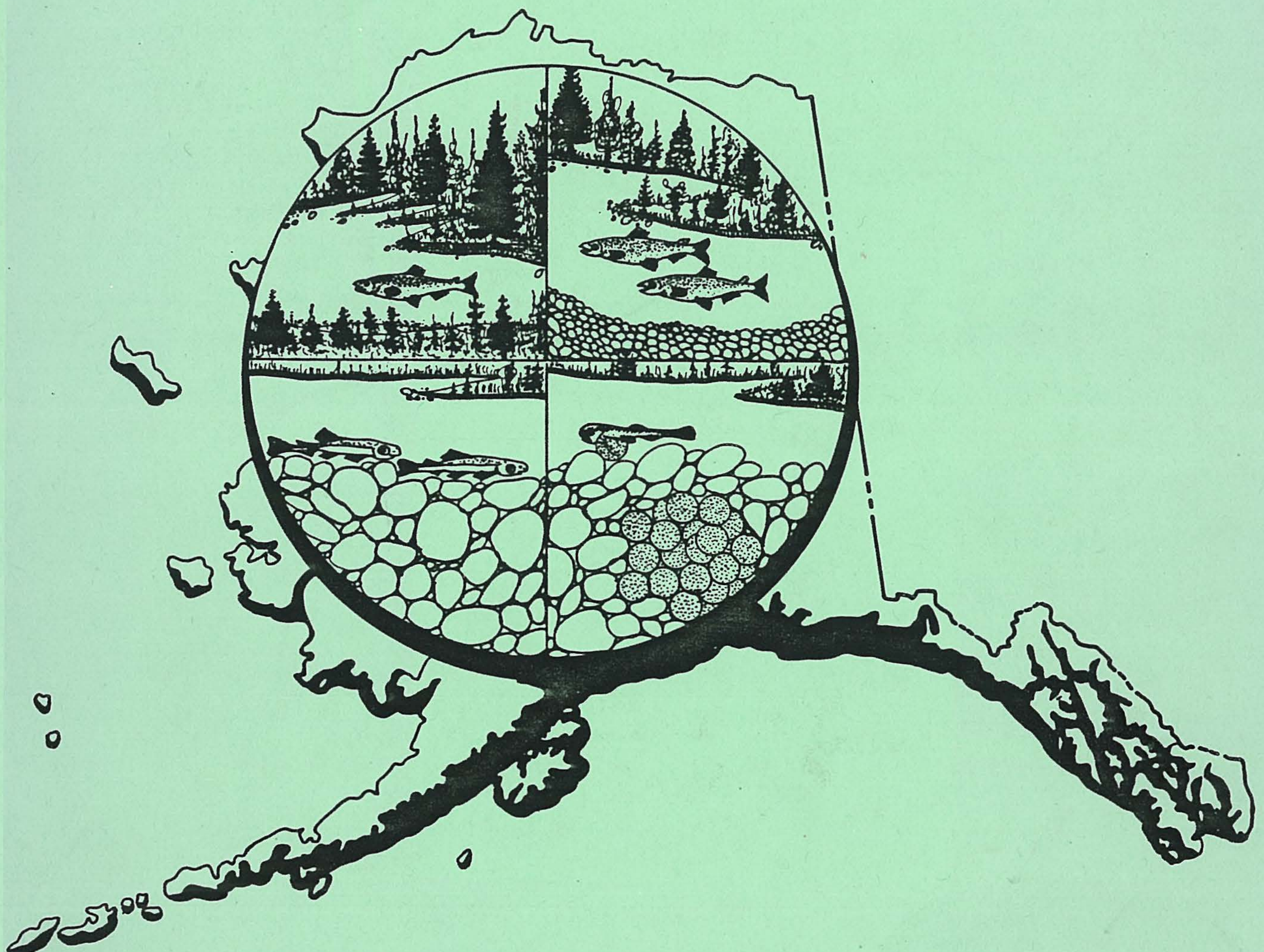
FRESHWATER HABITAT RELATIONSHIPS

DOLLY VARDEN-*SALVELINUS MALMA* (WALBAUM)



ALASKA DEPARTMENT OF FISH & GAME
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FRESHWATER HABITAT RELATIONSHIPS
DOLLY VARDEN CHAR (<u>SALVELINUS</u> <u>MALMA</u> (WALBAUM))

By

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I. INTRODUCTION

A. Purpose

The purpose of this project is to describe how selected physical and chemical features of lotic habitat within Alaska influence the survival and behavior of the various life stages of anadromous Dolly Varden char (Salvelinus malma (Walbaum)).

Objectives of this project are:

1. to gather data from published and unpublished sources within Alaska and from conversations with Alaskan fishery biologists concerning the relationships between lotic aquatic habitat and anadromous Dolly Varden survival and behavior.

2. to develop an Alaska data base for habitat-anadromous Dolly Varden char relationships. Because there are not sufficient data for the relationships between anadromous Dolly Varden char and conditions of the habitat, habitat suitability index relationships were not developed.

3. to identify data gaps and recommend appropriate projects to alleviate these gaps.

The following Life History Summary and Specific Habitat Relationships/Requirements sections will identify the lotic habitat relationships of the various life history and seasonal behavior stages of the anadromous Dolly Varden char which include:

upstream spawning migration,
spawning,
inmigrant migration to overwintering areas,

inmigrant overwintering areas,
egg and alevin development,
summer juvenile rearing,
juvenile migration to overwintering areas,
juvenile overwintering areas,
juvenile migration to summer rearing areas,
inmigrant migration to sea, and
smolt migration to sea

B. Distribution

The taxonomy of the Dolly Varden char, *Salvelinus malma* (Walbaum) is quite complex and a topic of debate. Morrow (1980) recognizes a northern and a southern form of Dolly Varden char, with the northern form equivalent to the anadromous Arctic char, *Salvelinus alpinus* (Linnaeus), and the southern form comprising the Dolly Varden char. Dolly Varden char is separate from the bull char, *Salvelinus confluentus*, which occurs in British Columbia, Washington, Oregon, Idaho and Montana (Behnke, 1980).

For purposes of this paper, Dolly Varden char are defined as those fish which occur south of the Arctic char and north of the bull char. Anadromous and non-anadromous Dolly Varden char are distributed within Alaska south of the Alaska Range.

