E13-2

Hebgen Lake Fry Recruitment Study

Final Report

January 1, 1991

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INTRODUCTION

The purpose of this study was to evaluate rainbow trout spawning and fry recruitment in the tributaries to Hebgen Lake. Attempts to bolster the wild rainbow trout population of Hebgen Lake began in 1983 with the first small introductions of the Eagle Lake strain of rainbow trout. In 1987 stocking levels were increased and over 200,000 fingerling rainbow, mostly of the De Smet Strain, have been stocked annually since.

Gill-net and electrofishing surveys of the reservoir in recent years have indicated that these stocking levels have resulted in improved populations of adult rainbow trout. The objectives of this study were to assess the spawning runs of rainbow trout in Hebgen tributaries and determine which tributaries were contributing wild rainbow trout fry back into Hebgen Lake. The eventual goal of the program is to eliminate stocking and manage for a wild self-sustaining fishery.

DESCRIPTION OF STUDY AREA AND METHODS

Hebgen Lake is a 12,700 acre reservoir astride the headwaters of the Madison River in southwest Montana. Because of the placement of the dam where the Madison River leaves a major valley, the reservoir is the recipient of ten tributaries (Fig. 1). These ten tributaries provide a unique opportunity to establish a wild self-sustaining rainbow trout fishery in a reservoir environment.

The thermal characteristics of Hebgen Reservoir tributary inflows are widely variable due to the presence of thermal features in the Yellowstone Park area. Thermal springs provide heated water to the Madison River which would otherwise be fed exclusively by cold, high elevation snowmelt.

Direct observation and electrofishing have been the primary methods used to monitor rainbow trout spawning runs. A summary of observations previous to 1990 is provided in an earlier report (Oswald et al 1990). During 1990, electrofishing surveys were conducted in the South Fork of the Madison, Black Sand Spring, and Grayling Creek. A mobile electrode system consisting of a small fiberglass boat, straight DC electrofishing unit, and 3,500 watt generator, was used to float down the river and collect as many fish as possible. Fish were measured, weighed, and assessed for sexual maturity.

A fish trap was manned on Duck Creek from May 2 - May 27, 1990 at a site about 400 yards downstream from the Yellowstone Park boundary. The trap-site was on a fish ladder which provides upstream passage around a man-made dam. Fish were collected at least once daily from the trap and measured, weighed, sexed, and tagged.

Temperature monitoring was conducted on the eight largest tributaries from late April through September (Figure 1). Hourly air and water temperatures were recorded with an Omnidata Model DP212 two channel electronic datapod. Data was stored on solid state memory modules (chips) and dumped to a computer database on a monthly basis.

Fry samples were collected at standardized trap sites which were installed as near as possible to the first day rainbow trout fry were observed moving downstream in each stream. Sites selected for monitoring were always at the tail end of runs with uniform substrate and water depths ranging from 0.5 to 1.5 feet. The sites selected were similar to preferred sites for measuring stream flows. The objective was to select sites that were as uniform as possible to eliminate variability from stream to stream and to provide representative samples of drifting fry.

Fry traps were installed at each site 1/3 of the way out from a randomly selected bank. Trap mouths were 30 inches wide by 18 inches tall. Traps were constructed of 1/16 mesh nylon netting five feet long tapered to a 6 - inch pvc coupler. A nylon mesh bag five feet long with baffles was attached at the coupler. To remove fry samples the coupler was unscrewed and contents were dumped into a bucket, leaving the trap frame mounted to rebar posts anchored in the stream. Traps were generally checked and cleaned at least daily. the traps worked very efficiently with very little mortality and only occasional debris clogging.

In order to estimate the total numbers of fry passing downstream the daily trap catch was extrapolated. Occasional evening trap checks confirmed that nearly all downstream fry emigration occurred at night. Extrapolation was done by the following procedure. At a representative stream flow with the trap installed a flow measurement was taken using a Gurley meter. The flow passing through the trap was measured across the trap mouth. The percentage of flow passing through the trap was used as an expansion factor.

Trapping of fry was done on a schedule of two days on and then two days off. Total estimated fry numbers were expanded by the flow percentage and then doubled to account for the alternate days and achieve the final estimate of fry passage for each trap site.

RESULTS
TEMPERATURE

Hourly temperature was recorded at each of eight monitoring sites (Figure 1) and then summarized to produce daily minimum, maximum and mean temperatures. That data is summarized for this report into monthly tabulations (Table 1, Table 2).

The data indicated that there were three types of thermal regimes in the tributaries to Hebgen Lake (Fig. 2). The first, and most common, was a "normal" pattern of cold spring temperatures followed by rapidly rising temperatures as ice melted out. Summer temperatures under the "normal" regime were variable due to weather conditions and decreased into the fall. Daily temperature fluctuations were usually less than 5° F during spring and cold weather periods but ranged from 5 to 15° F during midsummer. This "normal" pattern (Fig. 2) was exhibited by five of the streams monitored. Trapper Creek, Watkins Creek, and Grayling Creek were all very cold tributaries with late runoff. Cougar Creek and Duck Creek emerge from open meadows at lower elevations and consequently runoff was earlier and temperatures were warmer. Duck Creek water temperatures were the warmest of these five streams, partly as a consequence of a shallow artificial impoundment located on-stream immediately upstream from the monitoring site.

The second type of thermal regime was a very stable "spring-influenced" pattern exhibited by Black Sand Spring and the South Fork of the Madison River (Fig. 2). Since Black Sand flows into the South Fork above the monitoring site and contributes a substantial proportion of the flow of the South Fork, the two had similar temperature regimes. Black Sand Spring was a constant 48-51° F throughout the monitoring period with a daily variation of only 1° F being the norm. The South Fork exhibited daily temperature fluctuations of 5-15° F throughout the monitoring period but maximum temperatures were a cool 58° F and the daily average from April through September was nearly always between 47° and 52° F.

The third type of thermal regime was the "thermal-influenced" pattern exhibited by the Madison River (Fig. 2). Due to the year-around thermally - heated inflow from Yellowstone Park the Madison River was by far the warmest tributary to Hebgen Lake. Average daily water temperatures reached 68° F during August and hourly maximums as high as 82° F were recorded on August 4, 5, 6 and 14. The coldest temperature recorded was only 41° F. Springtime temperatures (April-May) in particular were much warmer than streams without the thermal influence (Fig. 2).

In summary, the tributaries to Hebgen Lake exhibited a wide degree of temperature variation. The coldest, Trapper Creek, had an

average daily temperature (44° F) that was 16° F colder than the average for the Madison River (60° F). As will be discussed later in this report, this temperature variation appears to play a critical role in rainbow trout spawning and recruitment.

