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Downstream Migration of Stained Kokanee Fry in a Montana River System

By:

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Abstract

The downstream migration of kokanee fry stained in a 1:30,000 solution of Bismarck brown Y was monitored during three experiments in the Flathead River System. Fry migrated from dusk to dawn and travelled the same speed or slightly faster than the flow rate in moderate velocity sections of the river, and up to twice as fast as the flow rate in the low velocity river section. The fastest fry migrated the 100 km downstream from McDonald Creek through the Flathead River system to Flathead Lake in 20 hours. Fry stained for 50 minutes in the 1:30,000 solution of Bismark brown Y showed good dye retention for one week. At two weeks, the stain was still visible on fry examined on a white background. Mortalities were low for stained and unstained fry held as controls.

Introduction

Kokanee (*Oncorhynchus nerka*) mature in three to five years in Flathead Lake, then migrate upstream in the fall to spawning grounds in the Flathead River System. The resultant 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 had focused on unmarked fry of assumed, but uncertain, origin (Fraley and Graham 1982).

In this study, we marked three groups of kokanee fry emigrating from McDonald Creek with a vital stain (Bismarck brown Y) and followed their movements downstream. We conducted these experiments to determine the timing of fry recruitment into Flathead Lake, located 100 km downstream, and to determine if fry migration was passive (similar to flow rate) or active (faster than flow rate). 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 sockeye fry (e.g., Hartman et al. 1962) but few have marked the fry to follow movements of known groups of 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 the effects of two concentrations and exposure times of Bismarck brown Y on dye retention and mortality of fry.

Study Area

The Flathead River system in northwest Montana is a major tributary of the Clark Fork of the Columbia River (Figure 1). Flathead Lake is the largest natural lake west of the Rocky Mountains, is considered oligomesotrophic, and has a surface area of 476 km^2 and a mean depth of 32.5 m (Potter 1978). Kerr Dam, located on the outlet, regulates the upper 3 m of the lake.

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

Kokanee rear to maturity in Flathead Lake, then return to natal areas to spawn, usually at the end of their fourth growing season. Kokanee spawn in many habitats, including springs, streams, larger river channels and along the shoreline of the lake. Presently, the major spawning area for kokanee in the Flathead 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, but their numbers in both locations have been reduced by the operation of Hungry Horse Dam. Few kokanee spawn in the North Fork drainage.

McDonald Creek is a gravel-bottomed stream, and its water temperature is moderated by McDonald Lake. From 1979 to 1986, the kokanee spawning escapement into the creek ranged from 21,500 to 120,000 fish, averaging 75% of the total run. Estimates of fry emigration from the creek from 1982 to 1986 ranged from 6.6 to 13.1 million.

Methods

We conducted three experiments on downstream kokanee fry movements during the spring in 1983 and 1984. In each experiment, emigrating kokanee fry were captured with drift nets suspended overnight from the Quarter Circle Bridge at the mouth of McDonald Creek and counted volumetrically. Captured fry were assumed to be outmigrating from the creek. The fry were emersed for 50 minutes in an aerated live tank with solutions of Bismarck brown Y vital stain in a concentration of 1:30,000 (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 otherwise could have caused mortality to fry.

After staining, the fry were held in a mesh live car in the stream for one hour and allowed to recover before they were released. Groups of fry were held in mesh bags in the stream throughout the course of the experiment and checked periodically as controls for dye retention and mortality.

We sampled migrating fry downstream through the river system by capturing them in drift nets suspended from bridges located at 8, 34, 55 and 96 km downstream of the release site (Figure 1). The drift nets consisted of a metal frame (0.5 m^2), with a tapered, trailing net bag 1.8 m long (3.2 mm mesh size). In areas of slow water velocity, the end of the bag was tied shut and fry were captured in the cod end. In areas of faster velocities, a holding box was attached to the end of the net bag to protect captured fry (Figure 2).

The drift nets (3 to 10 per site) were checked at one to two-hour intervals during the hours of darkness and the number of stained and unstained fry were noted. Nets remained in position during the day and were checked at dusk. We maintained each netting station until it appeared that virtually all stained fry had passed. During these experiments, nets were set in areas of higher current velocity to capture as many fry as possible. Previous experiments (Fraley and Graham 1982) had confirmed that most fry were distributed in the areas of the water column with greatest flow velocities.

Results

We recaptured 807 (1.2%) of the 65,687 outmigrating kokanee fry stained and released in McDonald Creek during the three experiments. The stained fry migrated at night downstream through the Flathead River system in a protracted wave, generally passing each netting station over a period of one to four hours. No stained fry were captured in nets maintained during the day. During each experiment, a similar percentage of total fry captured at each of the first three Sites were stained. Most stained fry migrated as fast or slghtly faster than the rate of flow past Sites 1, 2 and 3.