C. Life History Summary

Migration of mature and immature Dolly Varden char from the ocean to southeastern Alaska may be concurrent and can extend from July through October. Immature individuals may stay in streams as long as spawners (two to three months) although non-spawning immature Dolly Varden char seldom remain more than one month prior to emigrating to other stream and lake systems, probably to overwinter. About 80% of the non-spawning immigrants left Hood Bay Creek, Alaska before the spawning fish (Armstrong and

Winslow, 1968). During 1966, tagged immature fish remained in Hood Bay Creek for 14 days (Armstrong, 1967), and mature fish for 85 days.

Age at maturity is variable; most Dolly Varden in southeast Alaska reach maturity by age four or five. Males may mature before females (Armstrong and Blackett, 1965).

Tagging studies in southeast Alaska (Armstrong, 1965a and 1974; Blackett, 1968; Heiser, 1966) indicated that mature, anadromous Dolly Varden char use their natal streams to spawn and lakes to overwinter. Immature fish originating in streams without lakes may enter several streams prior to finding a lake for overwintering. Immature fish of lake-stream origin probably re-enter the same system to overwinter. These tagging studies indicate that immature and spawned-out anadromous Dolly Varden char from numerous stream systems may use the same lake for overwintering.

The Dolly Varden, like other chars, usually spawns between September and November (Scott and Crossman, 1973). Blackett (1968) determined that the peak of spawning activity in Hood Bay Creek occurred between late October and early November. Spawning occurs in other southeastern Alaska streams from mid-September to mid-October (Blackett, 1968; Blackett and Armstrong, 1965). Both sexes display spawning coloration, although males are often scarlet on the ventral side and have black snouts.

Selection of spawning sites by anadromous Dolly Varden char appears to be influenced by various physical factors including current velocity, water depth and substrate composition. Fish have been reported spawning in sidechannel and mainstem riffle/run and pool reaches of streams on Kodiak Island and in southeast Alaska (Blackett, 1968; Wilson, Trihey, Baldrige, Evans, Thiele and Trudgen, 1981).

Limited observations indicate that the fish's spawning behavior is similar to other chars (Blackett, 1968; Scott and Crossman, 1973). Fish are usually paired, although more than one male may accompany a female (the largest male is usually dominant). The female is solely responsible for excavation of the redd (a depression in the stream substrate where fish spawn and deposit fertilized eggs). She forms the redd by turning on her side and thrashing the substrate with her caudal fin. The completed redd is typically oblong shaped. Dimensions of the redd vary with the size of the female and substrate and current velocities; redds are generally 30 to 61 cm (12-24 in) long and may be as deep as 30 cm (12 in). The male spawner actively defends the redd from male intruders and will nip and bite other males, sometimes grasping another male in the caudal peduncle for up to six seconds. Female spawners are not aggressive. (Blackett, 1968)

Fecundity of Dolly Varden char is variable among anadromous Alaska stocks and is greater with increasing female fish age and length (Blackett, 1968). For example, females about 300 mm fl (fork length) from Hood Bay Creek, Alaska contained less than 1000 eggs and females exceeding 450 mm fl supported at least 2000 eggs. Ripe eggs are usually 0.45 to 0.6 cm in diameter (Blackett, 1968).

The spawning pair descend into the redd and press against each other laterally. After the pair completes spawning the female may dig at the upstream end of the redd and displace gravel over the fertilized eggs. This gravel layer probably protects the eggs from sunlight and predation, reduces mechanical disturbance by ice and other objects while allowing water to transport oxygen to and metabolic wastes from the developing eggs.

Fish may spawn again with the same or a different partner and, unlike salmon, are capable in subsequent years. Males are less likely to survive spawning than females (Armstrong and Kissner, 1969). Armstrong and Kissner (1969) estimated that post-spawning mortality in Hood Bay Creek, Alaska was about 61% for male fish and 4% for female fish in 1967 and about 49% for male fish and 9% for female fish in 1968. This differential mortality is not understood, but the aggressive behavior of male spawners is probably a factor.

Emigration of spawned-out Dolly Varden char to the sea or to overwintering areas usually occurs within two weeks after completion of spawning. Fish surveys in Hood Bay Creek indicated that all spawned-out adults left the stream by late November (Armstrong and Winslow, 1968). These fish may have entered the ocean to feed for several months or moved to overwintering areas (Armstrong, 1974).

Longevity of Dolly Varden char is variable but fish in southeast Alaska may live nine to twelve years (Heiser, 1966; Armstrong, 1963).

Development of Dolly Varden eggs and alevins to the emergent fry stage requires about 210 days (Blackett, 1968). Hatching has been documented from 129 to 136 days at 8.5°C. The 1.5 to 2.0 cm long alevin typically remains in the gravel for an additional 60 to 70 days.

Limited research has focused on the survival of anadromous Dolly Varden eggs and alevins. Blackett (1968) estimated that egg to alevin survival within an area of Hood Bay Creek, Alaska was about 41 percent.

Intragravel flow, dissolved oxygen and sediment composition can influence the development and survival of salmonid eggs and alevins. Little work has focused on egg and alevin survival in relation to physical and chemical factors. Inferences can be made from work on other salmonid species. For example, transport of dissolved oxygen to and metabolic wastes from developing eggs and alevins by intragravel flow is crucial for survival of salmonid eggs and alevins (Vaux, 1962; Wickett, 1958). Relatively low intragravel dissolved oxygen levels during the egg development stage of various salmonids may increase egg mortality, delay or hasten egg development or reduce the fitness of alevins (Alderdice, Wickett and Brett, 1958; Silver, Warren and Duodoroff, 1963). Coble (1961) and other investigators have determined that salmonid egg survival is enhanced by increased intragravel flow despite sufficient intragravel dissolved oxygen levels. Factors which could reduce the quantity or quality of intragravel water include reduced streamflow, sedimentation, and accumulation of organic debris (McNeil and Ahnell, 1964; Koski, 1966; Reiser and Bjornn, 1979).

Severe streamflow alterations can harm developing salmonid eggs and embryos. Mechanical scouring of the redd could dislodge substrate and destroy developing eggs and embryos. McNeil (1966) observed damaged pink and chum salmon redds and displaced eggs of both species in several southeastern Alaska streams following autumn spates. Koski (1966) reported low survival of coho salmon eggs subjected to freshets several days after redd construction.

Low flows and cold winter temperatures could cause redds to desiccate or to freeze. McNeil (1966) noted low survival of pink and chum salmon eggs in streams with low winter flows during harsh winter conditions in southeast Alaska.

