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Downstream Migration of Stained Kokanee Fry in the Flathead River System, Montana

Abstract

The purpose of this study was to determine the migration patterns of newly-emerged kokanee fry in the Flathead River, an upstream drainage of the Columbia River system. Knowledge of the timing of arrival of migrating fry to Flathead Lake from natal streams is vital in monitoring reproductive success of the kokanee population. In a series of three experiments, we stained kokanee fry in 1:30,000 solutions of Bismarck brown (a vital stain) and followed their movements downstream through the river system. Fry migrated from dusk to dawn and traveled at the same speed or slightly faster than the current in moderate velocity sections of the river, and up to twice as fast as the flow rate in the low velocity river section. Fry migrated 100 km from McDonald Creek through the Flathead River system to Flathead Lake in as little as 20 hours. Fry stained for 50 minutes in the 1:30,000 Bismarck brown solution showed distinct dye retention for one week. Stain was still visible after two weeks on fry examined on a white background. Mortality was low for control groups of stained and unstained fry. Our experiments indicated that most migrating kokanee fry in the Flathead River system moved actively to take advantage of currents. Actively migrating kokanee fry probably experience higher survival because of reduced exposure to riverine predators. Kokanee fry behavior during migration in the Flathead River system is similar to that of sockeye salmon fry in coastal streams.

Introduction

Kokanee (*Oncorhynchus nerka*) mature in three to five years in Flathead Lake, Montana, then migrate upstream in the fall to spawn in the Flathead River system. Fry emerge in the spring and migrate up to 120 km downstream to the lake. The pattern and rates of fry migration had not been understood clearly because previous work focused on unmarked fry of uncertain origin (Fraley and Graham 1982).

We marked three groups of kokanee fry with a vital stain (Bismarck brown Y) and followed their movements downstream for 100 km from McDonald Creek to Flathead Lake. We conducted these experiments to determine timing of fry recruitment to Flathead Lake and to determine if fry migration was passive or active. This information is needed for our studies of seasonal growth and distribution of young-of-the-year kokanee in the lake. Other workers have monitored migration of (anadromous) sockeye salmon fry (e.g., Hartman *et al.* 1962) but few have followed the movements of marked fish. Stober and Hamalainen (1980) followed movements of stained sockeye fry in the Cedar River, Washington.

In this paper, we report on the timing and rate of movement of kokanee fry migrating from McDonald Creek downstream through various sections of the Flathead River to Flathead Lake.

We also report on dye retention and mortality of fry stained in a 1:30,000 solution of Bismarck brown Y.

Study Area

The Flathead River system in northwest Montana is a headwater drainage of the Clark Fork of the Columbia River (Figure 1). Flathead Lake is the largest natural lake west of the Rocky Mountains. It is oligomesotrophic and has a surface area of 476 km² and a mean depth of 32.5 m (Potter 1978). Kerr Dam on the outlet regulates the level of the lake within 3 m of the surface.

The Flathead River enters the north end of the lake. The lower 35 km of the inlet river is influenced by Kerr Dam, and is slough-like with a silt bottom. From there upstream for 55 km to its forks, the river has a moderate gradient and gravel-rubble substrate. The North, Middle and South forks drain areas of nearly equal size from portions of the Great Bear and Bob Marshall Wilderness Areas, Glacier National Park, and the Flathead National Forest.

Kokanee rear to maturity in Flathead Lake and return to natal areas to spawn, usually at the end of their fourth growing season (Fraley and Graham 1982). Kokanee spawn in many habitats, including springs, streams, large river channels, and along the shorelines of lakes. Presently, the major spawning area for kokanee in the Flathead

