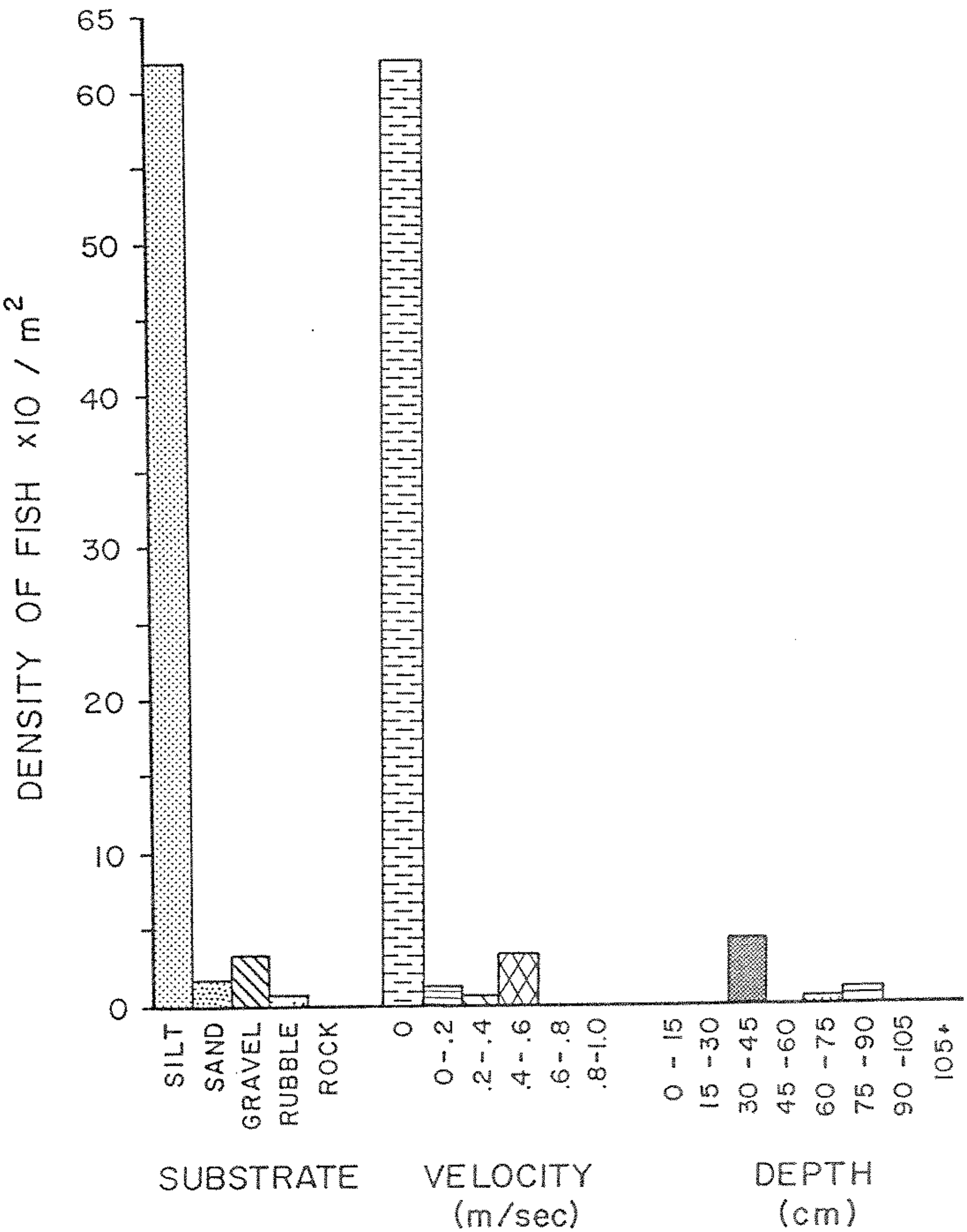

Figure 2. Density of juvenile Arctic grayling in relation to substrate, velocity, and depth.

