

Fish movements – the missing piece

John H. Eiler

National Marine Fisheries Service, Auke Bay Laboratory
11305 Glacier Highway, Juneau Alaska 99801-8626 USA

Abstract

Movement patterns are an important component in the life-history strategies of fish species, constituting the mechanism used to access the resources necessary for survival. Fish adapt their movements to accommodate for restrictive local conditions. Although often oversimplified due to the difficulty in collecting data, or considered ancillary to other types of information, an understanding of movement patterns can provide significant insight into the management of fish populations. Advances in technology are providing new tools for collecting detailed information on movements. Findings from three radio telemetry studies on three salmonid species in Alaska, U.S.A., are discussed in relation to survival strategies and management considerations.

Introduction

Movement patterns are an important component in the life-history strategies of fish species, constituting the mechanism used to bring individuals into contact with the resources needed to survive and reproduce. Competition and limited resources often make it necessary to adapt movement patterns to accommodate for restrictive local conditions. However, from an energetics standpoint, there can be a substantial cost associated with movement, so there has to be a tangible benefit to make it worthwhile.

Management decisions related to fish populations often give less consideration to movement patterns

than other aspects of their life history, primarily because collecting movement information is difficult and often relatively expensive. Because of dwindling budgets, agencies have to be selective in order to obtain the best data with the funds available. Management decisions are often based on "logical" assumptions to fill in the missing pieces of information. The problem inherent with this approach is that our perspective is often limited, and seemingly logical assumptions, particularly in relation to the natural pressures affecting wild populations, are not always valid.

New technologies are providing powerful tools to address information needs. Since the 1960s, radio telemetry has been used to collect information on a variety of aquatic species (Winter 1983). Initially, most studies were limited to small numbers of tagged individuals, usually fewer than 40, and relatively small areas. Advances in telemetry have made it possible to track large numbers of wide-ranging individuals (Burger *et al.* 1985; Block *et al.* 1998), making it feasible to collect detailed movement information on a variety of fish species.

This paper presents findings from radio telemetry studies on three salmonid species in Alaska, U.S.A., that illustrate the potential significance of movement data. Local conditions undoubtedly influence the life-history strategies exhibited by fish populations. Alaska, located in northwestern North America, is a diverse ecosystem, consisting of an extensive coastline and vast interior. Habitat types range from temperate rain forest to tundra. In addition to the marine

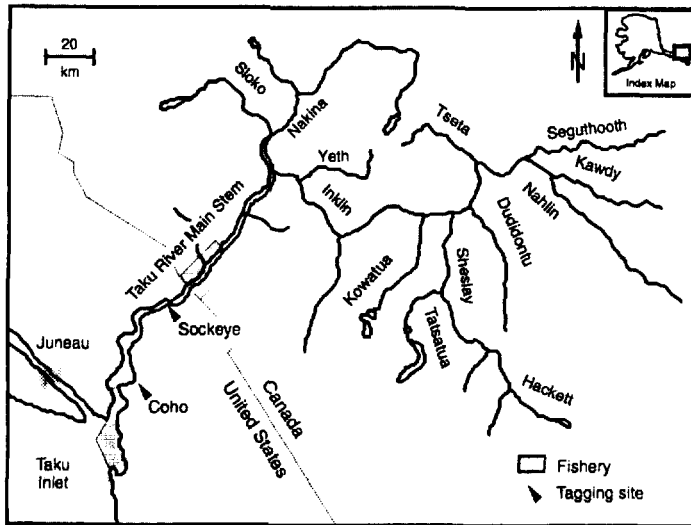


Figure 1. Map of the Taku River drainage showing the location of US and Canadian commercial fisheries.

environment, large river systems and small coastal streams occur throughout the area and support important fish populations. Winter conditions, particularly in the interior, can be extremely harsh, with temperatures ranging to below -30°C (National Oceanic and Atmospheric Administration 1997). The information presented shows that movement patterns and the underlying forces related to them are not always straightforward, and can provide important insight into the management of fish populations.