SPAWNING OBSERVATIONS

Only one stream, Duck Creek, was intensively monitored during 1990 to evaluate the timing and duration of the spawning run. A trap was installed at the pond-site in the fish ladder (Fig. 3) and maintained from May 3 - May 27, 1990. During that period a total of 1,277 adult rainbow trout were passed upstream (Table 3). the ratio was 3.2 female:1.0 male. It was apparent from the distribution that a major portion of the run of males must have preceded trap installation. Seventy percent of the males captured were taken in the first four days (May 3-6).

Upstream movement was strongly correlated with water temperature (Table 3). During the twenty-five day trapping period observation of the fish ladder indicated most fish movement occurred in late afternoon and reached peak levels when water temperatures exceeded 50° F. On fourteen of the twenty-five days maximum water temperatures exceeded 50° F. During these 56% of the trap days, 84% of the female and 93% of the male rainbow trout passed upstream.

All of the female rainbow trout and 95% of the males were between 14.0 and 19.9 inches long (Table 4). Nearly 80% of the males and over 90% of the females were between 16.0 and 18.9 inches. The fish were in fair condition with females having an average condition factor of 33.4 and males 32.6. Routine health samples collected from thirty fish on May 18, 1990 indicated no pathogens. Fish did have a moderate to heavy infestation of Salmoncola spp., a parasitic copepod, on the gills and fins. Spawntaking was conducted on May 18 and May 24 with an average egg-take of just over 1,000 eggs per ripe female. Subsequent hatchery eyeup exceeded 90%.

Attempts to quantify spawning runs on streams other than Duck Creek were much less intensive. Electrofishing of the South Fork of the Madison on April 26, May 3, and May 9 was moderately successful. Spawning activity appeared to be concentrated in a two-mile reach downstream from the Highway 20 bridge (Fig. 4). Size distribution and appearance of these fish was very similar to those from Duck Creek with the peak length frequency around 17-17.9 inches. By May 3 spawning appeared to be nearly completed with almost all females that were captured either ripe or spawned out. Maximum daily water temperatures on the South Fork exceeded 50° F every day from April 20th, when the thermograph was first installed, throughout May.

Black Sand Spring Creek was electrofished May 8, 1990. Forty-four adult rainbow were captured with the 23 females mostly ripe or spent. Nearly all appeared to be upstream migrants from Hebgen Lake.

Grayling Creek was electrofished on May 25, 1990 from the Grayling Creek Ranch at the mouth of the canyon downstream to the lake (Fig. 5). Active spawning was occurring and 111 adult rainbow and two cutthroat trout were captured. Sex ratio of rainbow trout was 2.6 female:1 male with 58% of the females ripe, 15% green, and 27% already spawned out. Based on this sample it appeared spawning was near the peak. Examination of water temperatures indicated daily maximums exceeded 50° F on only two days, May 5 and June 9, during the period of April 2 - June 22. However, May 21 - May 28 was the first period that daily maximums routinely exceeded 45° F. It appears that rainbow trout in Grayling Creek spawned in colder water temperatures than that observed in other streams. The Grayling Creek spawners were also noticeably different in appearance than the Duck Creek and South Fork fish. A high percentage of the Grayling Creek fish (50.5%) had noticeable fin erosion on the dorsal, pectoral, and/or adipose fins indicating they were fish of hatchery origin. This was not the case in other streams surveyed where noticeable fin erosion was seen on less than 5% of the fish sampled.

Trapper Creek was not sampled but 20 or more spawning rainbow were observed there on May 19, 1990. This was presumed to be near the beginning of the spawning period. A few fish were also observed in Watkins Creek on that date.

Examination of scale samples from these spawning fish from Duck Creek, South Fork, and Grayling Creek indicated most were either 3 or 4 years old. However, patterns of growth were very complex and inconsistent, with numerous check marks present. The author does not feel confident in the age analysis at this point. Previous work conducted in the reservoir indicated 14-18" fish would be 3-5 years old in the spring (Oswald et al 1990).

In summary, the 1990 spawning observations indicated that Duck Creek, the South Fork Madison River, and Grayling Creek all produced substantial spawning runs. Lesser numbers of adult fish were found in Black Sand Springs, Trapper Creek, and Watkins Creek. No observations were made on Cougar Creek, the Madison River or Red Canyon Creek. Spawning appears to be strongly related to water temperature with onset occurring by April 15 in the warmer streams and not until late May in the colder streams. The Madison River, with the warmest water temperatures, presumably has a very early run but this has not been documented.

FRY TRAPPING

Trapping of fry was initiated on each stream once fry emergence was either observed or expected (based on spawning observations and temperature analysis). Fry trap counts were expanded (see methods section of this report) to produce total estimates of fry emigration for each stream or site (Table 5).

In total, over 660,000 fry were estimated to have emigrated past the trap sites. Eliminating duplicate sites (more than one on the same stream) results in a total fry estimate of about 590,000 rainbow trout emigrating from Hebgen Lake tributaries. It is important to point out that this estimate does not include the Madison River, which is probably a major fry contributor. The estimate is also conservative in that some fry production occurred downstream from trap sites, particularly on Duck and Grayling Creek, and thus was not measured. It does not seem unreasonable to place the estimate of total rainbow trout fry production from Hebgen Lake tributaries at nearly one million fish during the 1990 spawning season.

Fry emigration patterns, timing, and intensity varied widely from stream to stream. Following is a discussion of individual drainages in order of their relative estimated production.

DUCK CREEK DRAINAGE: Lower Duck Creek was far and away the largest producer of emigrating rainbow trout fry. Exactly 50% of the total basinwide estimated fry production came through the lower Duck Creek trap site, with 294,434 emigrating fry produced. An examination of the timing and intensity of this downstream movement shows that nearly all of the emigration occurred during July (Figure 6). Fry were extremely numerous during mid-July with the trap collecting as many as 2,000 fry in a single night. Expansion of this trap catch produced a total estimated emigration rate of up to 30,000 fry per night.

Virtually all of the documented fry emigration through the lower Duck Creek site came from a very short reach of stream extending from the trap site upstream about 1.0 mile to the base of the dam (Fig. 3). At the dam, where the fish trap was installed, a second fry trap was used to document emigration from the upper Duck Creek drainage. Only 804 fry were estimated to have passed downstream at this site, despite intensive monitoring throughout the month of July and early August. This was somewhat puzzling due to the fact that a known contingent of 1,277 adult rainbow trout were passed upstream through the fish trap. The 970 females had potential to produce about 1 million eggs.