Koski (1966) determined that significant accumulations of fine sediments within chum salmon redds can retard or prevent the emergence of fry. Deposition of fine sediments in anadromous Dolly Varden char spawning areas could retard or prevent fry from emerging.

Water temperature affects hatching rates of salmonid eggs; warmer than normal water temperatures can accelerate hatching and result in earlier than normal fry emergence (Sheridan, 1962). Blackett (1968) determined that Dolly Varden began hatching after 129 days in water with a mean temperature of 8.5°C. No upper or lower temperature tolerance limits of Dolly Varden char eggs or alevins were found in the literature.

Upon emergence, anadromous Dolly Varden char occupy relatively quiet stream reaches. Blackett (1968) and Armstrong and Elliot (1972) noted yoy fish in shallow stream margins of Hood Bay Creek, Alaska. Armstrong and Elliott also found yoy fish in rivulets along Hood Bay Creek during early summer. These stream margins were often only 1 m wide and 4 cm deep. No evidence of yoy fish entrapment by dewatering within these stream margins was detected in the literature. Yoy Dolly Varden, which feed primarily from the benthos, characteristically remain on or near the substrate, sometimes remaining motionless and occupying gravel interstices. Yoy coho salmon, however, feed primarily from the surface within these same areas (Blackett, 1968).

Earlier research indicates that juvenile salmonids occupy areas (Wickham, 1967) with relatively slow current velocities often adjacent to areas with faster current velocities and with higher densities of drifting invertebrates (Everest and Chapman, 1972). A fish moves periodically into the areas of greater food availability to forage and returns to resting positions in areas of slower current. This minimizes energy expenditures and maximizes feeding success (Chapman and Bjornn, 1969). As fish grow they often occupy deeper and faster areas of the stream (Everest and Chapman, 1972). This behavior probably applies to juvenile Dolly Varden char. Leggett (1969) suggested that the cylindrical body shape of bull char, which is morphologically similar to Dolly Varden, probably enables these fish to occupy areas of faster current velocities than most other salmonids. Other salmonids typically have laterally compressed bodies.

Habitat selection by older pre-smolt Dolly Varden char is not well documented, although the char are distributed in deeper, sometimes faster habitat than yoy fish. Heiser (1966) noted that yearling and older pre-smolt Dolly Varden char occupied both still and flowing reaches of several inlet tributaries of Eva Lake. This lake was characterized by gravel and silt substrates with varying amounts of vegetation. Researchers studying Hood Bay Creek classified it into ten habitat types ranging from sloughs, undercut bank margins, pools and riffles. Baited minnow traps were placed in each habitat type, and length and frequency of pre-smolt coho salmon and Dolly Varden char were compared from each habitat type during July and August 1971. Pre-smolt Dolly Varden char and coho salmon were taken from all habitat types. The smallest Dolly Varden char (41-50 mm) were taken in sloughs and sidechannel undercut bank areas, and the largest Dolly Varden were found in riffles.

Yearling and older pre-smolt Dolly Varden char occupy "pools, quiet sidechannels and sloughs and tributaries off the mainstems of both. . ." the Terror and Kizhuyak Rivers, Alaska, although juvenile fish are occasionally found behind boulders in faster water (Wilson, Trihey, Baldrige, Thiele and Trudgen, 1981). Minnow traps were found to give a biased indication of habitat occupancy by fish because the bait may attract fish from a considerable distance. Habitat conditions where the fish are actually residing may be quite different from conditions immediately around the trap.

Reed and Armstrong (1971) noted that juvenile coho salmon and Dolly Varden char were capable of entering and exiting baited minnow traps fished for 24 hours. The placement of two lengths of wire across the entrance to each trap resulted in a higher fish retention rate.

Distribution and abundance of pre-smolt Dolly Varden char may be influenced by intra and interspecific fish interactions. Observations of juvenile coho salmon, Oncorhynchus kisutch (Walbaum), and Dolly Varden char in Hood Bay Creek and in aquariums (Armstrong and Elliott, 1972) revealed that Dolly Varden fry are aggressive among themselves and in association with coho fry. Dolly Varden were frequently attacked by coho salmon fry but were never observed attacking coho fry. More Dolly Varden fry remained near the substrate when associated with coho fry than when they were alone. Coho fry occupied the upper half of the aquaria when alone and with Dolly Varden char fry.

Aquaria tests with older, pre-smolt Dolly Varden char and coho salmon indicated that Dolly Varden established and defended territories when alone and when with coho fingerlings. Dolly Varden fingerlings generally occupied positions within the aquaria at or near the bottom, but when alone, they occupied more mid and shallow depth positions. Coho fingerlings were consistently found in the upper strata of aquaria and seldom attacked Dolly Varden char fingerlings (Armstrong and Elliott, 1972).

Juvenile, anadromous Dolly Varden char grow relatively slowly during the three to four years prior to emigrating to the Pacific Ocean. Young of the year fish from Hood Bay Creek, Alaska grew about 10 mm between July 7 and October 1, 1965, reaching a mean fork length of about 38 mm (Blackett, 1968). Growth rates of pre-smolt fish may vary and length ranges of yoy and older age classes often overlap. Pre-smolt fish in Alaska generally grow 10 to 30 mm annually, primarily during the summer months (Armstrong, 1963; Heiser, 1966; Blackett, 1968).

The summer diet of stream rearing pre-smolt Dolly Varden char is influenced by food availability, fish size and stream habitat selection (Armstrong and Elliott, 1972). Gut analysis of pre-smolt fish from Hood Bay Creek during the summer rearing period (April to November) showed that substantial numbers of immature and adult aquatic insects were eaten throughout this period. Emergent and emigrant yoy salmon consumed invertebrates from April to June and salmon eggs from July to November. Relatively large pre-smolt Dolly Varden char ate more and larger food items than smaller fish. Pre-smolt fish occupying stream reaches characterized by overhanging vegetation and relatively low current velocities (such as sloughs and stream margins) generally consumed more terrestrial and surface floating insects than fish occupying mid-channel areas with moderate to fast current velocities and with greater invertebrate drift. No drift samples were taken to compare drift composition with fish gut contents. Pre-smolt Dolly Varden char occupy areas at or very near the substrate in streams with coho salmon. The char may browse along the substrate or consume drifting invertebrates (Armstrong and Elliott, 1972).

Land practices which result in removal of vegetation along stream margins and deposition of fine sediments in the stream channel could possibly reduce the abundance and fitness of pre-smolt Dolly Varden char (Armstrong and Elliott, 1972; Elliott and Dinneford, 1976).