Taku River sockeye salmon

Sockeye salmon (*Oncorhynchus nerka*), an important commercial species in the North Pacific Ocean, spawn in many rivers along the western coast of North America and the eastern coast of Asia. Exhibiting an anadromous life cycle, the juvenile salmon leave fresh water and spend several years in the marine environment before returning to their natal streams to spawn. Returning adults typically migrate to areas associated with lake systems, and spawn along lakeshores and in nearby inlet streams (Foerster 1968). The Taku River (Figure 1), a large, glacial river flowing through Alaska, U.S.A., and British Columbia, Canada, drains a watershed of over 16 000 km². This river is an important producer of sockeye salmon with an average run of over 233 000 fish (Pacific Salmon

Commission 2000). Returns of Taku River sockeye salmon support commercial and subsistence fisheries in both countries and have been the focus of numerous disputes over harvest allocation. However, the large size, remote nature, and turbidity of the drainage make it difficult to collect information needed to manage the returning salmon.

In 1984 and 1986, radio telemetry was used to follow the movements of adult sockeye salmon returning to the Taku River to spawn. The fish were captured with fish wheels (Meehan 1961) near the river mouth and placed in a tagging cradle submerged in a trough of fresh water. Radio transmitters, 6.5 cm long and 2.0 cm in diameter, were inserted through the mouth and into the stomach of the fish. Salmon do not feed extensively during this period of their spawning migration. Compared to attaching the tag externally, this approach also minimises any adverse effect on the hydrodynamic shape of the fish, particularly when it is swimming upstream against strong current. A total of 375 fish were tagged during the study. Radio-tagged fish moving upriver were located weekly from fixed-wing aircraft until they reached their final destination. Helicopters were used to pinpoint the fish in localised areas and to access these sites for collecting samples (Eiler *et al.* 1992).

Before this study, relatively little was known about sockeye salmon returns to the Taku River other than general information on run timing, the location of certain spawning areas, and harvests from the commercial fishery. Because sockeye salmon is typically a lake-dependent species, it was assumed that most spawners travelled to lake systems in the upper drainage (D. J. Ingledue, Alaska Department of Fish and Game, Douglas, Alaska, U.S.A., unpublished report), and management decisions were based on escapement estimates from these areas. Surprisingly, only 37% of the radio-tagged fish travelled to areas associated with lakes; the remaining 63% were tracked to riverine areas – sections of the drainage without lakes (Eiler *et al.* 1992). Spawning in these riverine areas by tagged and untagged fish was verified during aerial surveys in 1986, when normally turbid side channels and sloughs cleared as a result of several weeks without precipitation and unusually low water levels. Spawners in riverine areas used a variety of habitat types, including main-river channels, side channels, and upland sloughs - spawning areas previously considered unsuitable for this species. The fish were not considered strays, because large numbers of untagged fish were also observed, and sockeye salmon typically home with great precision to their natal streams (Quinn *et al.* 1987). Genetic information collected from the Taku River also indicated that sockeye salmon from riverine areas were genetically distinct from fish returning to the major lake systems (Guthrie *et al.* 1994).

The primary reason riverine areas were considered unsuitable for spawning sockeye salmon is the perceived lack of juvenile rearing habitat. After emerging from redds, juvenile sockeye salmon typically rear in lakes for one or more years before migrating to sea (Foerster 1968). However, sockeye salmon in some river systems have adopted alternative strategies that compensate for the lack of typical rearing areas. About half of the fish sampled in riverine areas of the Taku River migrated to sea as juveniles before their first winter. Similar observations have been reported in other major river systems (Bugaev 1984; Wood *et al.* 1987).

Adult sockeye salmon also use lakes as holding areas where they can complete the physiological maturation process associated with spawning. This habitat component is seemingly absent in riverine areas. However, intensive tracking of radio-tagged fish suggests that sockeye salmon were staging in river channels in the vicinity of spawning areas before pulsing into the side channels and slough to spawn.