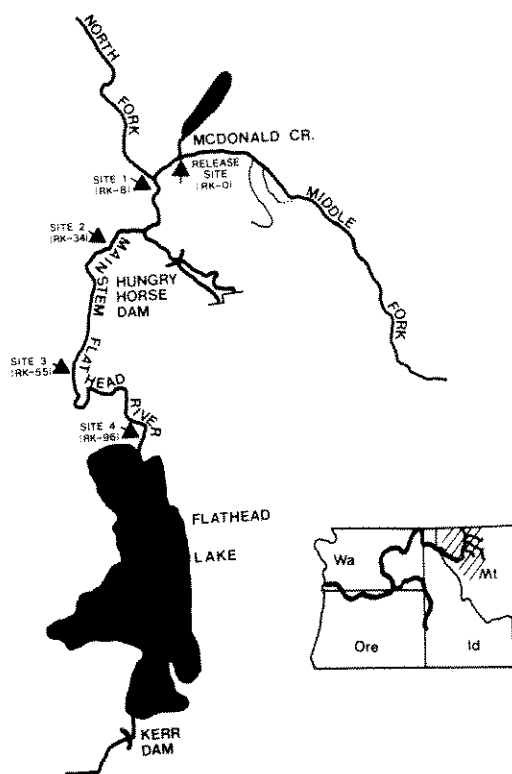


Figure 1. Locations of the kokanee fry release and capture sites in the Flathead River drainage, and location of the drainage within the Columbia River system (inset).

system is the 4-km outlet of McDonald Lake, in the Middle Fork drainage within Glacier National Park. Kokanee spawn in the South Fork of the Flathead River from Hungry Horse Dam downstream 8 km to the confluence with the main Flathead River, and in portions of the main stem Flathead River. However, the spawning populations at both locations have been reduced by the operation of Hungry Horse Dam and other factors (Fraley and Decker-Hess 1987). Few kokanee spawn in the North Fork drainage.

The substrate of McDonald Creek is mainly gravel and water temperature is moderated by McDonald Lake. From 1979 to 1986, kokanee spawning escapement into the creek ranged from 21,500 to 120,000 fish, accounting for 75 percent of the spawning run from Flathead Lake (Fraley and Decker-Hess 1987). Estimates of fry emigration from the creek from 1982 to 1986 ranged

from 6.6 to 13.1 million (Beattie and Clancey 1987).

Methods

We conducted three experiments on kokanee fry migrating downstream during the spring in 1983 and 1984. Fry were captured with drift nets suspended overnight in McDonald Creek from the Quarter Circle Bridge below the outlet of McDonald Lake at the confluence of the Middle Fork Flathead River. Nets were located at intervals across the stream channel at surface, sub-surface and bottom depths (Fraley and McMullin 1983). Captured fry were assumed to be out-migrating from the creek. Fry were counted volumetrically and emersed for 50 minutes in an aerated live tank with solutions of Bismarck brown Y vital stain at a concentration of 1:30,000 (i.e., 1 g dye/30 l water). Powdered dye was mixed with water in a 19 liter bucket (0.5 g dye/15 l water) then filtered through cotton cloth into the live car to remove dye residues which could have caused fry mortality (Fraley and McMullin 1983). Ward and VerHoeven (1963), and Stober and Hamalainen (1980) also stained salmon fry with Bismarck brown Y at a concentration of 1:30,000; they reported fry mortality of less than one percent and dye was retained for 7 to 13 days. Mundie and Traber (1983) used a dye concentration of 1:46,000 and reported almost no fry mortality and dye retention for five days.

After staining, fry were held in a mesh live car in the stream for one hour and allowed to recover before they were released. Our observations indicated that released fry distributed themselves along the bottom of the streambed. We captured no fry until dusk in drift nets maintained near the capture site. Therefore, we assumed that released fry remained near the capture site until dusk. Our observations indicated that fry frequented the streambed gravels during the day. Control groups of 50 stained and 50 unstained fry were held in mesh bags in the stream near the capture site throughout the course of each experiment and checked periodically for mortality and dye retention.

We sampled migrating fry with drift nets suspended from bridges located 8, 34, 55 and 96 km downstream from the release site (Figure 1, Sites 1, 2, 3, and 4). Drift nets consisted of a metal frame (0.5 m²) with a tapered, trailing net bag

1.8 m long (3.2 mm mesh size). In areas of reduced velocity, the end of the bag was closed and fry were captured in the cod end. At faster velocities, a holding box was attached to the net to protect captured fry (Figure 2).

Drift nets (3 to 10 per site) were checked during the night at one to two-hour intervals and the number of stained and unstained fry were noted. Nets were left in place during the day and checked again at dusk. We operated each netting station until all stained fry had passed. During these experiments, nets were set in areas of high current velocity to capture as many fry as possible. Previous experiments (Fraley and Graham 1982) showed that migrating fry prefer areas of the water column with maximum velocity.

Flow rates in the Flathead River were calculated between sites 1 and 2, and sites 2 and 3, by timing releases of water from Hungry Horse Dam past each site. This was accomplished at flow levels similar to those experienced during the fry experiments. The rate of flow between sites 3 and 4 was calculated by measurements of water velocities at 0.5 m depth in channel

transects spaced at 5 km intervals. Maximum velocities at each of the eight transects were averaged to arrive at an assumed flow rate for the 40 km section.