The seasonal distribution of pre-smolt Dolly Varden char is apparently influenced by fluctuating flows and declining water temperatures during the late summer and fall. Fish appeared to be distributed evenly throughout Hood Bay Creek, Alaska from July through September. By November there were considerably fewer fish in the downstream reaches. Significantly more pre-smolt Dolly Varden char were captured in the upper stream reaches during this time. Fish were observed schooling in mid-stream in

October, behavior which had not been noted previously. Water temperatures during July through September ranged from 5° to 9°C (41°-48°F), and water temperatures during October and November were substantially lower (Blackett, 1968). Armstrong and Elliott (1972) found substantial numbers of pre-smolt Dolly Varden char in the upper reaches of Hood Bay Creek in late winter where water temperatures were consistently 6°C warmer than in downstream reaches. Armstrong and Elliott (1972) concluded that warm, ice-free reaches of Hood Bay Creek attract overwintering pre-smolt Dolly Varden char and that survival rates are higher in the warmer regions. Downstream reaches of Hood Bay Creek become frozen during the winter.

Elliott and Reed (1974) and Elliott (1975) determined that pre-smolt Dolly Varden char leave Starrigavan Creek, Southeast Alaska and enter spring-fed tributaries during autumn. The tributaries are characterized by relatively warm winter water temperatures and somewhat stable flows. Immigration of pre-smolt Dolly Varden char and coho salmon to overwintering areas usually commenced in September, peaked in early October, and ceased by December. Spates and decreasing water temperatures within Starrigavin Creek appeared to stimulate movement of fish into these streams.

Selection of lotic overwintering habitat by juvenile Dolly Varden char is not well documented.

Elliott and Reed (1974) noted that juvenile Dolly Varden char in Spring Pond Creek burrowed into logging slash and other debris when water temperatures decreased to 2°C. Fish reappeared when water temperatures rose above about 2°C.

Other researchers have noted movement of juvenile salmonids when stream water temperatures decrease in the autumn. As water temperatures decrease, fish activity levels and digestion rates drop (Reimers, 1957; Chapman and Bjornn, 1969). Chapman (1966) stated that the distribution of winter rearing juvenile salmonids in the Pacific Northwest and other temperate areas is probably space related. Fish reduce feeding and seek overwintering areas when water temperatures decrease to or below 5°C. Winter stream conditions, including reduced flows, partial or complete ice-cover and water temperatures at or near freezing do not constitute suitable aquatic habitat for rearing salmonids. Juvenile salmonids reduce the risk of mechanical injury and displacement by avoiding shallow, cold stream reaches by moving to warmer and deeper stream reaches, burrowing into substrate interstices, or associating with submerged logs and root masses. Factors which could adversely affect the winter survival of juvenile (pre-smolt) anadromous Dolly Varden include freezing during streamflow reductions and displacement and injury from dislodged substrate material during spates. The movement of juvenile Dolly Varden to more suitable overwintering habitat in response to reduced winter streamflows has not been documented. Bustard (1973) reported the movement of yoy steelhead trout (Salmo gairdneri (Richardson)) to overwintering areas in response to altered flows in Carnation Creek, British Columbia. Bustard (1973) speculated that yoy steelhead trout overwintering within "small rubble, often less that 15 cm in diameter" could be susceptible to injury from substrate movement during spates in Carnation Creek, British Columbia. Hartmann (1968) found that stable submerged log jams provide excellent winter habitat for fish, although loose logging debris which is susceptible to displacement by floods is not suitable for salmonid overwintering habitat.

Removal of submerged logging debris, naturally occurring fallen trees and root masses, and destruction of bankside vegetation and associated submerged roots could significantly reduce the abundance of juvenile Dolly Varden char in streams where these materials are used for overwintering habitat. Bustard (1973) emphasized the need to identify and preserve quality fish overwintering habitat, especially along small permanent and intermittent streams that may be overlooked as valuable fish habitat during timber harvest operations.

Food consumption by pre-smolt Dolly Varden char in overwintering areas is much reduced from summer levels (Armstrong and Elliott, 1972; Elliott and Reed, 1974). Armstrong and Elliott (1972) ascribed the difficulty in obtaining juvenile Dolly Varden char by baited minnow traps in the headwaters of Hood Bay Creek to the relatively low water temperatures, 5°C to 6.1°C, which influence fish activity.

Emigration of pre-smolt Dolly Varden char from winter to summer rearing areas appears to be influenced by water temperature and flow conditions (Elliott, 1975 and 1976). Rising water temperatures were associated with the emigration of pre-smolt Dolly Varden from Spring Pond Creek, Alaska. Fish emigrated from March or April through June. Floods appear to retard fish emigration within Spring Pond Creek.

Emigration of immature and mature anadromous Dolly Varden from lakes usually occurs after ice breakup in lakes. Factors, other than the breakup of ice, which could influence the timing of fish emigration from lakes include water temperature and streamflow (Armstrong, 1965b).

Behavioral and physiological changes, collectively termed smoltification, and subsequent seaward migration of age 2 to 4 and sometimes older juvenile anadromous Dolly Varden typically occurs in southeast Alaska streams from April to June. Non-lake systems may support an additional autumn smolt migration (Armstrong, 1965 and 1970; Armstrong and Kissner, 1969). Physiological changes for salinity tolerance, probably begin before seaward migration (Conte and Wagner, 1965). Factors affecting timing of smoltification are speculative but fish size appears to be influential (Armstrong, 1965a). For example, Armstrong (1965) suggested that fish which reach migratory size several months after spring leave streams without lakes, such as Hood Bay Creek, and enter streams with lakes, such as Eva Creek, where they overwinter until the following spring. Fish have not been found to migrate seaward from lake-stream systems, such as Eva Lake during autumn. Armstrong (1965) speculated that fish that reach migratory size in lakes during the autumn probably overwinter and migrate seaward the following spring. Dolly Varden smolts may range in length from about 100 to 180 mm fork length (Heiser, 1966). Armstrong (1970) determined that spring smolts from Hood Bay Creek, $\bar{x}$ = 129-134 mm (fl) were considerably smaller than autumn smolts, $\bar{x}$ = 141-146 mm (fl) during 1967, 1968 and 1969.

D. Economic Importance

Anadromous Dolly Varden char are an important and sought after sport fish (Morrow, 1980).