Little information is available on the productivity of riverine sockeye salmon compared to those that spawn in areas associated with lakes. In riverine areas, the lack of lacustrine rearing habitat, extreme changes in main-channel and side-channel water levels (making these areas susceptible to freezing or desiccation), and heavy silt loads may result in low or highly-variable production by riverine spawners. However, the large returns of riverine spawners to the Taku River suggest that these are not always limiting factors. The ability of sockeye salmon in some drainages to spawn and rear in riverine areas, as well as in the vicinity of lakes, provides the flexibility to adapt to changes in local conditions and colonise new areas. Before this study, harvest levels for Taku River sockeye salmon were based on abundance estimates from lakes in the upper drainage. Movement information from this study provided a better understanding of run characteristics and a basis for improved management.

Taku River coho salmon

Coho salmon (*O. kisutch*), another commercially important salmon species, also spawns in the Taku River. Compared to other salmonids, less is known about coho spawning runs, due to poor weather conditions during the fall when the fish return to spawn and the extensive use of cover by this species. Telemetry studies, similar to those described for sockeye salmon, were conducted on Taku River coho salmon. Returning adults were captured near the river mouth with small-mesh gill nets (Figure 1), and 444 fish were tagged with radio transmitters. Radio-tagged salmon moving upriver were tracked with remote tracking stations (Figure 2). Tracking stations, located at 15 sites in the drainage, detected the radio-tagged

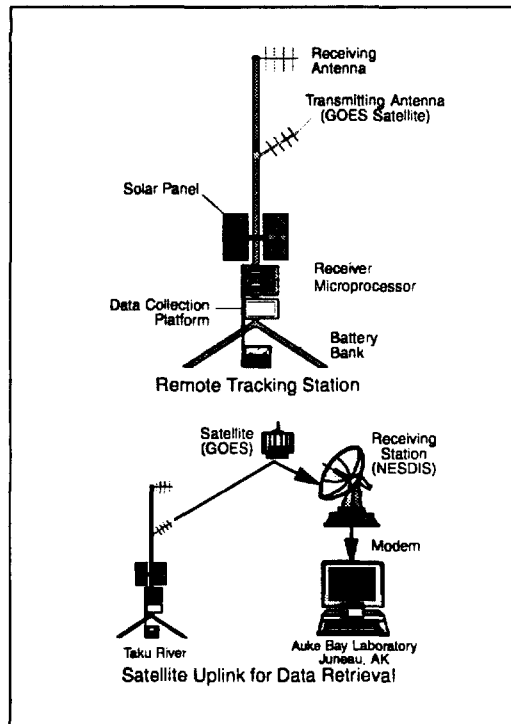


Figure 2. Remote tracking system used to record the movements of radio-tagged fish in large, isolated rivers.

fish, and recorded the date and time they were at the site (Eiler 1995). A satellite uplink was used to retrieve the data, because access to the stations was severely limited. Helicopter surveys were conducted when weather permitted during October and November to locate radio-tagged fish in spawning areas and access these sites to verify the presence of untagged fish.

Although coho salmon were tracked to areas throughout the drainage, temporal differences in distribution were observed. Fish tagged during August travelled primarily to upper reaches, whereas fish arriving during September and October used spawning areas in lower sections of the drainage. Spawning habitat ranged from main-stem side channels to upland sloughs associated with beaver ponds.

The movement patterns observed for coho and sockeye salmon differed substantially. Sockeye salmon exhibited relatively continual upriver movement while migrating to spawning areas; the fish would then hold

in nearby staging areas for several weeks before moving into spawning areas. Coho salmon movement patterns were much more varied. Rather than holding in one particular area, the fish would often move extensively between areas, sometimes travelling over 20 km between holding sites. Both upriver and downriver movements were observed. In one extreme case, a coho salmon was tracked to a known spawning area over 200 km upriver. After remaining in the area for eight days, the fish moved back downriver, and within 48 hours had left the drainage, possibly destined for another river.