Results

We recaptured 807 (1.2%) of the 65,687 out-migrating kokanee fry stained and released in McDonald Creek during the three experiments. Stained fry migrated at night in loose aggregations through the Flathead River system, generally taking 1 to 4 hours to pass by each netting station. No stained fry were captured during the day. A similar percentage of total fry captured at each of the first three sites was stained. Most stained fry migrated as fast or slightly faster than the river current past sites 1, 2 and 3.

Movements of stained fry in the slower-flowing river section between sites 3 and 4 were more variable. Most fry traveled nearly twice the flow rate; however, some fry swam more slowly, taking up to five nights to reach site 4. Movement rates of fry varied among the three experiments, as indicated below.

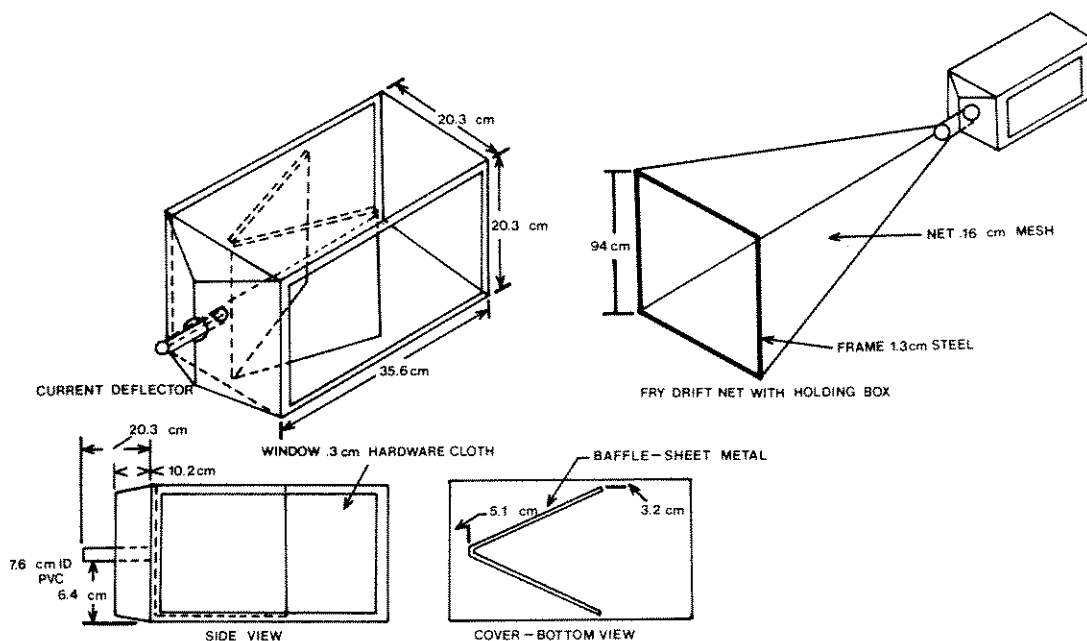


Figure 2. Fry holding box and drift net. Box is 1/2-inch plywood with 1/8-inch hardware cloth windows painted to reduce mesh size. Hinged top is 1/2-inch plywood; baffle and deflector are sheet metal.

Experiment 1

On 3 May 1983, 10,664 kokanee fry captured overnight in McDonald Creek in drift nets were dyed and released the next morning. We assumed that fry left the creek beginning at dusk or 2000 hours, based on lack of daytime captures in drift nets maintained at the release site. Past studies of nocturnal movements of fry in the creek support this contention (Fraley and Graham 1982). At 0130 hours (5.5 hours after dusk), stained fry had moved 8 km downstream to site 1 (Figure 3). Of 371 fry captured at site 1, 31 (8.5%), were stained. Only four stained fry were captured during the next 60 hours of sampling at Site 1. Fry reached site 2, 34 km downstream from McDonald Creek, at 0600 hours. We collected 164 fry during the night, and 18 (11%) were stained. We assumed that fry remained in the gravel along the margins of the Flathead River during the day as we had observed in McDonald Creek.

By 0030 hours the following night (5 May), the fry had moved 55 km downstream to site 3. We captured 52 fry during the night, and five (9.6%) were stained. We monitored site 4, just above Flathead Lake, for 10 days after the fry passed site 3; however, none of the 671 captured fry were stained.