II. SPECIFIC HABITAT REQUIREMENTS

A. Upstream Migration

Adult and immature anadromous Dolly Varden char leave the Pacific Ocean and enter various lake and non-lake stream systems from July through December. Various studies have indicated that lake and non-lake streams may support spawning anadromous Dolly Varden char although almost all fish (both spawning and non-spawning) entering non-lake streams such as Hood Bay Creek, Alaska, leave these streams and enter streams with lakes where they overwinter (Armstrong, 1963; Armstrong, 1965b; Armstrong and Winslow, 1968; Armstrong and Kissner, 1969). This section will discuss the upstream migration of anadromous fish in non-lake streams.

1. Stream Flow

Adult and immature anadromous Dolly Varden may migrate up non-lake streams for varying distances from July through November. Peak numbers of fish have been reported during spates in August and September in Hood Bay Creek (Armstrong, 1967; Armstrong and Winslow, 1968; Armstrong and Kissner, 1969).

Peak numbers of fish have been recorded entering selected streams during periods of high water in August and September (Armstrong and Winslow, 1968; Armstrong, 1969). Upstream fish migration may be hindered by high current velocities resulting from rapids and culverts. Low flows and shallow water depths could also prevent upstream fish passage.

2. Water Temperature

Water temperatures coinciding with the commencement, peak and termination of the inmigration of anadromous Dolly

Varden in Hood Bay Creek, Alaska during 1967, 1968 and 1969 were about 4.4° to 12.6°C, 6.1° to 11.1°C and 3.3° to 4.4°C (Armstrong, 1967; Armstrong and Winslow, 1968; Armstrong and Kissner, 1969). Water temperatures at the end of the inmigration are slightly lower than those during the beginning.

3. Light

Most Dolly Varden move upstream in Hood Bay Creek at night (Armstrong and Kissner, 1969).

4. Current Velocity

No information regarding the upstream swimming ability of anadromous Dolly Varden was found in the literature.

B. Spawning

1. Current Velocity

There are only limited observations of anadromous Dolly Varden spawning habitat with respect to current velocity. Blackett (1968) reported fish spawning in a reach of Hood Bay Creek, Alaska which had current velocities ranging from 0.3 to 1.2 m/sec (1.0-3.8 ft/sec). Blackett and Armstrong (1965) noted fish (presumably spawning) in a reach of Rodman Creek, southeast Alaska, with a current velocity estimated to be about 0.63 m/sec (2 ft/sec).

2. Substrate

Anadromous Dolly Varden typically spawn in small gravels. Blackett (1968) found fish spawning primarily in small gravels, 6 to 50 mm in diameter in Hood Bay Creek. Blackett and Armstrong (1965) observed what appeared to be fish spawning in Rodman Creek, southeast Alaska, in substrate composed of "25% sand and 75% rubble." No substrate classification scheme was presented. Spawning anadromous fish use gravels ranging from 2 to 32 mm in diameter in the Terror and Kizhuyak Rivers, Kodiak Island, Alaska (Wilson et al., 1981).

3. Water Depth

The relationship between spawning habitat and water depth is speculative. Blackett (1968) observed spawning fish at depths exceeding 0.3 m whereas Blackett and Armstrong (1965) noted probable spawning activity in a different southeastern Alaska stream in water depths of about 1.25 m.

4. Cover

There is little available information on the influence of stream cover on selection of spawning habitat, however, cover may be a requirement.

C. Inmigrant Migration to Overwintering Areas

Inmigrant, immature Dolly Varden in non-lake streams such as Hood Bay Creek, Alaska usually leave within several weeks; however, spawners may remain for up to three months (Armstrong, 1967). Periods of high water may enhance outmigration of immature and spawned-out Dolly Varden in Hood Bay Creek (Armstrong and Kissner, 1969).

Immature and spawned-out adult Dolly Varden inmigrate to overwintering areas of Eva Lake at different times. Immature individuals entered primarily during July, August and September, and spawned-out adults entered in late October and November

(Blackett and Armstrong, 1965). Most fish passed upstream during periods of darkness.

D. Inmigrant Overwintering Areas

Lakes, including turbid glacial lakes support overwintering populations of juvenile and adult Dolly Varden char (Armstrong, 1965b; Schmidt, Robards and McHugh, 1973). The char typically remain in Eva Lake from December through mid-March (Armstrong and Blackett, 1965). Their distribution within lakes may be quite restricted (Armstrong, 1965b; Schmidt et al., 1973).

E. Egg and Alevin Development

1. Water Temperature

Blackett (1968) determined that anadromous Dolly Varden eggs hatched in 129 days with 675 thermal units. Absorption of the yolk sac was completed about 65 days later when water temperatures were 2.2° to 2.8°C.

F. Summer Juvenile Rearing

1. Water Depth

Recently emerged Dolly Varden char typically occupy extremely shallow rivulets, tributaries or streamside margins (Blackett, 1968; Armstrong and Elliott, 1972). They may occupy deeper stream reaches as they grow (Armstrong and Elliot, 1972).

2. Current Velocity

Recently emerged Dolly Varden char may occupy extremely shallow, low current velocity stream reaches (Blackett, 1968; Armstrong and Elliot, 1972). Minnow traps captured juvenile, pre-smolt Dolly Varden char in Hood Bay Creek from a variety of lotic habitat types. The largest juvenile char, about 150 mm fork length, were captured in riffles (Armstrong and Elliott, 1972).

3. Instream Cover

Juvenile Dolly Varden have been observed in proximity to various forms of instream cover including root balls, trees and undercut banks (Armstrong and Elliott, 1972; Wilson, et al., 1981).

4. Substrate

Recently emerged fry have been found along stream margins with varying sizes of substrate, shallow depths and very low current velocities (Blackett, 1968; Armstrong and Elliott, 1972). Heiser (1966) noted juvenile Dolly Varden char occupying "gravel or muddy substrata" within tributaries of Eva Lake, Alaska.

Deposition of significant amounts of fine sediment in streams with limited flushing abilities could reduce the quality of juvenile anadromous Dolly Varden rearing habitat. Laboratory stream channels containing unimbedded rubble (0.30 m in diameter) consistently supported more juvenile steelhead trout, Salmo gairdneri (Richardson), and chinook salmon, Oncorhynchus tshawytscha (Walbaum), than stream channels containing imbedded rubble and with water temperatures exceeding 5°C (Bjornn, Brusven, Molnau, Milligan, Klampt, Chacho and Schaye, 1977). Bjornn et al. (1977) ascribed the reductions in fish abundance in the channels with imbedded rubble to loss of intersticial cover.