Exploration of the upper Duck Creek drainage on August 1 revealed evidence of very limited spawning habitat. Most of Duck Creek is a slow, meandering, heavily-sited stream with very few gravel bars.

Very few rainbow trout fry were observed in this meadow reach. A concentration of trout redds and fairly high densities of rainbow trout fry were observed in the lower end of Campanula Creek, a tributary which joins Duck Creek 5.4 miles above the reservoir from the North (Fig. 3). Campanula Creek is heavily beaver-dammed with a higher-gradient actively eroding channel that provided some better spawning gravels. While it appears that beaver activity would limit access in Campanula Creek to the lower two miles, it may be an important spawning tributary to the Duck Creek drainage. The failure of the upper Duck Creek fry trap to document fry production from this site may indicate that these fry are delayed in their emigration and/or rearing for a period of time in upper Duck Creek.

The recruitment of fry to Hebgen Lake from lower Duck Creek may be critical. Nearly 300,000 fry emigrated from a 1-mile reach of this stream. Subsequent evaluation also discovered considerable spawning habitat and another 100 or more redds in the remaining 1 mile of Duck Creek downstream from the fry trap site and above the junction with Cougar Creek. Consequently, 300,000 emigrating fry is probably an underestimate of the total contribution of this stream.

SOUTH FORK MADISON RIVER DRAINAGE: The South Fork drainage of the Madison River produced the second highest fry output with an estimated 163,090 fry emigrating through the lower trap site (Fig. 7). This was 28% of the basinwide total production. The upper trap site, one mile above the mouth of Black Sand Spring and about seven miles upstream from the lake produced an estimated 23,188 fry; only 14% of the total for the South Fork drainage and 4% of the total basinwide estimate.

The relative timing and duration of fry emigration from the two South Fork sites illustrates the effect of colder water temperatures. At the lower South Fork site, about 1 mile upstream from Hebgen Lake, the major fry emigration occurred during July with the peak on July 17, (Fig. 7). The pattern was similar to Duck Creek but about one week later and about half the intensity. Migration from the colder headwaters, which were not influenced by spring water inflow from Black Sand Spring was mostly during the last week of July and early August with a peak on July 28 (fig. 8).

The upper South Fork of the Madison produced only 23,188 fry. Several large beaver dams on the South Fork, as little as 1-1/2 miles upstream from Black Sand Spring, may limit upstream migration of adult rainbow trout from Hebgen Lake (fig. 4).

Black Sand Spring was trapped near the lower end of it's 3/4 mile length. It contributed an estimated 30,714 rainbow trout fry to the South Fork of the Madison (fig. 9). The long duration of the Black Sand emigration (mid-June through mid-August) was somewhat

surprising given the constant water temperatures discussed earlier. Emigration of fry from Black Sand Spring may have accounted for much of the fry output detected in the lower South Fork during late June and early July. Overall, Black Sand Spring contributed about 5% of the basinwide total fry estimate.

In summary, the South Fork of the Madison River appears to be an extremely important drainage for rainbow trout fry production, perhaps ranking second only to Duck Creek. From the present information it appears that most of the fry production in the drainage comes from the mainstem of the South Fork in a 5-mile reach from one mile above the lake upstream to the mouth of Black Sand Spring. Tributary streams to the lower South Fork including Denny, Cream, and Buttermilk Creeks need to be investigated for possible spawning and recruitment (fig. 4).

GRAYLING CREEK: Due to a logistical error fry emigration on Grayling Creek was apparently well underway prior to the installation of traps. Consequently, estimates are probably underestimates, particularly at the lower site. On lower Grayling Creek only 16,190 fry were estimated to have passed the trap site. The peak occurred the first night the traps were set out (July 24) which also indicates we were late getting in (fig. 10).

Fry trap data from upper Grayling Creek appears to be more reliable. At this site, about 4 miles upstream from the lake, an estimated total of 74,714 fry passed. Due to the much colder springtime water temperatures, and consequent later spawning and slower egg development, the upper Grayling Creek emigration occurred primarily during the last week of July and throughout August (fig. 11). The peak was August 1, a full three weeks later than on Duck Creek. Again, the starting date appears to have missed the early part of the emigration.

The estimated production from Upper Grayling Creek was 13% of the basinwide total. This was surprisingly high given the steep canyon and precipitous rapids in lower Grayling Creek about one mile below the upper trap site (fig. 5). To the observer, passage through this canyon appears difficult, if not impossible, but spawning fish from Hebgen Lake have been observed upstream from these rapids at least as far as the Yellowstone Park boundary. There is a second major waterfall of about five feet in height which constitutes an almost certain barrier on Upper Grayling Creek. It is located in Wyoming about 3/4 mile upstream from the Montana-Wyoming border (fig. 5). No rainbow fry were observed upstream from this site, approximately 11 miles upstream from Hebgen Lake. Little Tepee Creek was observed to have rainbow fry near the mouth but was not investigated. It should be examined in the future.

The relatively low numbers of fry at the lower Grayling trap site are puzzling. There is no logical explanation other than the likelihood that we missed most of the emigration due to the timing of trap installation. Overall, Grayling Creek appears to have potential but did not produce fry with near the abundance seen in Duck Creek and the South Fork of the Madison.

TRAPPER CREEK: Total estimated fry production from Trapper Creek was 44,070 or 7% of the basinwide total. This stream represents the extreme of cold water temperatures and late emigration. Emigration occurred during late August and into early September with a peak on August 25th, nearly 7 weeks later than Duck Creek (fig. 12).

Trapper Creek does offer one advantage over some of the other streams. Virtually all of the spawning occurs in the lower 1/2 mile of the stream so emigrating fry are virtually assured of reaching the lake. Their fate from that point is uncertain.

COUGAR CREEK: Despite a drainage similar in size and location to Duck Creek, Cougar Creek is not a major rainbow trout fry production source. Fry production occurred mainly during July with a peak on July 21 (fig. 13). Total estimated production was 13,308 fry, only 2% of the basinwide total.

Investigation of the lower two miles of Cougar Creek did not indicate the presence of any high quality spawning substrate. The entire drainage appears to be heavily silted and due to the 1988 fires it is now prone to heavy sediment discharges. It is doubtful that Cougar Creek can sustain major spawning runs now or in the future.

WATKINS CREEK: Despite observed spawning activity and fry production during 1989, a trap site near the mouth of this stream in 1990 produced no fry. the trap was run throughout August. Since the thermal regime is very similar to Trapper Creek it appears that there was no fry production during 1990. Watkins Creek has experienced considerable channel degradation and is subject to dewatering due to irrigation. This may explain the failure to recruit fry in 1990.