Aerial surveys are conducted on clear-water areas of the Taku River during the fall in order to count coho salmon spawners. The counts are used as an abundance index for the drainage, and assume that sources of bias such as observability and annual variation are minimal or can be accounted for, both debatable points. However, telemetry data from this study also suggest that fish holding in areas before

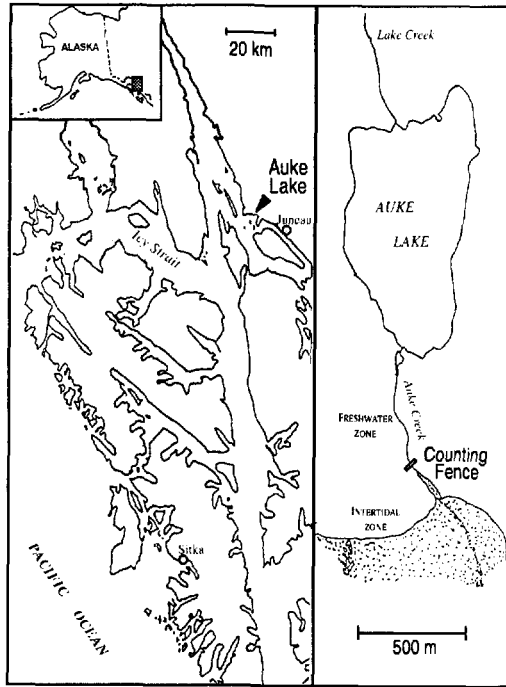


Figure 3. Map showing the location of Auke Lake near Juneau, Alaska U.S.A.

spawning may move extensively between sites. This pattern of movement, combined with the timing of the surveys, may have a significant impact on the survey counts.

Cutthroat trout in southeastern Alaska

Coastal cutthroat trout (*Oncorhynchus clarki*), a prized sport fish species, occur along the western coast of North America from northern California to Prince William Sound in Alaska (Scott and Crossman 1973). Cutthroat trout in southeastern Alaska spawn in the spring, with the peak of spawning in early to mid-May. Cutthroat populations exhibit two life-history strategies in southeastern Alaska - resident and sea-run. Resident cutthroat trout rear in small rivers and streams for several years before migrating into lakes, where they spend the remainder of their lives. Sea-run cutthroat leave their natal rivers and streams and migrate to small coastal lakes. In the spring they leave these lakes and migrate back through saltwater to spawning streams. After spawning, they return to the

rich marine environment to feed until late summer and fall, when they re-enter lakes to overwinter (Jones 1976). However, little information is available on the composition and migration pattern of these sea-run populations.

Cutthroat populations are typically small and vulnerable to overfishing and habitat loss. Since the late 1970s, cutthroat numbers and harvests in southeastern Alaska have declined (Schmidt 1997). In 1994, the Alaska Department of Fish and Game and the National Marine Fisheries Service conducted a radio telemetry study to document the movements and spawning distribution of adult sea-run cutthroat emigrating from Auke Lake - a small, coastal lake near Juneau, Alaska.

In the spring, emigrating sea-run cutthroat trout were caught at a counting fence located at the outlet of Auke Creek (Figure 3). Thirty-one adults were placed in a tagging cradle submerged in a trough of fresh water, and tagged with radio transmitters 2.8 cm long and

1.0 cm in diameter. The tags were inserted through the mouth and into the stomach. After tagging, the fish were released to continue their ocean migration. Aerial tracking surveys were flown weekly to locate radio-tagged fish in local creeks and rivers. Because radio transmitters cannot be detected in saltwater, the surveys were timed to coincide with low tides to increase the opportunity of locating radio-tagged fish in stream mouths (i.e. areas inundated by seawater at higher tide stages). A remote tracking station was also placed near the mouth of the Mendenhall River (8 km down the coast from Auke Creek) to record the passage of radio-tagged fish moving upriver; resident cutthroat trout spawn in several tributaries of this drainage. Ground surveys were also conducted in the rivers and streams where radio transmitters were detected to obtain a more precise location and identify potential spawning areas.