G. Juvenile Migration to Overwintering Areas

1. Water Temperature

Juvenile (pre-smolt) Dolly Varden char have been reported moving upstream in Starrigavin Creek when water temperatures decreased from about 7° to 4°C. The fish entered Spring Pond Creek, a spring-fed tributary characterized by more stable water temperatures and flows (Elliott and Reed, 1974; Elliott, 1975). No fish movement into Spring Pond Creek was noted after Starrigavin Creek water temperatures decreased below 4°C.

2. Stream Flow

Freshets within Starrigavin Creek, Alaska appeared to stimulate immigration of juvenile Dolly Varden char to Spring Pond Creek (Elliott and Reed, 1974; Elliott, 1975) until water temperatures decreased below 4°C.

H. Juvenile Overwintering Areas

1. Water Temperature

Fry overwintering areas in southeast Alaskan streams usually have relatively warm water temperatures. Spring Pond Creek, a tributary of Starrigavin Creek, supports overwintering Dolly Varden char. This stream usually has winter water temperatures at or above 1.0°C (Elliott and Reed, 1974; Elliott, 1975).

The headwater reaches of Hood Bay Creek also appear to support overwintering juvenile Dolly Varden char. Armstrong and Elliott (1972) found the greatest numbers of juvenile fish during March and April in headwater reaches of Hood Bay

Creek where water temperatures were 5° to 6.1°C. Downstream reaches were characterized by water temperatures of 3.9°C.

Elliott and Reed (1974) noted that Dolly Varden fry hid among substrate interstices as water temperatures in Spring Pond Creek decreased to 4°C to 2°C. When water temperatures rose above 2°C in March, fish began to move about the stream.

2. Stream Flow

Stable winter flow conditions such as those found in Spring Pond Creek, are probably very important to winter survival (Elliott and Reed, 1974; Elliott, 1975).

3. Substrate

Debris and large substrate material may enhance the quality of fish overwintering areas. Elliott and Reed (1974) noted juvenile Dolly Varden char burrowing into logging debris and slash when water temperatures declined to 4°C or below in Spring Pond Creek, Alaska.

Deposition of fine sediments in streams with limited sediment flushing capabilities could imbed substrate material and significantly reduce the available overwintering habitat for juvenile Dolly Varden char. Experiments of overwinter habitat selection by juvenile chinook and coho salmon and steelhead and cutthroat trout (*Salmo clarki* (Richardson)) at water temperatures less than 5°C indicate that substrate (15-30 cm in diameter) with interstices devoid of fine sediment consistently supported more fish than substrate imbedded with fine sediment (Bustard, 1973; Bjornn et al., 1977).

I. Juvenile Migration to Summer Rearing Areas

1. Water Temperature

Juvenile (pre-smolt) Dolly Varden char were found to emigrate from Spring Pond Creek, a spring-fed stream inhabited by overwintering juvenile and adult resident and anadromous Dolly Varden, to Starrigavin Creek when water temperatures rose to 4° to 5°C in April 1974 (Elliott, 1975).

2. Stream Flow

Elliott (1975) suggested that floods in Spring Pond Creek depressed the downstream movement of juvenile Dolly Varden. Fish emigration increased when flows decreased.

J. Inmigrant Migration to Sea

1. Water Temperature

Most immature and mature Dolly Varden char (not including smolts) emigrated from Eva Lake Creek, Alaska shortly after ice-breakup. Water temperatures ranged from 4.4° to 6.7°C (Armstrong, 1965b).

2. Stream Flow

Although ice-breakup in Eva Lake appeared to strongly influence fish migration to the sea, peak numbers of emigrants moved downstream during flood states (Armstrong, 1965b).

3. Light

Most Dolly Varden char emigrated from Eva Lake during darkness. During the height of the migration individuals were detected moving downstream during both night and day (Armstrong, 1965b).

K. Smolt Migration to Sea

1. Water Temperatures

Water temperatures coinciding with the initiation, peak and the near-end of the spring Dolly Varden smolt migration in Hood Bay Creek, Alaska were 3°, 5° and 6°C, respectively, during 1967, 1968 and 1969 (Armstrong, 1970).

Water temperatures at the beginning, peak and end of the smolt migration during 1962 and 1963 were 3°, 5° and 8°C in Eva Lake, and 6° and 10°C in Eva Creek (Armstrong, 1970). These values are somewhat similar to water temperatures during the spring smolt outmigration from Hood Bay Creek, Alaska.

Dolly Varden smolt stopped migration in mid-June 1957 in the Anchor River, Alaska when the water temperature reached 13.3°C (Allin, 1957).

The autumn smolt migration in Hood Bay Creek, Alaska began when water temperatures were 8°C and ended when water temperatures were 6°C during 1967, 1968 and 1969 (Armstrong, 1970).

2. Stream Flow

Floods apparently influenced the timing of the spring and autumn Dolly Varden cnar smolt migration in Hood Bay Creek, Alaska. Peak numbers of smolts migrated downstream during periods of high water (Armstrong, 1970). Smolts have also been noted emigrating from Mendenhall Lake (near Juneau) during the spring and early summer. Peak migrations often coincide with freshets (Bethers, 1974).

3. Light

Most smolt migrate downstream in Hood Bay and Eva Creeks during darkness, although the peak of smolt emigration in Eva Creek occurred during both night and day (Armstrong, 1970).

III. CONCEPTUAL SUITABILITY INDEX CURVES

Habitat suitability index curves were not constructed for anadromous Dolly Varden char. There were limited data relating the various Dolly Varden life stages to the physical and chemical characteristics of the habitats. When data were available, they were often not in a form which could be used to construct habitat suitability curves.

IV. DEFICIENCIES IN DATA BASE

A limited number of investigations indicate that juvenile anadromous Dolly Varden char move to spring-fed reaches of streams with relatively warm water temperatures during the fall and leave these areas the following spring, as evidenced by baited minnow trap samples from Hood Bay Creek (Blackett, 1968; Armstrong and Elliott, 1972) and by weir sampling in the Starrigavin Creek watershed (Elliott and Reed, 19/4; Elliott, 1975, 1976 and 1977). The Starrigavin watershed was affected by timber harvest and deposition and removal of logging debris.

The relationships between upstream swimming capabilities of juvenile and adult anadromous Dolly Varden and current velocity, water temperature, water depth and stream gradient have not been sufficiently investigated. Excessive stream gradient and high current velocities associated with natural stream features or culverts could impede migration of juvenile and adult fish to summer and winter rearing and spawning areas. The upstream swimming performance of anadromous Dolly Varden is probably influenced by the above factors as well as fish size, spawning condition and, possibly, sex.