Table 9. Fish lengths versus depth and velocity.

Species	Length (mm)	No. of fish	Average depth (cm)	Average velocity (m/sec)
Round whitefish	15-34	22	24.6	0.04
	35-54	44	42.3	0.103
	55-74	30	40.0	0.241
	75+	2	70.0	0.37
Chinook salmon	15-34	23	28.7	0
	35-54	200	43.0	0.125
	55-74	104	45.3	0.389
	75+	0	--	--
Arctic grayling	15-34	18	39.5	0.169
	35-54	141	48.6	0.251
	55-74	29	55.6	0.373
	75+	62	79.0	0.338

Table 10. Correlation of juvenile fish length versus depth and velocity.

Species	Correlation coefficient	
	Length vs depth	Length vs velocity
Chinook salmon (n = 329)	0.352*	0.695*
Arctic grayling (n = 250)	0.468*	0.425*
Round whitefish (n = 98)	0.443*	0.604*

* Significant at the 5% level.

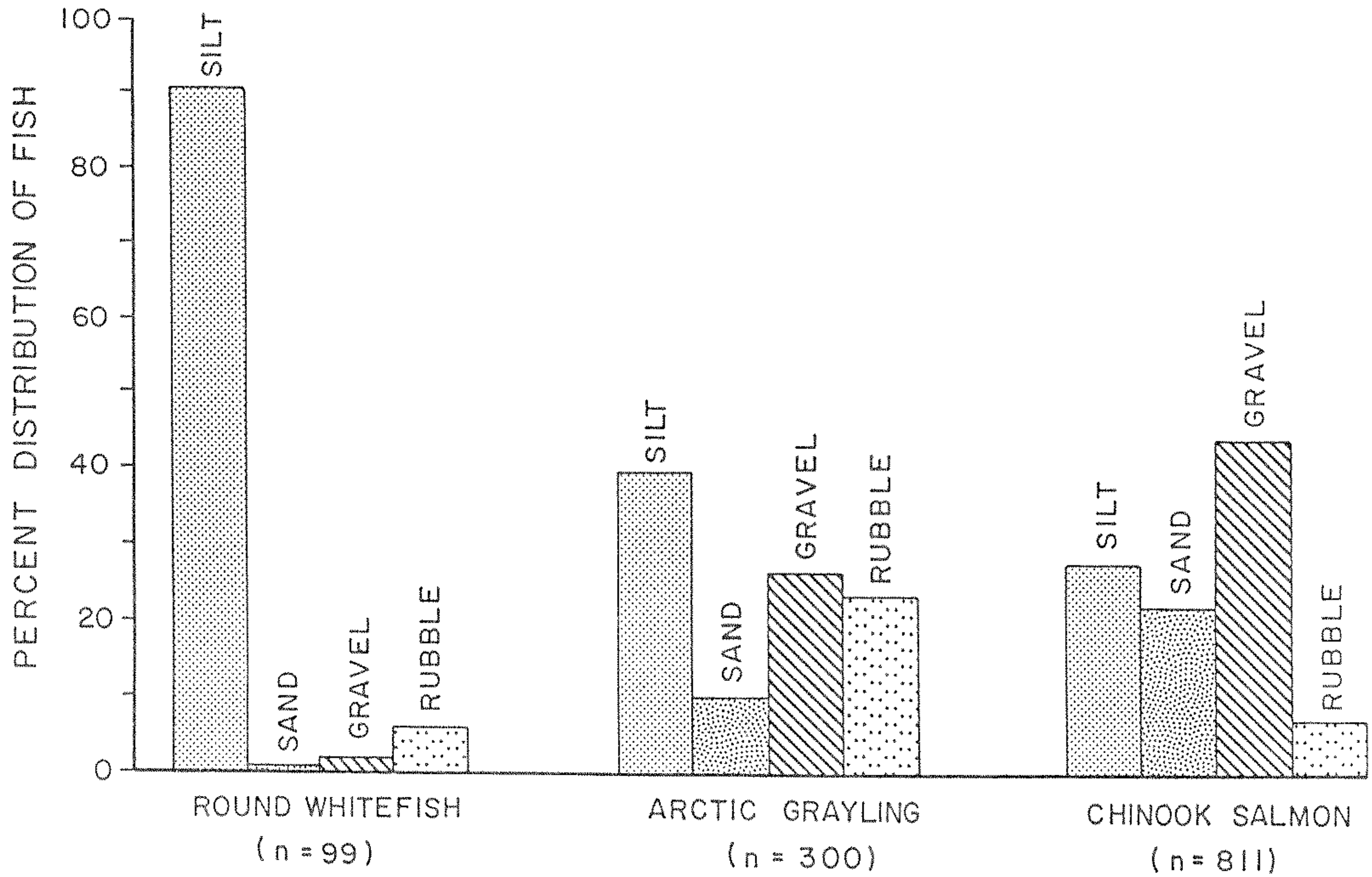

Figure 5. Distribution of juvenile round whitefish, Arctic grayling, and chinook salmon over substrate types.

difference between distribution over various substrate types in allopatry versus sympatry was significant ($p < 0.05$).

Juvenile Arctic grayling were also found predominantly over silt substrates (Figure 5). Out of the 300 fish caught, 39.7% were associated with silt. Gravel substrates were utilized by 26.7% of the grayling, 23.3% of the fish were found over rubble, and the remaining 10.3% were associated with substrates of sand. These were significant differences in substrate use ($p < 0.001$). In allopatry ($n = 251$), 39.4% of the grayling were associated with silt substrates, 30.7% were found over gravel, 27.1% over rubble, and 2.8% of the fish were over sand substrates (Figure 7). This was a significant difference ($p < 0.001$). A significant difference also occurred in sympatric communities ($n = 49$, $p < 0.001$), where sand substrates were utilized by 49.0% of the grayling captured or observed. Silt substrates were utilized by 40.8% of the fish, 6.1% of the grayling were associated with gravel, and 4.1% were over rubble. The difference in substrate association by Arctic grayling in allopatry versus sympatry was significant ($p < 0.05$).

Juvenile chinook salmon were associated more often with substrates of gravel (Figure 5). Out of 811 fish caught, 43.9% were found over gravel. Silt substrates were utilized by 27.4% of the chinook, 21.8% of the fish were associated with sand, and only 6.9% were found over rubble substrates. These differences were significant ($p < 0.001$). When chinook salmon were found allopatrically ($n = 622$), 41.0% were associated with gravel substrates. They were found equally distributed over sand and silt, with 28.3% over sand and 28.6% over silt. Rubble