Movement rates of stained fry in the slower flowing river section between Sites 3 and 4 were more variable. Most fry traveled nearly twice as fast as the flow rate. However, some fry swam more slowly, reaching Site 4 up to five nights after the majority of fry had passed. Movement rates of fry varied between the three experiments, as indicated below.

Experiment 1

On May 3, 1983, 10,664 kokanee fry were captured, dyed and released in McDonald Creek. Based on past studies of diel movements of fry in the creek (Fraley and Graham 1982), we assumed that the fry left the creek beginning at dusk or 2000 hours. At 0130 hours (four hours after dusk), stained fry had reached Site 1, 8 km downstream (Figure 3). A total of 371 fry were captured at Site 1, and 31, or 8.5 percent, were stained. Only four stained fry were captured during the next 60 hours of sampling at the 8-km point. At 0600 hours, the fry had reached Site 2, 34 km downstream from McDonald Creek. We sampled 164 fry during the night, and 18, or 11 percent, were stained.

By 0030 hours the following night, or approximately 12 hours of total travel time (based on only nocturnal migration), the fry had reached Site 3, 55 km downstream. We captured 52 fry during the night, and five, or 9.6 percent, were stained. We monitored Site 4, just above Flathead Lake, for ten days after the fry passed Site 3. We captured 671 fry, but none were stained.

Experiment 2

On March 28, 1984, we captured, stained and released 14,500 kokanee fry in McDonald Creek. By 2300 hours, stained fry had reached Site 1 (Figure 4). Numbers of stained fry captured at site one peaked at 2400 hours. Of the 1,888 fry captured at Site 1, 376 (20 percent) were stained.

The first stained fry reached Site 2 by 0500 hours the following morning (March 29) and continued passing the site until dawn. The fry then apparently held in the area during the day, as none were captured in the nets maintained during the light hours. At 2100 hours that evening, we again began to capture stained fry in our nets, and they continued passing that point until 2400 hours. Of the 453 fry captured at site 2, 57 (13 percent) were stained.

Stained fry reached Site 3 by 0200 hours that same night, and continued passing until 0500 hours. Of the 539 fry captured at Site 3, 78 (14 percent) were stained. We continued to monitor

Site 4 for eight additional days, but captured no stained fry.

Experiment 3

On April 23, 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 at 1900 hours and pulled at 2100 hours, confirming that fry began emigrating at dusk (approximately 2000 hours).

By 2200 hours, stained fry reached Site 1 (Figure 5). Fry continued passing this point until 0200 hours (April 24). Of the 751 fry captured, 131 (17 percent) were stained.

Stained fry reached Site 2 by 0230 hours, and continued passing until 0500 hours. A total of 367 fry were captured, 72 (20 percent) of which were stained. The first stained fry reached Site 3 by 0500 hours the same morning (nine hours of travel time). Stained fry continued past Site 3 at 2100 hours that evening, after apparently holding in the area during the daylight hours. Stained fry were captured at this site until 2400 hours. Of the 123 fry captured, 14 (11 percent) were stained.

By 1000 hours the next morning (April 25), 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 5). During the time fry were passing ths site, from 2 to 4 percent of all fry captured were stained. We continued maintaining nets at this site until May 1. Of the 1,789 fry captured during the entire period, 20 (one percent) were stained.

Movement Rates vs. Flow Rates

Most fry migrated downstream at nearly the same rate or faster than the calculated flow rate under similar flow conditions during experiments number one and number three (Table 1). During experiment one, flows in the Middle Fork and in the main stem Flathead River averaged 108 and 466 m^3/sec., respectively, while during experiment three, flows averaged 110 and 325 m^3/sec. in the same streams. Fry moved more than twice as fast as the flow rate from Site 3 to Site 4. We assumed that similar current velocities existed under similar discharges during these experiments.

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

Fry Mortality and Dye Retention

Control groups of 50 stained and 50 unstained fry held in net cages in McDonald Creek during experiment one experienced similar mortality rates. After eight days, mortality was ten percent in the stained group and eight percent in the unstained group. After 15 days, mortality was 19 percent and 16 percent, respectively, in the stained and unstained control groups.

In experiment two, 50 dyed fry and 50 undyed fry were held for five days with no mortality and good dye retention.