Lotic habitat selection by spawning anadromous Dolly Varden char is probably collectively influenced by current velocity, water depth, substrate composition and imbeddedness and instream and bankside vegetation. Few studies have objectively described the above lotic habitat conditions. If a specific area of a stream is characterized by one unfavorable spawning habitat feature, such as excessive current velocity or unsatisfactory substrate composition, that particular area of stream will not be selected by spawning fish despite other favorable habitat conditions.

Habitat conditions available for Dolly Varden spawning sites influence selection of spawning areas, although, methods of objectively describing this habitat have varied. For example, within a hypothetical stream, stream reach A may support one pair of spawning fish and reach B, four pairs. These two reaches may contain equal amounts of "spawning habitat" as defined by current velocity, water depth and substrate composition and imbeddedness. The difference between the two reaches may be that "spawning habitat" within stream reach A was concentrated in one area and "spawning habitat" within stream reach B was scattered among relatively large substrate and fast water. The non-contiguous distribution of spawning habitat in stream reach B probably allows more fish to spawn because of increased cover and visual isolation. This example illustrates the need to examine entire stream reaches to better understand selection of spawning habitat.

The influence of dissolved oxygen levels, rates of intragravel flow, sediment compositions and water temperatures on the survival and development of anadromous Dolly Varden char is not understood. Numercus research focusing on the eggs and alevins of other salmonids indicate that the physical and chemical factors exert a substantial and often interactive influence on the survival and fitness on the development stages.

Adult and immature (post-smolt) Dolly Varden typically overwinter in lakes, although fish have been found in spring-fed reaches of streams in southeast Alaska. The importance of glacial or glacial-influenced lakes and streams has not been adequately examined. The relationships between overwintering habitat and water depth, current velocity, substrate composition, water temperature and other variables has not been determined. The distribution of overwintering Dolly Varden in selected lakes may be quite restricted, although physical and chemical factors which may limit the fish's distribution are not known.

Juvenile (pre-smolt) Dolly Varden have been documented moving to spring-fed tributaries and burrowing into logging debris when water temperatures approached 4°C. There were no references found in the literature of juvenile fish using mainstem reaches of rapid-runoff streams for overwintering habitat. The apparent affinity of yoy and older juvenile fish to rapid run-off streams during the summer indicates that this type of area could be used for overwintering habitat.

There is little available information concerning the lotic summer micro-habitat selection by juvenile (pre-smolt) anadromous Dolly Varden char with respect to various physical and chemical lotic habitat variables, food availability and the presence of other fishes. Some investigators have attempted to describe juvenile fish habitat quantitatively by bankside observation, electro-shocking and baited minnow traps with varying degrees of success. Apparently snorkeling has not been used for fish observation in clearwater streams. Snorkeling has been shown to be a valuable fish observation technique in clearwater streams of the Pacific Northwest and the midwest (Everest and Chapman, 1972; Fausch, 1978).

Some work has focused on the feeding habits of juvenile (pre-smolt) fish occupying mainstem versus stream margins but no drift or benthos sampling was done to formulate "forage ratios." Few observations of the feeding behavior of juvenile Dolly Varden char have occurred in streams except for yoy fish in very shallow, low current velocity areas along stream margins.

Some observations of juvenile coho salmon and Dolly Varden char have occurred in aquariums and streams. The behavior of juvenile Dolly Varden char and other salmonids occurring in the same regions has not been studied adequately.

V. RECOMMENDATIONS AND FURTHER STUDIES

Studies should be designed and conducted to determine the survival, movements and behavior of all life stages of anadromous Dolly Varden char with respect to physical, chemical and biological habitat components within selected pristine Alaska drainages. The above relationships should be examined thoroughly both within the drainage and by supplemental laboratory and field studies prior to the occurrence of any land use activities which could modify the habitat. Several years of study could be required to meet this objective. Investigations should continue during and after land use activities to adequately monitor the fish life stage-habitat relationships. Such research and supplemental laboratory and field studies could provide land managers with needed information to protect and enhance anadromous Dolly Varden habitat.

Field and laboratory studies should be designed and conducted to determine the upstream swimming capability of immature (pre and post-smolts) and gravid and spawned-out adult anadromous Dolly Varden char in relation to current velocity, water depth, water temperature, stream gradient and length of potential migration barriers. Studies could be similar to those described by MacPhee and Watts (1976) for testing Arctic grayling swimming performance. Results of these tests could be used for determining the best methods for installing culverts to allow fish migration and to designs of culverts and other fish passage facilities.

Studies should be designed and conducted to evaluate the influence of water temperature, dissolved oxygen, rate of intragravel flow, substrate composition and possibly other physical and chemical habitat variables on the survival and development of anadromous Dolly Varden char eggs and alevins and the fitness and survival of emergent fry. Controlled environmental laboratory tests should complement field studies.

Standardized methods should be developed and evaluated to objectively describe current velocity, water depth, substrate composition and imbeddedness, instream and bankside cover and water temperatures at anadromous Dolly Varden spawning sites. The above lotic habitat data collected at a number of redds within a stream or stream reach could be examined by frequency analysis for each lotic habitat component. These frequency analyses would help describe lotic habitat selection by spawning fish, in relation to current velocity, water depth, substrate composition and imbeddedness and possibly other lotic habitat variables. The frequency analyses would not determine fish spawning habitat preferences because streams and stream reaches are characterized by a finite combination of acceptable habitat variables. Readers are urged to consult Appendix III of the Terror River, Alaska Instream Flow Report by Wilson et al. (1981) which discusses fish spawning habitat selection and the assumptions associated with habitat suitability curve construction.

Standardized methods should be developed and refined to evaluate current velocity, water depth, substrate composition and imbeddedness and instream and bankside cover at anadromous char spawning sites to better understand habitat selection within individual streams or stream reaches. For example, lotic habitat types could be characterized by current velocity, water depth, instream and bankside cover conditions within those ranges measured at redds. Measurements of substrate composition and imbeddedness which were not used for spawning habitat by anadromous Dolly varden char could help us to better understand spawning habitat selection of this fish in various streams.

Weirs should be used to monitor juvenile (pre-smolt) anadromous Dolly Varden char movements in relation to streamflow, water temperature and other physical and chemical habitat variables in small, intermittent and larger streams within a drainage. Snorkling and minnow trapping could supplement sampling with weirs.