GENERAL OBSERVATIONS: Overall, the efficiency of the fry trap method used for this project was judged to be very good. No problems were encountered with clogging except for a couple of minor instances.

It was discovered on the South Fork of the Madison and Black Sand Spring that early fry samples contained a significant proportion of brown trout. Examination of specimens collected from each site once a week was used to classify fry by species and eliminate brown trout from the estimated totals. Generally, pigmentation patterns

on the adipose fin, chin, and dorsal fin made separation of the two species relatively simple.

Weekly fry samples were measured from each of the sites (Table 6). Surprisingly, samples showed very little growth through the season. This contradicts data from grab samples collected during 1989 (Oswald et al 1990) which showed average growth rates of fry of about 2 mm/week. This apparent discrepancy may be a result to sampling methods. It appears from the 1990 trapping data that fish over 28 mm were rarely captured. Fish larger than this may actively avoid the nets by emigrating more slowly or during the day. It is also possible that fry which do not emigrate immediately may stay in the stream for an unspecified period. Such fish would be captured in grab samples but not by drift nets. If the average growth rate of fry is about 2 mm/week, then samples collected with drift nets appear to be nearly all emigrating within three weeks of the time they reabsorb their yolk sacs. This usually occurred by the time total length exceeded 21 mm.

There was also little variation in length for fry samples from different streams (Table 6). Fry from Duck, Trapper, and Cougar Creeks consistently averaged up to 1 mm shorter than in the other streams but there was no apparent or obvious explanation for this minor differential.

DISCUSSION

The total estimated fry emigration from Hebgen Lake tributaries monitored during 1990 was about 590,000 fish. Most of that production (78%) came from just two streams. Duck Creek contributed 50% of the total and the South Fork of the Madison drainage contributed 28% (fig. 14).

The bulk of the emigration (78%) took place during July (fig. 15). Another 16% of the fry emigrated during August, 5% during June, and 1% in September. The timing of the emigration may be a critical factor in determining survival of fry. Early emigrants from Duck Creek, Black Sand Spring, and the South Fork Madison River would reach the lake two full months earlier than late migrants from Trapper Creek. This two month differential in age could result in a growth advantage of up to two inches for these early migrating fish.

Survival of fry once they reach the lake is dependent on several factors; including food supply, predation, and overall condition. In most waters, fish stocked from the hatchery at a larger size have a distinct survival advantage going into winter. If this relationship is true with wild fish, then early migrants should also have a distinct advantage.

Early spawning and fry emigration is strongly correlated to tributary water temperatures. It is probably no coincidence that historic runs trapped for egg collection in the 1940's and 1950's were in the Madison River, Duck Creek, and the South Fork Madison River. These are the three warmest drainages in the Hebgen Lake basin and are probably today the major rainbow trout producers. The timing of egg development, hatching and fry swim-up are directly related to water temperature. A "temperature unit" is defined as 1° F above freezing for 24 hours. Thus, during a full day at 42° F an egg would accumulate 10 temperature units. At a constant 40° F eggs hatch in 80 days after acquiring 640 temperature units (Piper et al 1982). At a constant temperature of 45° F rainbow trout eggs hatch after accumulating 624 temperature units, or in 48 days. At 50° F a total of 558 temperature units are required (31 days). Thus, at the warmer water temperatures of streams such as the Madison River or Duck Creek, eggs may hatch in half as many days as they do in colder streams.

Once the eggs are hatched there is an additional time period and temperature units required for the sac fry to absorb much of their yolk sac and emerge or "swim up" from the gravel. Based on observation of spawning rainbow trout and fry emigration on Hebgen Lake tributaries it appears that emigration occurs after about 1,080 temperature units have been accumulated by the egg and fry, roughly double the temperature units required to hatch the eggs.

Using this value of 1,080 temperature units, and knowing the peak emigration date and temperature regime of Hebgen Lake tributaries, we can backdate and calculate the peak spawning date.

The reconstructed timeline of spawning, hatching, and fry emigration based on temperature units (fig. 16) concurs very closely with observations of spawning activity. This is a very useful and dependable relationship to use in determining when to expect fry emigration given only the known values of spawning dates and water temperatures.

Backdating of peak fry emigration to a total of 1,080 temperature units illustrates the effect of water temperature on the progression of egg and fry development. In Duck Creek, only 44 days were required from peak spawning to peak emigration (fig. 16). Intermediate values of 60 and 64 days were calculated for the lower South Fork of the Madison and Black Sand Spring, respectively. At the other extreme were Trapper and Grayling Creeks at 73 and 77 days, respectively (fig. 16).

Backdating from peak emigration did not appear to work well on Grayling Creek where peak spawning was predicted for May 8, much earlier than it was observed to occur. The Grayling Creek situation needs further examination.

MANAGEMENT RECOMMENDATIONS

This study succeeded in identifying critical rainbow trout spawning reaches in tributary streams to Hebgen Lake, documenting the timing of fry development, and estimating total fry emigration for the system. However, one very important component of the system was not evaluated, that being the Madison River.

The extremely warm thermal regime of the Madison River was documented and limited fry sampling was conducted in 1990. From these observations it is apparent that the Madison must have a very early rainbow trout spawning run, perhaps as early as January. Major emphasis should be placed on identifying the timing, intensity, and destination of this early run. Subsequently, the output of emigrating fry to Hebgen Lake should be quantified. Just as fry emigrating late to Hebgen Lake may be at a survival disadvantage, it would also appear that Madison River fry may enter the lake very early (April) when the lake is still solidly frozen. This, too, would seem disadvantageous.

Selected critical spawning habitat has been identified for rainbow trout in Duck Creek (fig. 3), the South Fork of the Madison River drainage (fig. 4), and Grayling Creek (fig. 5). These watersheds should be evaluated to determine sediment loads in those critical spawning reaches through a series of substrate samples. Further investigation of egg survival and hatching rates may also be appropriate. Environmental perturbations should be minimized in these drainages pending results of those studies.

Finally, the contribution of at least 590,000 rainbow trout fry from Hebgen Lake tributaries is a conservative estimate since the Madison River and early portion of the Grayling Creek emigration are not included in the total. A survival rate of 50% of those fry would exceed the input to the lake fishery from the present stocking program and should allow the Hebgen Lake fishery to sustain itself without further hatchery plants. Future studies need to evaluate fry survival in the reservoir itself. Over time, as Hebgen is converted to a self-sustaining fishery, it is expected that rainbow trout spawning runs in some drainages may intensify whereas others may disappear completely. The success or failure of emigrating fry to survive and return to spawn will determine the fate of those spawning runs.