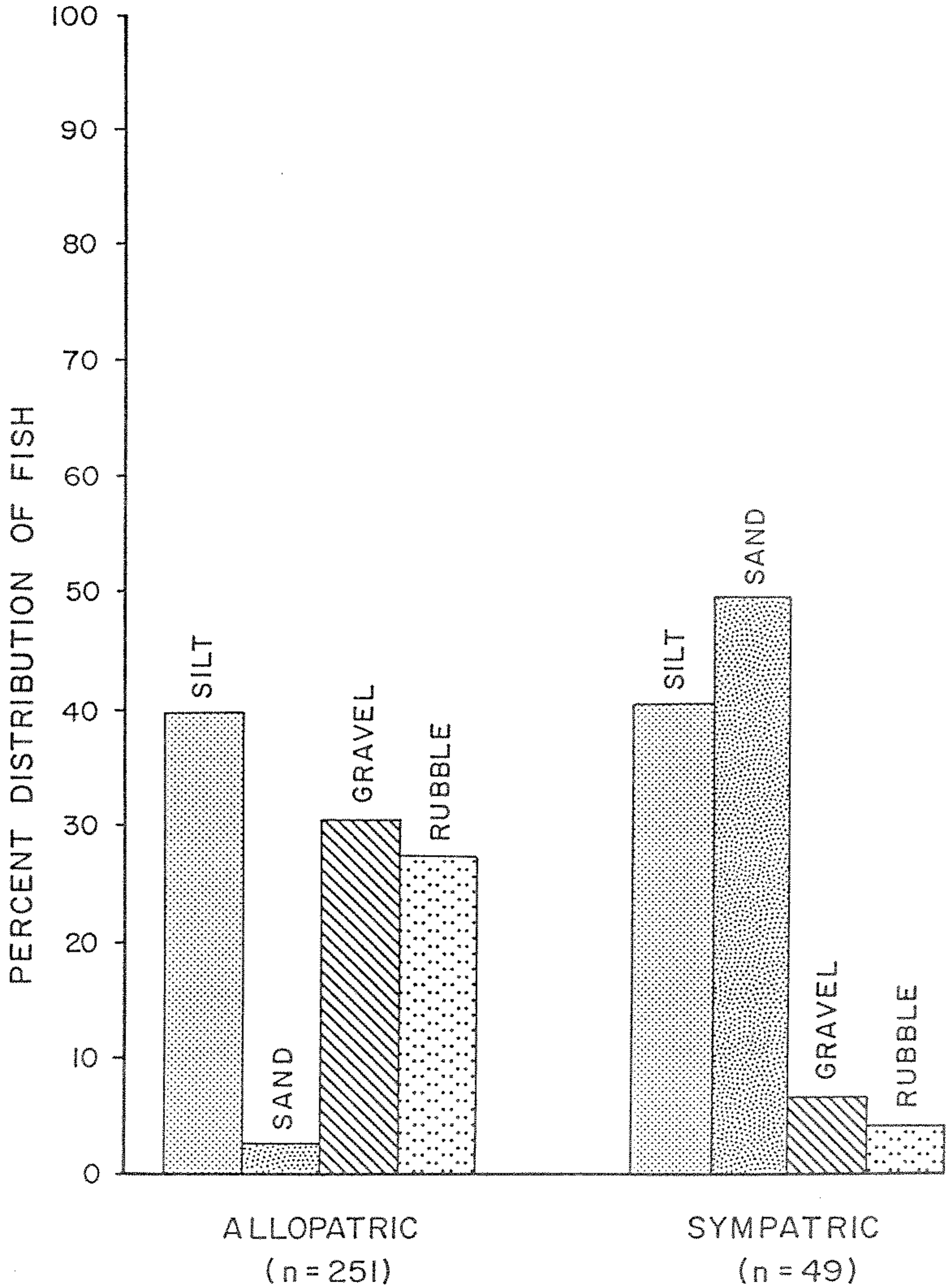

Figure 7. Distribution of juvenile Arctic grayling over substrate types--allopatric versus sympatric.

were found in the same habitat early in the season and did not segregate until temperatures in the main river increased. At that point, chinook salmon remained in the main river, while the coho salmon moved into cooler tributaries.

Arctic grayling have previously been observed moving from quiet, nearshore areas into swiftly moving water as they became larger (Kratt 1977). Vascotto (1970) found juvenile Arctic grayling in interior Alaska in shallow pools during June and July and in deeper pools during August. There has been very little work done on juvenile round whitefish habitat use, although one observation was made of age I round whitefish living in the same general area as the adults, although in shallower water (Hale 1981).

In the analysis of juvenile salmonid habitat use, fish densities and associations with various habitat characteristics were examined. The highest densities of all three species were found in slow or non-moving water of zero to 0.2 m/sec velocities. I attribute these high densities to the tendency towards schooling. Juvenile salmonids tend to school in non-moving waters, such as lakes, and to form territories in waters with a measurable water velocity (Keenleyside 1979). The natural density of schooling fish is much greater than a community of fish holding individual territories where they are spaced farther apart. Both chinook salmon and Arctic grayling were observed schooling during June and July in small pools of zero water velocity. The density data for various substrates show highest densities over silt and sand substrates which are characteristic of slow-moving pools of water.