Fry stained for 50 minutes in a 1:30,000 solution of Bismarck brown Y stain showed good dye retention for one week. At two weeks, the stain was still visible on fry examined on a white background. Fin and mouth areas retained stain for up to 20 days. Fry dyed for 45 minutes in a 1:20,000 solution of the stain during earlier experiments retained the dye for less than one week. Ward and VerHoeven (1963), Stober and Hamalainen (1980) and Mundie and Traber (1983), also stained salmon fry with Bismarck brown Y. All of these researchers used concentrations of 1:30,000 with low mortality rates and had dye retention of 7 to 13 days.

Discussion

Kokanee fry emigrated from McDonald Creek, beginning at dusk, in a protracted wave. The fry migrated downstream during dark hours, then held in the gravels, probably along the stream margin, during the day. 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 in 1982, the majority of fry emigrated from McDonald Creek from 2400 hours to 0300 hours. Fry emigration began at one-half hour after sunset (2030 hours) and continued to sunrise (0530 hours). Brannon (1972), Stober and Hamalainen (1980) and Nelson (1965) reported most 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 from the early to late portion of the fry emigration season and from year to year.

Kokanee fry moved as fast or faster than flow rates in each river section. This indicated that they actively maintained position in the current. To travel as fast or faster than the flow rate between Sites 1 and 3, the fry probably swam through eddies and back currents. Most fry migrated actively, up to twice the rate of flow, through the slow-moving river from Site 3 to Site 4. The fry were more scattered at Site 4 (one stained fry was captured two nights and one five nights, after the majority passed), indicating a larger variation in swimming rates of individual fry where there is less current to transport them. Hartman et al. (1962) found that sockeye fry migrated downstream as fast or faster than flow rates. Kokanee fry migrated at a slower rate during periods of lower flows (experiment 2). We do not have a good estimate of flow rate at the low discharges during the experiment.

Our experiments indicated that some kokanee fry hold for varying periods in the lower portion of the Flathead River before entering Flathead Lake. The lower portion of the river could serve as a resting and feeding area for some fry before they enter the lake. Relatively few stained fry were captured at Site 4 (3 km upstream of Flathead Lake) within ten days of their release from McDonald Creek during experiment three. No stained fry were captured at Site 4 during experiments one and two. Other factors which could have caused fewer stained fry in our samples at site four could be related to sampling a smaller portion of the water column, fry mortality, or the natural time dispersal of the group of fry moving downstream.

Kokanee fry derive the energy required for migration from stored reserves and by feeding on early instars of aquatic insects. An average of 10 percent of the fry emigrating from McDonald Creek had not yet absorbed their yolk sac. We have found that migrating fry in the Flathead River system feed mostly on chironomids. Similarly, Loftus and Lenon (1977) found that chironomids were the most important food organisms for chum salmon fry and chinook salmon fry in the Salcha River, Alaska. Becker (1973) reported that juvenile chinook fed mainly on chironomid adults and larvae in the Columbia River, Washington. Salmon fry fed mainly on chironomid larvae in rivers of Japan and Norway (Kaeriyama et al. 1978, Lillehammer 1973).

We have observed substantial variation in kokanee fry migration patterns in the Flathead System. During our experiments, most fry appeared to leave McDonald Creek and swim directly downstream with little or no residence time indicating an active rather than passive migration pattern. 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 some time in the creek before we captured them at the stream mouth. Spring areas in the Flathead System produce larger fry which stayed longer before emigrating (Fraley and McMullin 1983). Variations in residence times of fry in spawning areas and fry migration rates have probably been important in the survival of kokanee in the system.

Acknowledgments

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LITERATURE CITED

Becker, C.D. 1973. Food and growth parameters of juvenile chinook salmon, Oncorhynchus tshawytscha, in Central Columbia River. Fishery Bulletin 71:387-400.

Brannon, E.L. 1972. Mechanisms controlling migration of sockeye salmon. Internat. Pacific Salmon Fisheries Commission, Bull. XXI, 86 p.

Fraley, J.J. and P.J. Graham. 1982. The impact of Hungry Horse Dam on the fishery of the Flathead River. Completion report submitted to the Bureau of Reclamation. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana, USA.

Fraley, J.J. and S.L. McMullin. 1983. Effects of the operation of Hungry Horse Dam on the Kokanee Fishery in the Flathead River System. Annual report to the Bonneville Power Administration, Contract DE AI79-83BP39641, Project No. 81S-5. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana, USA.

Hartman, W.L., C.W. Strickland and D.T. Hoopes. 1962. Survival and behavior of sockeye salmon fry migrating into Brooks Lake, Alaska. Transactions of the American Fisheries Society 91:133-139.

Kaeriyama, M., S. Sato and A. Kobyashi. 1978. Studies on a growth and feeding habit of the chum salmon fry during seaward migration in the Tokachi River System - Influence of thaw on a growth and feeding habit of the fry. Scientific Reports of the Hokkaido Salmon Hatchery 32:27-41.