LITERATURE CITED

R. Oswald, W. Fredenberg, and D. Vincent, 1990. Statewide Fisheries Investigations. Survey and inventory of cold water lakes. Southwest Montana Major Reservoir Investigations. Montana Department of Fish, Wildlife and Parks job progress report F-46-R-3., Job II d, Helena.

TABLE 1: Summary of average daily temperatures for eight sites on tributaries to Hebgen Lake during 1990. Streams are arranged in order from coldest to warmest.

Monitoring Station	April 20-30	May 1-31	June 1-30	July 1-31	August 1-31	September 1-30	October 1-10	Total
Trapper Cr.		40.0*	42.8	47.3	47.5	45.0	39.3	44.2
Watkins Cr.		40.1*	42.1	49.3	50.6	46.9	37.1	45.3
Grayling Cr.	37.8	40.7	44.7	52.6*	53.0	49.1	39.3	46.9
Black Sand Spring	48.9	48.9	49.1	49.3	49.3	49.3	48.9	49.1
South Fork Madison R.	49.4	50.4	48.4	51.0	50.3	48.6	44.8	49.4
Cougar Cr.	40.7	43.6	50.2	57.7	56.3	51.8	42.7	50.7
Duck Cr.	42.1	46.7	55.2	63.6	61.9	56.6	45.0	52.9
Madison R.	51.0	54.8	60.8	65.7	67.9	59.8	48.9	60.4

* Partial Data

TABLE 2: Summary of monthly maximum and minimum water temperatures for eight sites on tributaries to Hebgen Lake during 1990. Streams are arranged in order from coldest to warmest.

Monitoring Station	April 20-30	May 1-31	June 1-30	July 1-31	August 1-31	September 1-30	October 1-10
Trapper Cr.		36/43*	37/51	42/53	42/53	39/50	33/44
Watkins Cr.		32/47*	36/54	43/58	43/60	37/57	32/49
Grayling Cr.	32/45	32/52	37/55	48/56*	43/64	39/59	32/50
Black Sand Spring	48/50	48/50	48/51	48/51	48/51	48/51	48/50
So. Fork Madison R.	40/56	39/56	42/58	46/58	45/57	44/55	40/51
Cougar Cr.	34/46	37/50	38/65	46/68	48/68	43/62	36/53
Duck Cr.	34/51	37/55	43/67	55/71	55/70	49/65	38/56
Madison R.	43/62	44/64	49/76	57/78	54/82	51/72	41/62

* Partial data

TABLE 3: Numbers of adult rainbow trout (by sex) captured daily in the Duck Creek fish trap during May, 1990 and corresponding water temperatures.

DATE	FEMALE	MALE	AVERAGE DAILY WATER TEMPERATURE	MAXIMUM DAILY WATER TEMPERATURE
May 3	54	66	46.6	51.8
4	70	60	49.6	52.7
5	65	31	49.3	54.5
6	135	58	51.1	54.5
7	45	13	46.6	52.7
8	26	2	41.0	43.7
9	2	3	43.4	49.1
10	27	7	47.1	50.9
11	58	9	46.3	50.0
12	4	3	44.5	46.4
13	18	1	43.5	45.5
14	9	4	44.1	46.4
15	23	2	44.7	46.4
16	17	2	44.0	47.3
17	106	14	47.1	50.9
18	44	9	48.4	50.0
19	26	0	46.6	48.2
20	20	3	45.6	47.3
21	19	3	46.4	51.8
22	99	10	50.3	52.7
23	29	4	49.9	52.7
24	43	1	48.5	52.7
25	6	1	44.1	46.4
26	0	0	46.5	50.0
26	25	1	49.4	53.6
TOTAL	970	307		

TABLE 4: Length frequency by sex of adult rainbow trout passing through the Duck Creek fish trap during May, 1990.

LENGTH INTERVAL (INCHES)	MALE	FEMALE
9.0-9.9	1	0
10.0-10.9	3	0
11.0-11.9	3	0
12.0-12.9	2	0
13.0-13.9	4	0
14.0-14.9	6	5
15.0-15.9	28	58
16.0-16.9	66	222
17.0-17.9	103	433
18.0-18.9	74	228
19.0-19.9	16	24
20.0-20.9	1	0
TOTAL	307	970

TABLE 5: Total estimated rainbow trout fry emigration, peak emigration date, and trapping period for each of ten fry trap sites on tributaries to Hebgen Lake.

TRAP SITE	ESTIMATED TOTAL FRY	EMIGRATION PEAK DATE	TRAP PERIOD
Lower Duck	294,434	July 9	6/26-8/2
Lower South Fork Madison	163,090	July 17	6/21-8/17
Upper Grayling	74,714	August 1	7/25-8/25
Trapper	44,070	August 25	8/1-8/29
Black Sand Spring	30,714	July 9	6/21-8/2
Upper SF Mad.	23,188	July 28	6/21-8/25
Lower Grayling	16,190	July 24	7/24-8/25
Cougar	13,308	July 21	7/8-8/10
Upper Duck	804	July 20	6/30-8/10
Watkins	0		8/1-8/25

TABLE 6: Average length (mm) of rainbow trout fry collected weekly from trap sites on Hebgen Reservoir tributaries during 1990.

Stream	6/15-6/21	6/22-6/28	6/29-7/5	7/6-7/13	7/14-7/21	7/22-7/29	7/30-8/5	8/6-8/13	8/14-8/21	Overall Mean
Duck (Lower)		23.8	23.2	23.9	23.7	24.1	23.6			23.7
South Fork Mad. (Lower)	26.3*	24.5	24.3*	25.0	24.8	24.7	24.3			24.8
Grayling (Upper)						25.0	24.8	25.1	24.6	24.9
Trapper								23.1	23.7	23.4
Black Sand Spring	25.0*	23.8	24.5*	24.9	24.9	24.1	24.4*			24.5
So. Fork Mad. (Upper)			23.5*	25.5*	24.5	24.6	24.9	24.9	24.5*	24.6
Grayling (Lower)							23.9	24.6*	27.8*	25.4
Cougar					23.2	23.9	23.0			23.4

* Sample size less than 15 fish, all others 15-25 fish.