Studies should be designed and conducted to describe summer habitat selection by juvenile (pre-smolt) anadromous Dolly Varden char with respect to a variety of physical and chemical habitat variables, food availability and the presence of other fish. Investigations using snorkling for fish observation should be conducted in clearwater streams using techniques similar to Everest and Chapman (1972) and Fausch (1978). Fish holding positions should be characterized by water depth, distance to streambed, lighting, substrate composition and imbeddedness, instream and bankside cover, current velocity and proximity to other fish, including char and other species. These investigations would complement fish movement studies along streams supporting weirs.

Studies of fish feeding behavior coupled with benthos and drift sampling and fish gut analysis should be conducted to better understand the feeding habits and apparent affinity of Dolly Varden char to the substrate.

More investigations should occur to detect and characterize overwintering habitat selection by various ages of juvenile (pre-smolt) anadromous Dolly Varden char with respect to water depth, current velocity, water temperature, overhanging vegetation, undercut banks, substrate material and proximity to stream margins. Identification of overwintering fish habitat is required for the protection of this fish species. Various land use activities could significantly reduce the quality of this habitat (Bustard, 1973). Habitat enhancement efforts should be formulated with an understanding of what constitutes good overwintering habitat for various ages of Dolly Varden char.

Laboratory and field tests, somewhat similar to those conducted by Bustard (1973), should be designed and conducted to complement studies of the distribution and behavior of overwintering anadromous Dolly Varden in selected streams. These tests should provide juvenile fish with a continuum of overwinter habitat types from no cover to total riparian cover, unimbedded to totally imbedded substrate of sand to large cobble substrate and a variety of water temperatures. Juvenile fish of various ages should be tested because fish size may influence overwinter habitat selection.

Studies should be designed and conducted to determine the presence of overwintering immature (post-smolt) and adult anadromous Dolly Varden char in clearwater and glacial lakes and streams. The distribution of overwintering fish in lakes can be quite limited. Studies of lotic overwintering areas with respect to various physical and chemical habitat conditions should be conducted to explain habitat selection criteria and to predict fish overwintering areas by the character of the habitat.

Radio telemetry should be considered as a viable technique to monitor movements of immature and adult anadromous Dolly Varden char in overwintering areas which are difficult to sample by gillnet or other methods.

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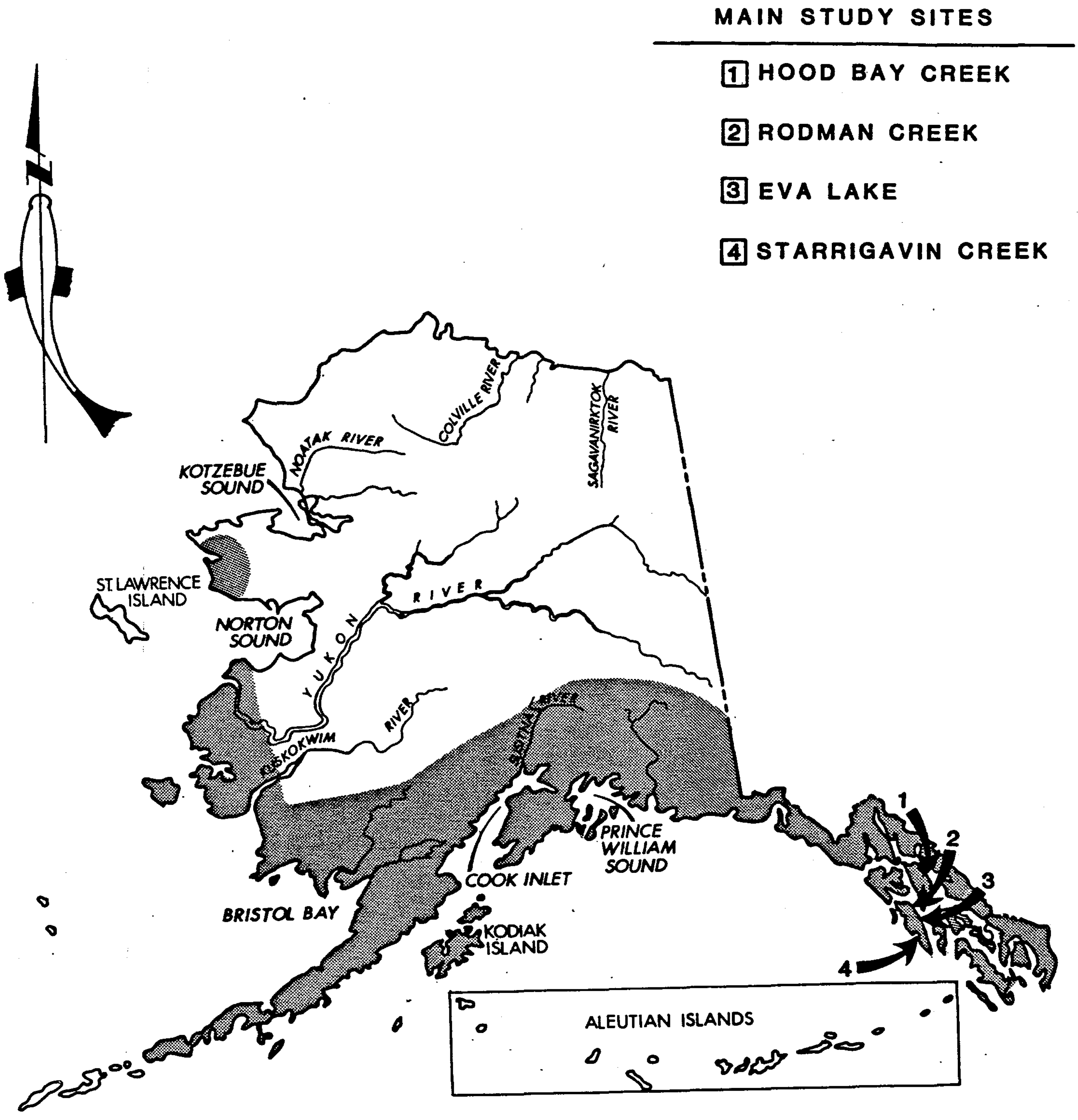

DISTRIBUTION OF DOLLY VARDEN - *SALVELINUS MALMA (WALBAUM)* FROM SCOTT AND CROSSMAN 1973, AND MAIN STUDY SITES.