Lillehammer, A. 1973. An investigation of the food of one-to-four-month-old salmon fry (Salmo salar L.) in the river Suldaislagen, West Norway. Norway Journal of Zoology 21:17-24.

Loftus, W.F. and H.L. Lenon. 1977. Food habits of the salmon smolts, Oncorhynchus tshawytscha and O. keta, from the Salcha River, Alaska. Transactions of the American Fisheries Society 106(3):235-240.

Mundie, J.H. and R.E. Traber. 1983. Movements of coho salmon (Oncorhynchus kisutch) fingerlings in a stream following marking with vital stain. Can. J. Fish. Aquat. Sciences 40(8):1318-1319.

Nelson, M.L. 1965. Abundance, size, age and survival of red salmon smolts from the Ugashik Lakes system, Bristol Bay,

1965. Alaska Dept. Fish and Game, Informational Leaflet - 85. 28 p.

Potter, D.S. 1978. The zooplankton of Flathead Lake: An historical review with suggestions for continuing lake resource management. Ph.D. Diss., University of Montana, Missoula, USA.

Stober, Q.J. and A.H. Hamalainen. 1980. Cedar River sockeye salmon production. Washington State Dept. Fish. 59 p.

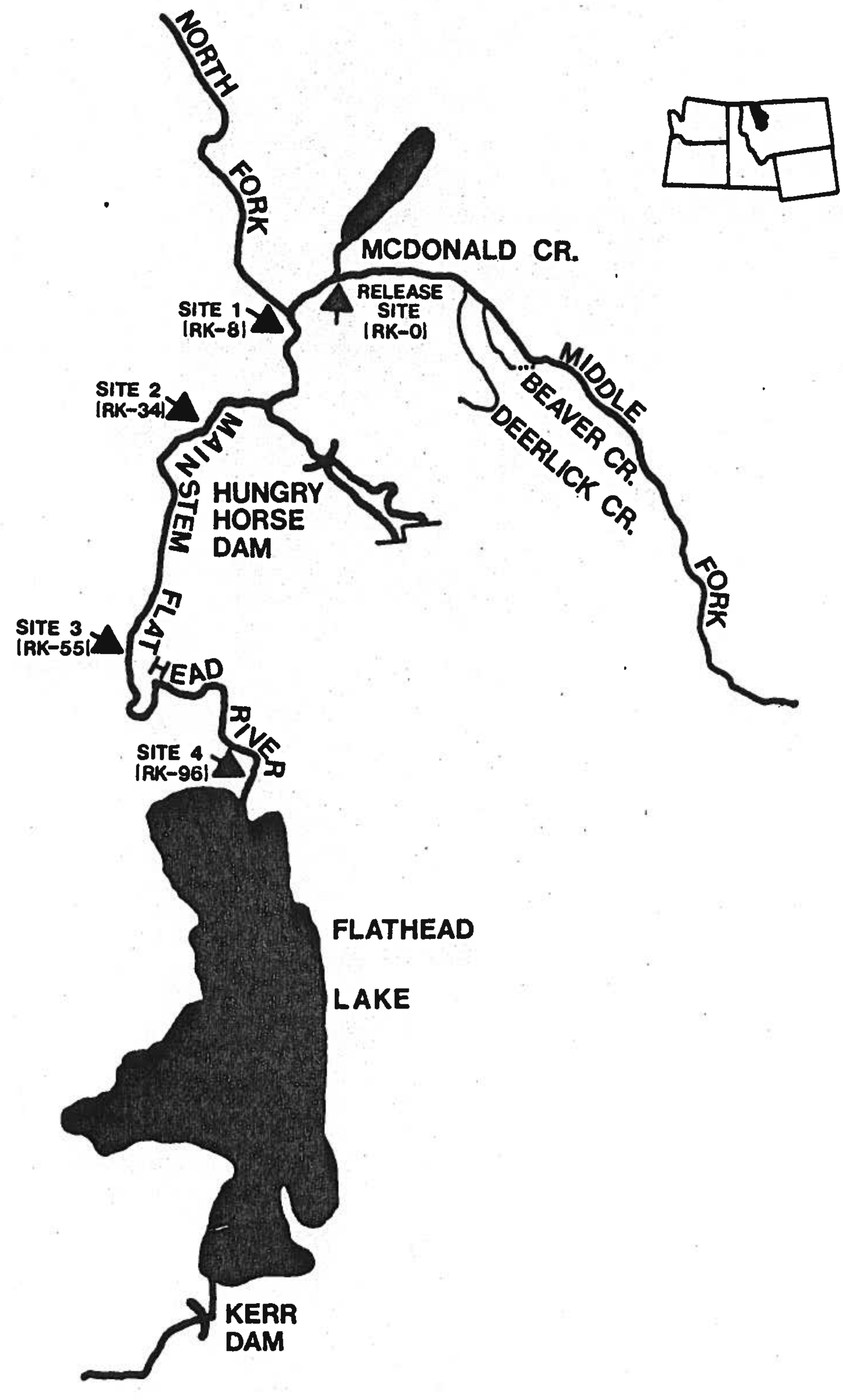
Ward, F.J. and L.A. VerHoeven. 1963. Two biological stains as markers for sockeye salmon fry. Transaction of the American Fisheries Society 92:379-383.