In this study, round whitefish were associated most often with silt substrates. Other studies, as described by Hale (1981), have found round whitefish adults to be associated with substrates ranging from mud to boulders. In allopatry, I found all of the whitefish over silt substrates. In sympatric communities, there was a shift towards the coarser substrates (Figure 6). This shift could be a result of displacement by other species.

Arctic grayling were associated with all four substrate types (silt, sand, gravel, and rubble). Previous studies have found Arctic grayling associated with shallow gravel riffles (Vascotto 1970) and quiet river-edge areas (Tack 1971; Kratt 1977). No specific studies have been done previously in an attempt to quantify habitat use or substrate association by grayling. Arctic grayling, when found in allopatric groups, appeared to be associated similarly with silt, gravel, and rubble substrates (Figure 7). In sympatric groups, there was a distinct shift away from the gravel and rubble substrates and towards the silts and sands.

Chinook salmon were also associated with all four substrate types. When the data were analyzed comparing allopatry to sympatry, the chinook salmon shifted from the finer grain materials (silt and sand) in allopatry towards the coarser gravel and rubble substrates when found in sympatry (Figure 8). Previous studies have been done on substrate associations by juvenile chinook salmon. In the Kenai River in Alaska, chinook salmon juveniles were typically found over substrates in the range of 16 to 64 mm (mean = 40 mm) (U.S. Fish and Wildlife Service 1983).

It appears that when the three species are found sympatrically, substrate associations shift. Arctic grayling increase their usage of silt and sand areas, while round whitefish and chinook salmon shift their associations towards the gravel and rubble substrates. A difference in habitat use in sympatry versus allopatry indicates that interactions, and perhaps interference, may be causing displacement from one habitat type to another. Habitat displacement has been shown in other fish species as well. Warmwater lake fishes (sunfish, bluegill, and largemouth bass) segregated primarily by habitat and thus avoid competition (Werner et al. 1977). Nilsson (1967) describes this type of displacement as "interactive segregation."

In my observations of habitat use, I found that chinook salmon frequently used cover, such as logs and debris, when alarmed. This use of cover has been noted before (Lister and Genoe 1970; U.S. Fish and Wildlife Service 1983). In the Kenai River, Alaska, 42-49% of the juvenile chinook salmon were found within one swimming "burst" of cover (U.S. Fish and Wildlife Service 1983). Overhanging banks, tree stumps and branches, vegetation, and large boulders provided such cover. In contrast, Everest (1969) found that the presence of cover had little influence on juvenile chinook salmon distribution.

Arctic grayling and round whitefish in this study were not observed utilizing available cover. Vascotto (1970) did observe juvenile Arctic grayling using brushy vegetation and rocks for hiding. Round whitefish fry have been seen seeking cover within rubble and under large rocks (Normandeau 1969).

Behavior Observations

Territoriality and Agonistic Interactions

Territoriality and agonistic interactions can influence resource partitioning and perhaps cause displacement of a species from a preferred habitat (Nilsson 1963). Keenleyside (1979) stated that a territorial social structure is quite common among juvenile salmonids. Aggression and territoriality generally occur in defense of available food and areas of optimum stream flow or cover (Newman 1960; Mason and Chapman 1965; Chapman 1966; Vascotto 1970; Kratt and Smith 1979). Juvenile salmonids also have a dominance-hierarchy type of social structure (Jenkins 1969).

Arctic grayling, chinook salmon, and round whitefish were all found to be territorial in this study. Also, hierarchies were observed in the field and in the laboratory. Previous studies on chinook salmon, both allopatrically and sympatrically with coho salmon or steelhead trout, and allopatric studies on Arctic grayling confirm these findings (Reimers 1968; Everest 1969; Vascotto 1970; Stein et al. 1972; Kratt 1977). Previous data on round whitefish social behavior appear to be limited to observations on adult spawning behavior. Neither territoriality nor agonistic behavior was observed in spawning adults by

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