Experiment 2

On 28 March 1984 we captured, stained and released 14,500 kokanee fry in McDonald Creek. By 2300 hours, stained fry had reached site 1 (Figure 3). Numbers of stained fry captured at site 1 peaked at 2400 hours. Of the 1,888 fry captured at site 1, 376 (20%) were stained.

Stained fry began to arrive at site 2 by 0500 hours the following morning (29 March) and continued passing the site until dawn. The fry apparently stopped moving during the day, as none were captured in the nets during daylight hours. At 2100 hours that evening, we again began to capture stained fry in the nets; they continued passing site 2 until 2400 hours. Of the 453 fry captured at site 2, 57 (13%) were stained.

Stained fry reached site 3 by 0200 hours that same night, and continued passing until 0500 hours. Of 539 fry captured at site 3, 78 (14%) were stained. We continued to monitor site 4 for eight additional days, but no more stained fry were captured.

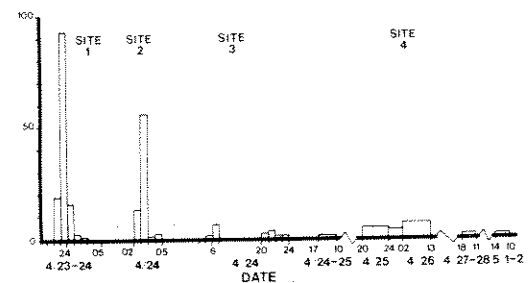
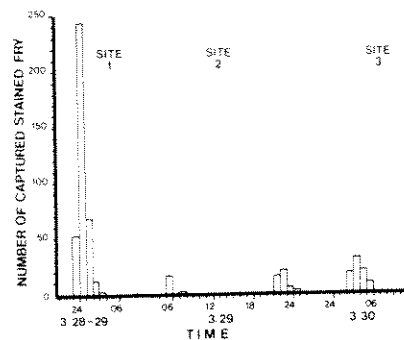
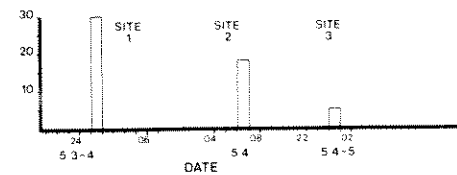


Figure 3. Number of stained fry captured and diel timing of migration during experiments 1 (top graph), 2 (middle graph) and 3 (bottom graph).

Experiment 3

On 23 April 1984 we captured, stained and released 40,523 fry in McDonald Creek. We maintained drift nets at the release site from 1200 hours that day. Large numbers of stained fry first appeared in nets set between 1900 and 2100 hours, confirming that fry began emigrating at dusk (approximately 2000 hours).

By 2200 hours, stained fry reached site 1 (Figure 3). Fry continued passing this point until 0200 hours (24 April). Of the 751 fry captured, 131 (17%) were stained.

Stained fry reached site 2 by 0230 hours, and continued passing until 0500 hours. Of 376 fry captured, 72 (20%) were stained. Stained fry reached site 3 by 0500 hours the same morning, after nine hours of travel time. Stained fry apparently stopped moving during the daylight hours, but resumed their migration past site 3 at 2100 hours the next evening. They were captured at this site until 2400 hours. Of the 123 fry captured, 14 (11%) were stained.

By 1000 hours the next morning (25 April), the first stained fry reached site 4, 96 km below the release point. We did not monitor the site hourly, so the fry arrived sometime between dusk and 1000 hours. Stained fry continued past site 4 that evening (Figure 3). From 2 to 4 percent of the captured fry passing this site were stained. Nets were operated at this site until 1 May. Of the 1,789 fry captured during the entire period, 20 (1.1%) were stained.

Fry Movement versus Current Flow

Most fry migrated downstream at nearly the same rate or faster than the calculated average flow rate during experiments 1 and 3 (Table 1). During experiment 1, flows in the Middle Fork and in the main stem Flathead River averaged 108 and 466 m³/sec, respectively. Flows averaged 110 and 325 m³/sec in the same streams during experiment 3. Fry moved nearly twice as fast as the river current between sites 3 and 4 (based on information from experiment 3). We assumed that similar current velocities existed under similar discharges during these experiments.