Table 1. Flow rates and movement rates of stained fry for each river section during experiment number 1 and number 3. No flow rates are available for the conditions present during experiment number 2.

River Section	Distance (km)	Flow rate[a] (km/h)	Maximum Movement Rate of Stained Fry (km/h)	
			Experiment 1	Experiment 3
Site 1 to Site 2	26	5.8	5.8	6.5
Site 2 to Site 3	21	6.0	7.0	6.8
Site 3 to Site 4	41	2.1	No Data	4.6

[a] Calculated from flow times of water releases from Hungry Horse Dam at flows similar to these existing during experiments 1 and 3.

List of Figures


NORTH
FORK
MCDONALD CR.
SITE 1
(RK-8)
RELEASE
SITE
(RK-0)
MIDDLE
BEAVER CR.
DEERLICK CR.
FORK
SITE 2
(RK-34)
MAINSTEM
HUNGRY
HORSE
DAM
SITE 3
(RK-55)
FLAT
HEAD
RIVER
SITE 4
(RK-96)
FLATHEAD
LAKE
KERR
DAM

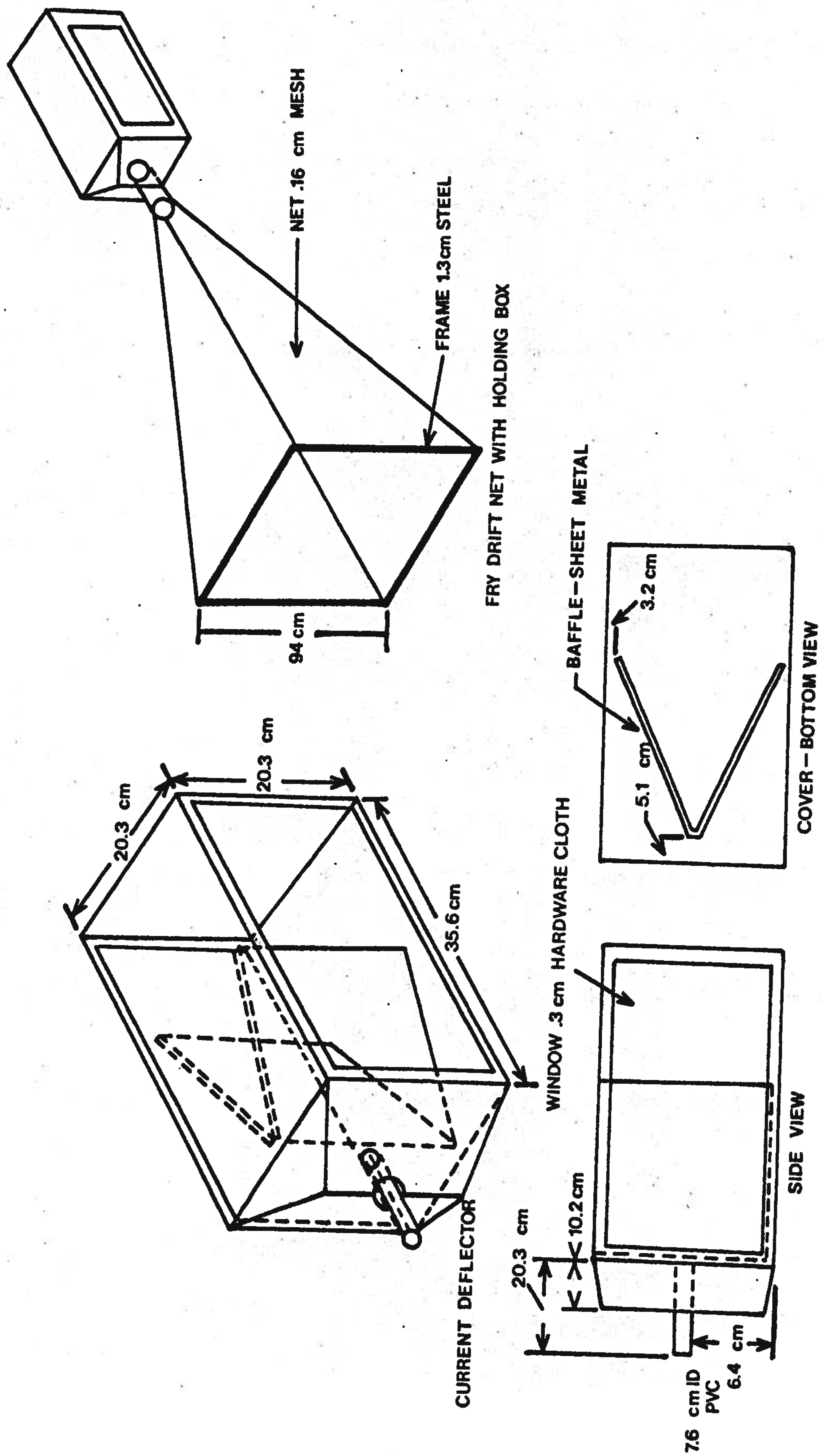
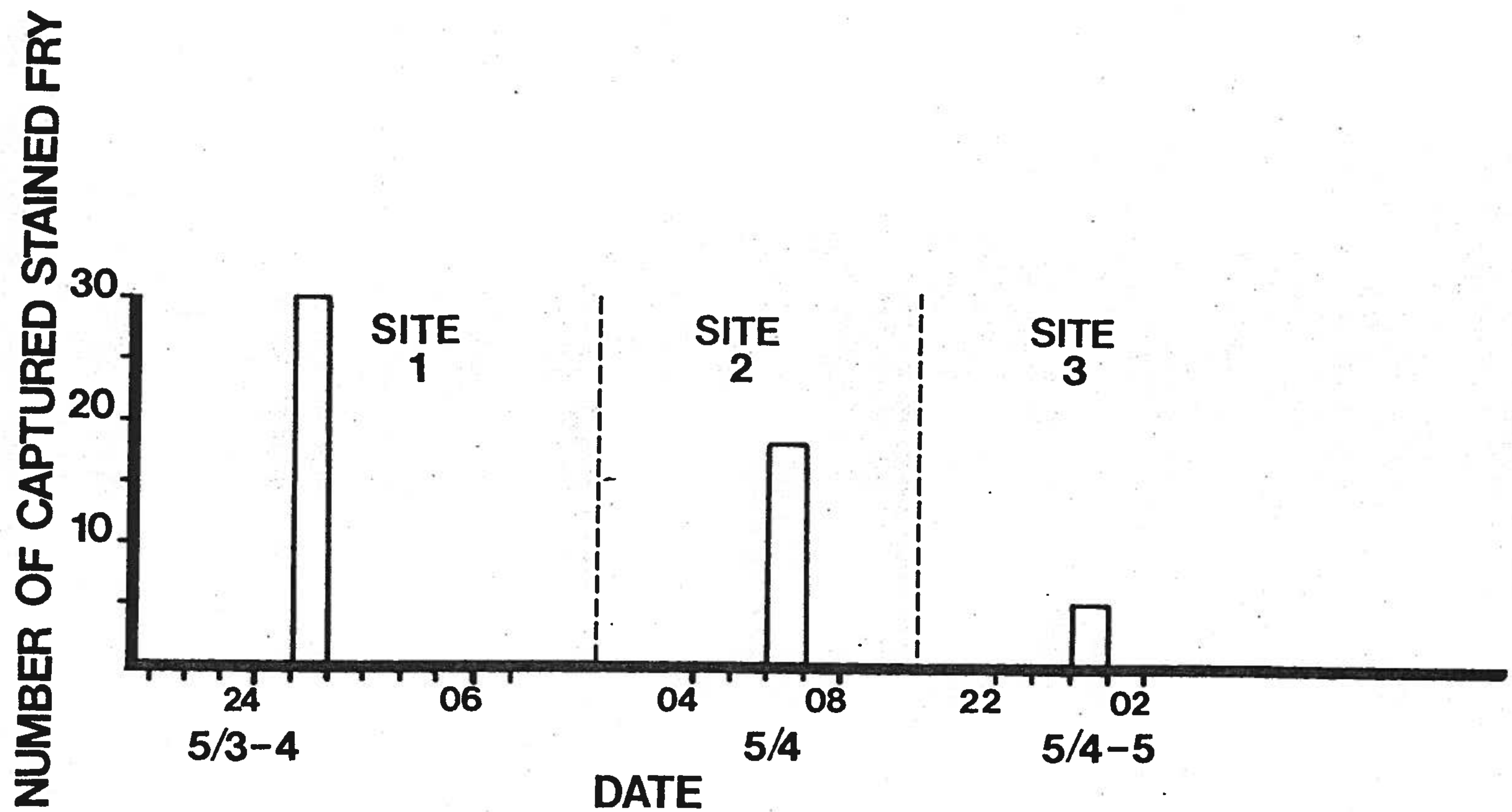
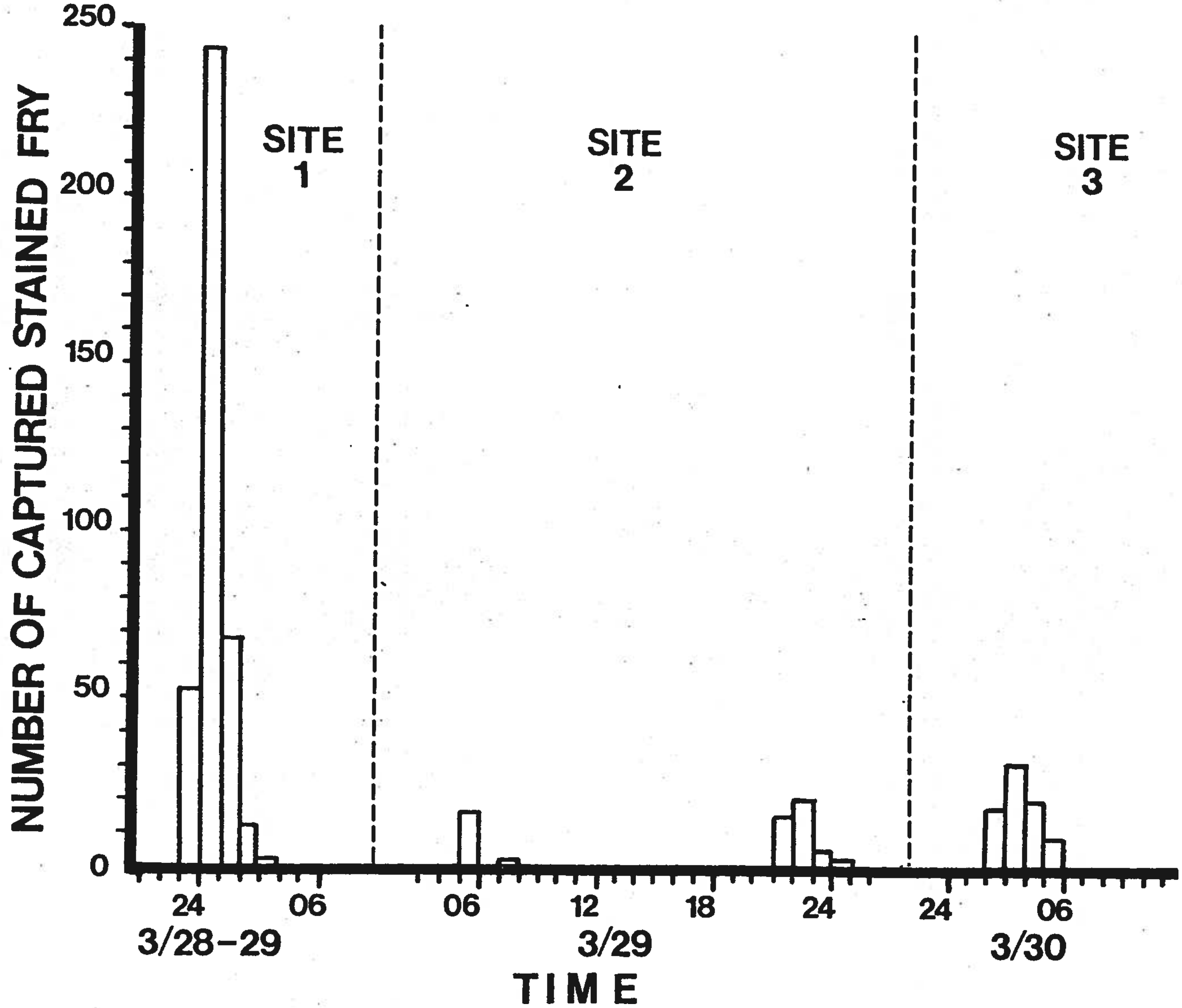