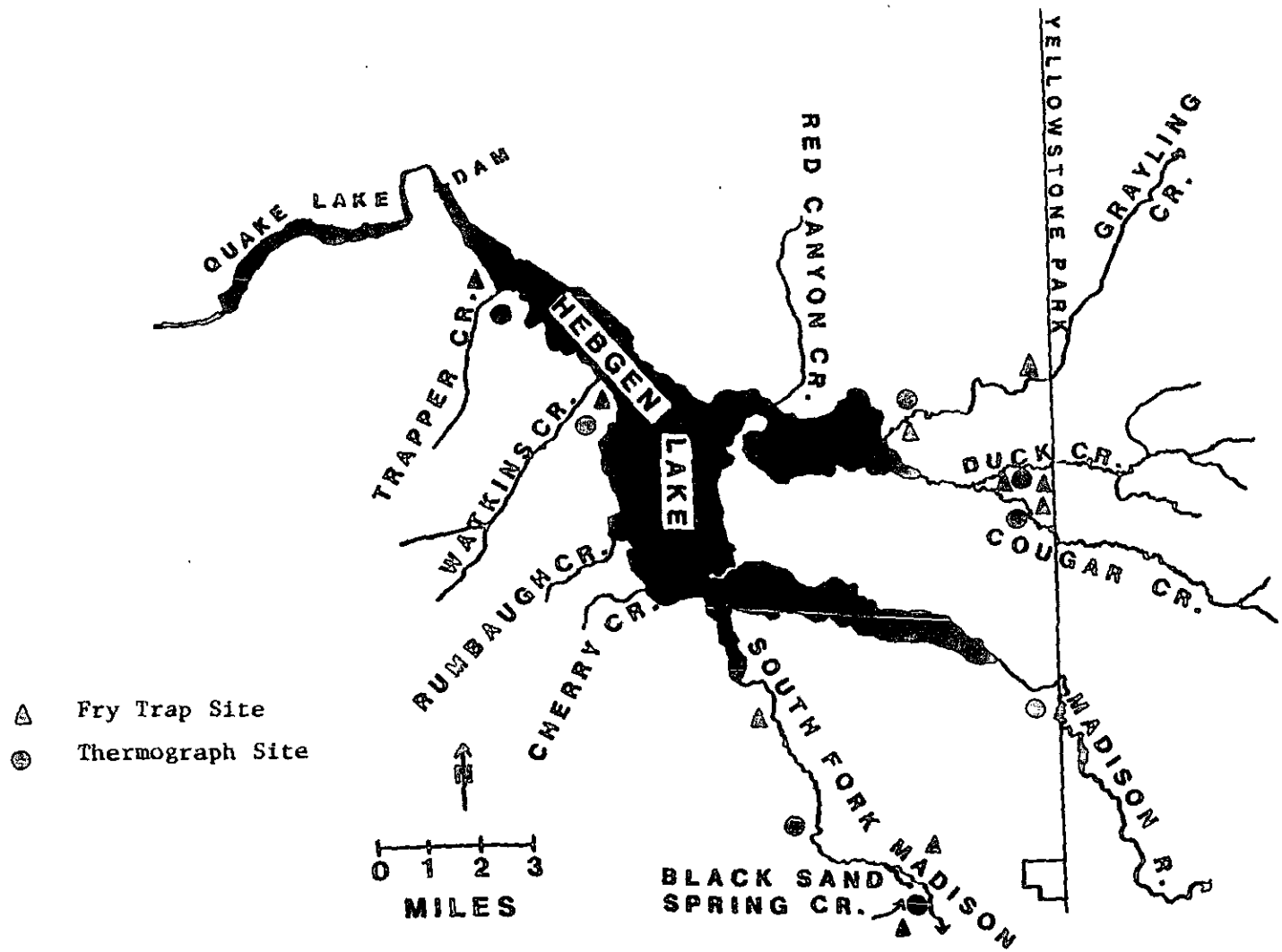

Figure 1. Map of the study area showing Temperature and Fry monitoring sites.