Cutthroat trout from Auke Lake were tracked to 10 streams throughout the Juneau area (Jones and Seifert 1997), indicating that the overwintering fish represented an aggregate population. The fish travelled to spawning areas up to 50 km from Auke Lake, appearing to closely follow the shoreline; movements to streams across deep, open stretches of water were not observed even though in some cases the distances involved would have been substantially less. Some fish were recorded in more than one stream during their spawning migration.

Several populations of resident cutthroat trout use river systems in the Juneau area. Before this study, it was assumed that sea-run cutthroat trout were a component of these local populations and would migrate to the same spawning areas. Instead, the fish travelled to small coastal streams incapable of supporting year-round resident populations due to the lack of suitable winter habitat. Several radio-tagged fish were tracked to headwater areas where stream width was no greater than 8 cm! Rearing juveniles were observed in these headwater areas, indicating that successful spawning was occurring. Sea-run fish travelling to more traditional spawning areas would have to compete with fish from existing resident populations. The

movement pattern documented during this study – using spawning streams devoid of winter habitat and, therefore, not suitable for resident fish – reflects an adaptive response by sea-run fish that avoids competition. By leaving these areas in the fall and returning to small lakes to overwinter, sea-run cutthroat trout utilise an otherwise unexploited niche.

The findings from this study have several management implications. Cutthroat trout congregate in small lakes to overwinter, and occur in sufficient numbers to constitute a harvestable population. However, movement data indicate that these fish are actually an aggregate of many small, distinct populations, essentially a mixed stock, which may be more vulnerable to overexploitation than a discrete resident population – a consideration important in managing local fisheries.

Findings from this study were also important in identifying previously unrecognised spawning habitat. Southeastern Alaska is heavily forested, and many areas are logged for timber. Buffer strips are mandated for spawning streams to protect critical habitat. Many streams used by sea-run cutthroat trout were not recognised as spawning habitat due to their small size and, therefore, were not protected. Efforts are being made to reflect the importance of these areas when classifying critical habitat.

Summary

Fishery management is typically a mixture of science, budget considerations, and politics. Managers often face the dilemma of having to manage wild populations with limited information. Seldom are sufficient funds available to collect all the information needed, making it necessary to prioritise research programmes to address the most critical areas. Which programmes are most necessary is often subject to debate. Although a key element in the life-history strategies of fish species, information on movement is often considered secondary to other research needs, especially because movement studies can be difficult and relatively expensive. Conventional wisdom or

logical assumptions are often used to fill in the missing information. However, the patterns of movement exhibited by fish populations are often much more complex than generally perceived.

The common theme in the studies discussed is that the movement patterns observed were significantly different from what was expected. Although the established pattern for sockeye salmon is to spawn in the vicinity of lakes, a major portion of the Taku River return travelled to sections of the drainage without lakes, and used areas previously considered unsuitable for spawning. Subsequent review of the literature and unpublished data suggests that this life-history strategy may be more common than originally thought (Eiler *et al.* 1992). Salmon are generally thought to return directly to natal streams to spawn. However, coho salmon in the Taku River exhibited wide-ranging movements after arriving at established spawning areas. Sea-run cutthroat trout overwintering in small coastal lakes, initially thought to be a component of local resident populations, were instead comprised of an aggregate of many, small populations and travelled to extremely small stream systems where spawning had not been documented.

Wild populations often adapt their behaviour to reflect limitations in resources and competition. Movement patterns are simply a reflection of these underlying forces and, not surprisingly, are not always straightforward. Although often oversimplified due to the difficulty in collecting data, or considered ancillary to other types of information, an understanding of movement patterns can provide significant insight into the understanding and management of fish populations.

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