NET .16 cm MESH
FRAME 1.3 cm STEEL
94 cm
FRY DRIFT NET WITH HOLDING BOX
BAFFLE–SHEET METAL
3.2 cm
5.1 cm
COVER–BOTTOM VIEW
20.3 cm
20.3 cm
35.6 cm
WINDOW .3 cm HARDWARE CLOTH
CURRENT DEFLECTOR
SIDE VIEW
20.3 cm
10.2 cm
6.4 cm
7.6 cm ID
PVC

FIG 2



NUMBER OF CAPTURED STAINED FRY
30
20
10
SITE 1
SITE 2
SITE 3
24
06
04
08
22
02
5/3-4
5/4
5/4-5
DATE

FIG 3



NUMBER OF CAPTURED STAINED FRY
250
200
150
100
50
0
SITE 1
SITE 2
SITE 3
24
06
06
12
18
24
24
06
3/28-29
3/29
3/30
TIME

FIG 4

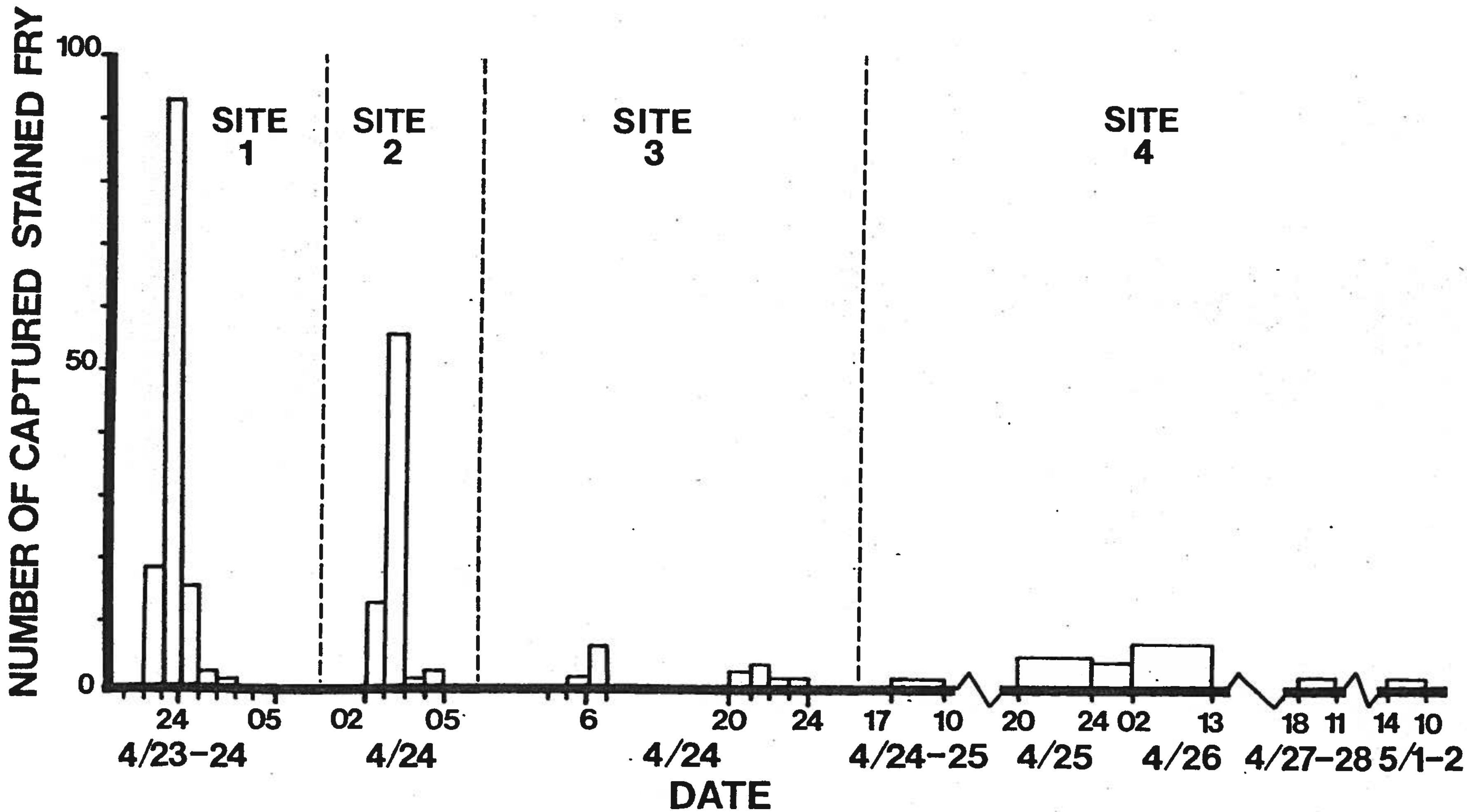

NUMBER OF CAPTURED STAINED FRY
100
50
0
SITE 1
SITE 2
SITE 3
SITE 4
24
05
4/23-24
02
05
4/24
6
20
24
4/24
17
10
4/24-25
20
24
02
13
4/25
4/26
18
11
4/27-28
14
10
5/1-2
DATE

FIG 5