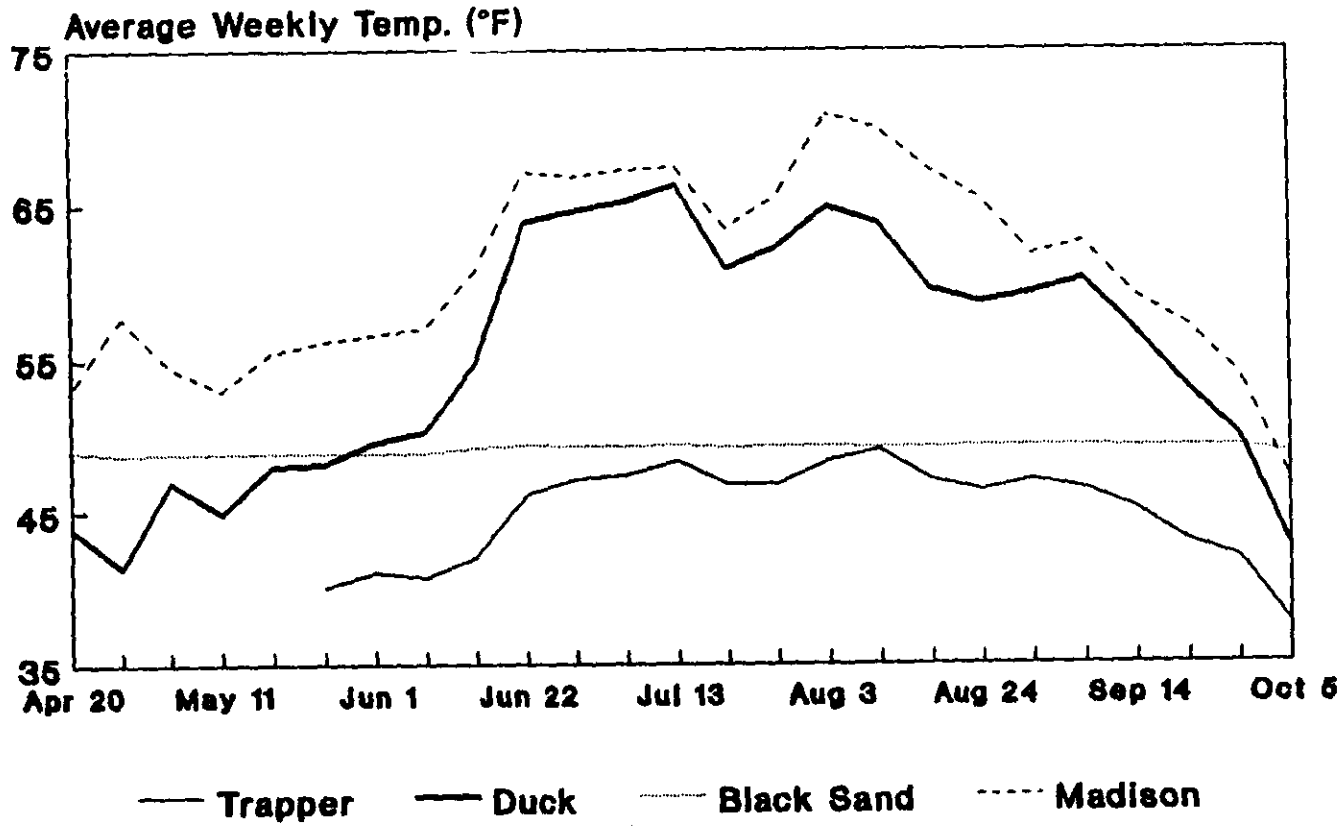

Figure 2. Average weekly water temperature (°F) for four tributaries to Hebgen Lake between April 20 and October 10, 1990. Trapper Creek and Duck Creek exhibit cold and warm "normal" patterns respectively. Black Sand Spring exhibits a "spring-influenced" pattern, and the Madison River illustrates a "thermal-influenced" pattern.

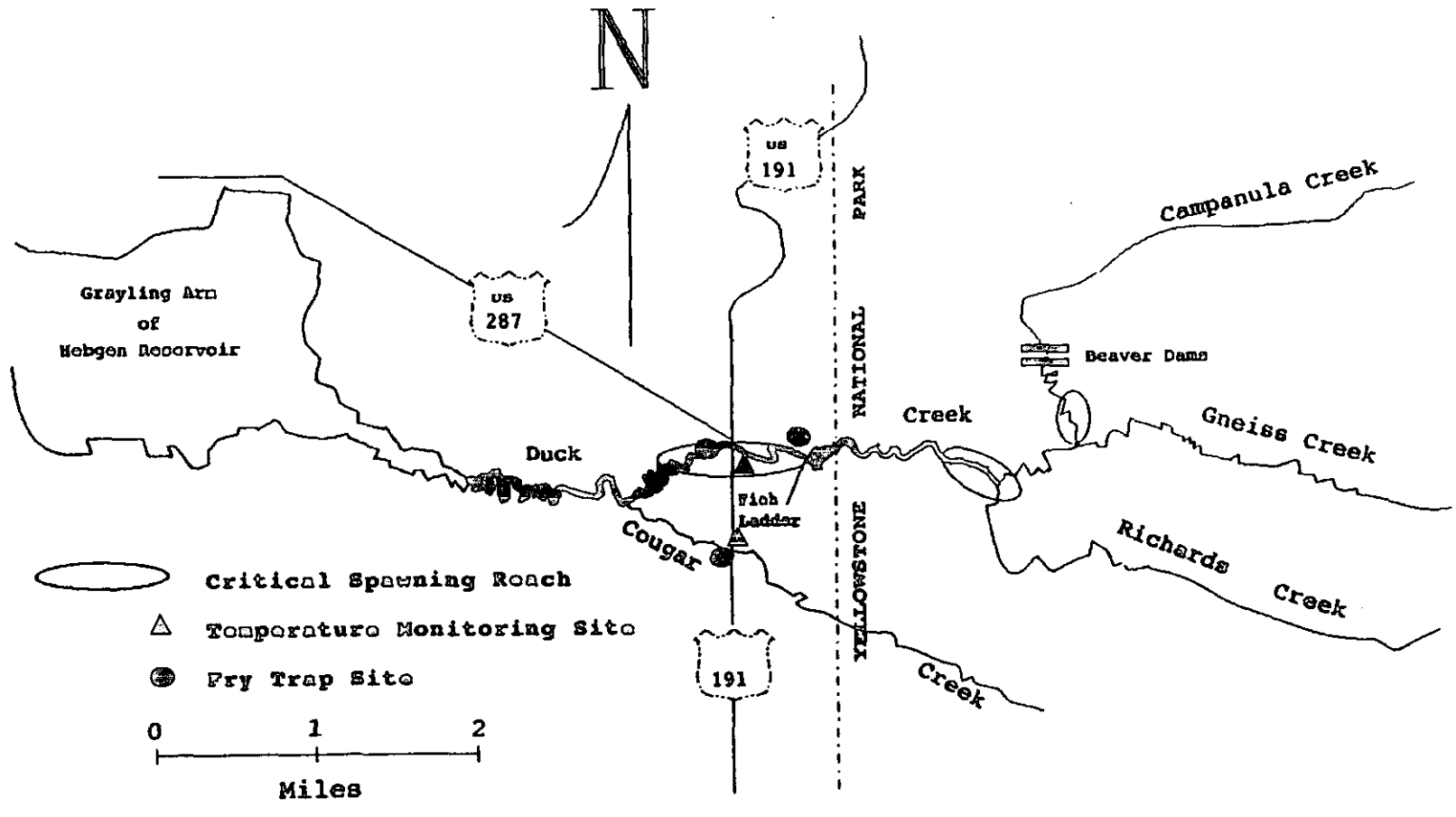

Figure 3. Detailed area map of Duck Creek drainage showing sampling sites and critical spawning reaches.