Stained fry moved downstream more slowly during experiment 2 (2.9 and 4.2 km/h between sites 1 and 2, and 2 and 3, respectively). Flows in the Middle Fork (26 m³/sec) and in the Flathead River (108 m³/sec) were much lower, and estimates of flow rates were not available.

Fry Mortality and Dye Retention

Similar mortality was observed in control groups of 50 stained and 50 unstained fry held in mesh bags in McDonald Creek during experiment 1. Mortality was 10 percent in the stained group and eight percent in the unstained group after eight days. In experiment 2, 50 dyed fry and 50 undyed fry were held for five days without mortality. The dye marking was distinct at the end of the holding period.

Fry stained for 50 minutes in a 1:30,000 solution of Bismarck brown Y stain showed distinct dye retention for one week. After two weeks, the stain was still visible on 90 percent of the fry when examined on a white background. Fin and mouth areas retained stain for up to 20 days.

Discussion

Kokanee fry emigrated from McDonald Creek in a loose aggregation beginning at dusk. Fry moved only at night, resting (or stopping) in gravel areas along the stream margin during the day. Our drift nets captured no stained fry during daylight hours. Previous studies of kokanee fry movements in the Flathead River system (Fraley and Graham 1982) also indicated nocturnal migration of fry. In an earlier diel experiment (Fraley and Graham 1982), the majority of fry emigrated from McDonald Creek between midnight and 0300 hours. Fry emigration began one-half hour after sunset (2030 hours) and continued until sunrise (0530 hours). Brannon (1972), Stober and Hamalainen (1980) and Nelson (1965) reported sockeye fry emigration occurred during a similar time period. Nelson (1965), however, found that although emigration always occurred at night, the exact hours of peak emigration varied widely throughout the emigration period, as well as from year to year.

Kokanee fry moved as fast or faster than the river current downstream from the North Fork. This indicated that they actively maintained position in the current, probably swimming through eddies and back currents. Many fry migrated up to twice the rate of current flow through the slow-moving section between sites 3 and 4. Fry were more dispersed at site 4 (one stained fry was captured two nights and one five nights after peak migration), indicating a larger variation in migration rates of individual fry where there is less current to transport them. Hartman *et al.* (1962) also found that sockeye fry migrated downstream faster than the water velocity. Kokanee fry migrated at a slower rate during periods of lower flows (experiment 2). We do not have an estimate of flow rate at the low discharges during experiment 2.

Our experiments indicated that some kokanee fry stage or congregate for varying periods in the Flathead River (between sites 3 and 4), possibly to rest or feed before entering the lake. Relatively few stained fry were captured at site 4 (3 km

TABLE 1. Current flows and movement rates of stained fry for each river section during experiments number 1 and number 3. Flow was not measured during experiment number 2.

River Section	Distance (km)	Gradient (m/km)	Current flow rate (km/h)	Mean Movement Rate of Stained Fry (km/h)	
				Experiment 1	Experiment 3
Site 1 to site 2	26	0.75	5.8	5.8	6.5
Site 2 to site 3	21	1.05	6.0	6.5	6.8
Site 3 to site 4	41	0.17	2.1	No Data	3.5

upstream from Flathead Lake) within 10 days of their release from McDonald Creek during experiment 3. No stained fry were captured at site 4 during experiments 1 and 2. Other factors which could have caused fewer stained fry in our samples at site 4 could be sampling inefficiency, fry mortality, or dispersal of fry.

Kokanee fry derive the energy required for migration from stored reserves and by feeding on early instars of aquatic insects. Approximately 10 percent of the fry emigrating from McDonald Creek had not yet absorbed their yolk sac. Migrating fry in the Flathead River system feed mostly on chironomids (Fraley and McMullin 1983).

Because many fry spend little or no residence time in the stream during migration, mortality caused by riverine predators is probably minimized. Stober and Hamalainen (1980) reported most stained sockeye fry in the Cedar River, Washington, emigrated from one to three days after they emerged from the gravel. The large size of some of the fry collected in McDonald Creek indicated that they had resided (for at least two weeks) in the creek before we captured them at the stream mouth. Spring areas in the Flathead system produce larger fry which, based on their size, remained up to one month before emigrating (Fraley and McMullin 1983). Variations in

pre-departure residence times of fry in spawning areas, and variation in fry migration rates may have been important in the survival of kokanee in the system. Fry arriving in Flathead Lake at different times and at different sizes could take advantage of variations in abundance of zooplankton food.

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