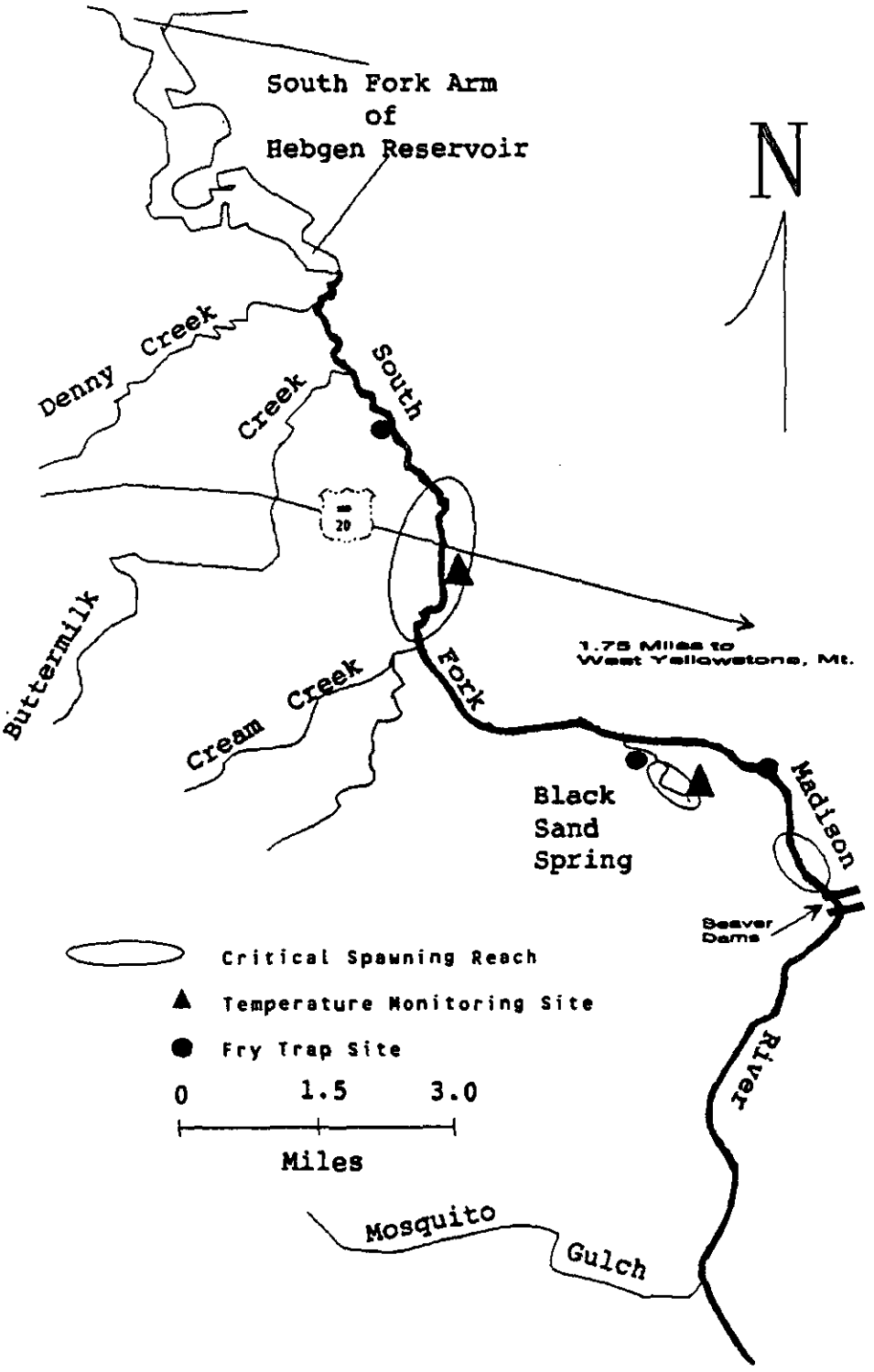

Figure 4. Detailed area map of South Fork Madison River drainage showing sampling sites and critical spawning reaches.

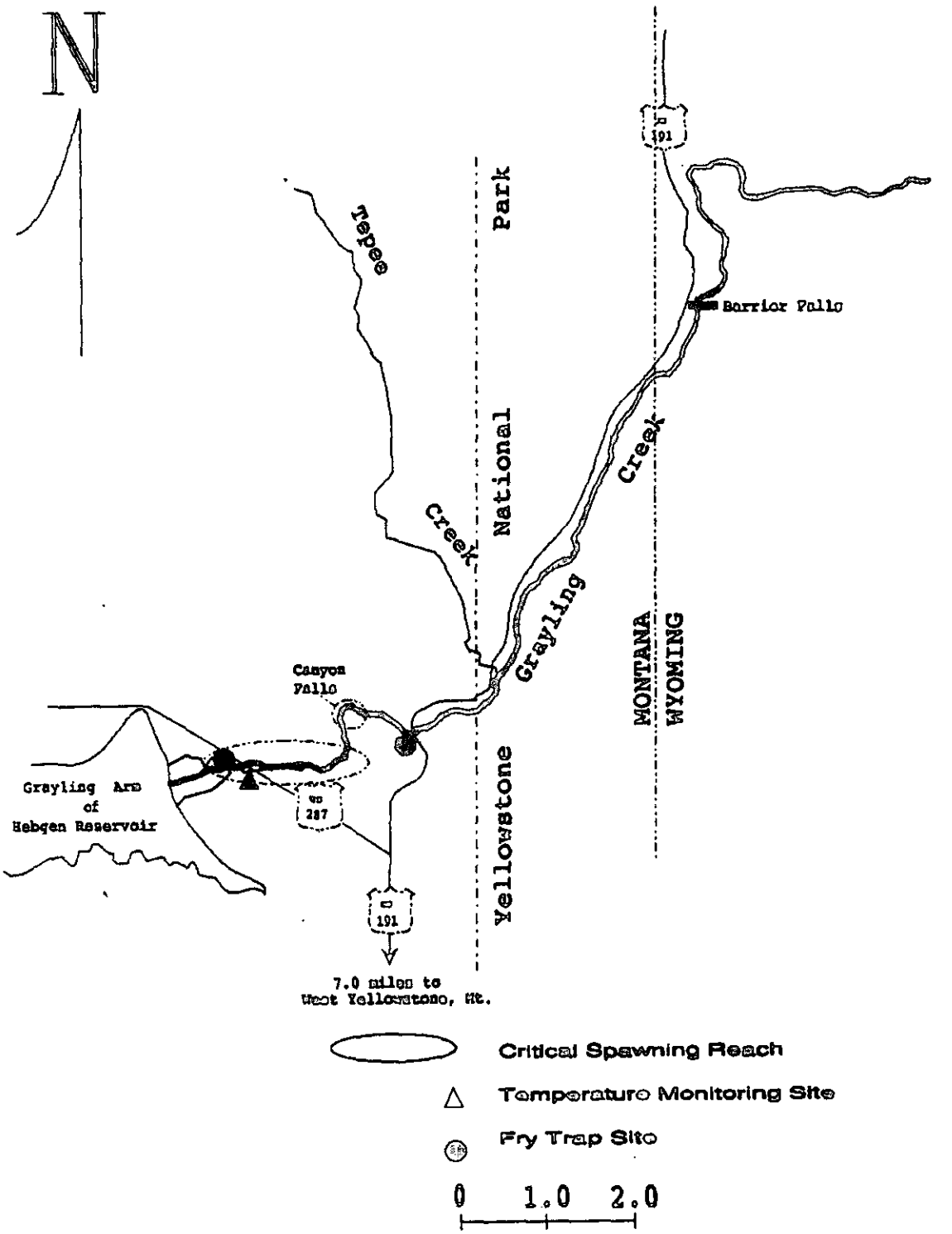

Figure 5. Detailed area map of Grayling Creek drainage showing sampling sites and critical spawning reaches.

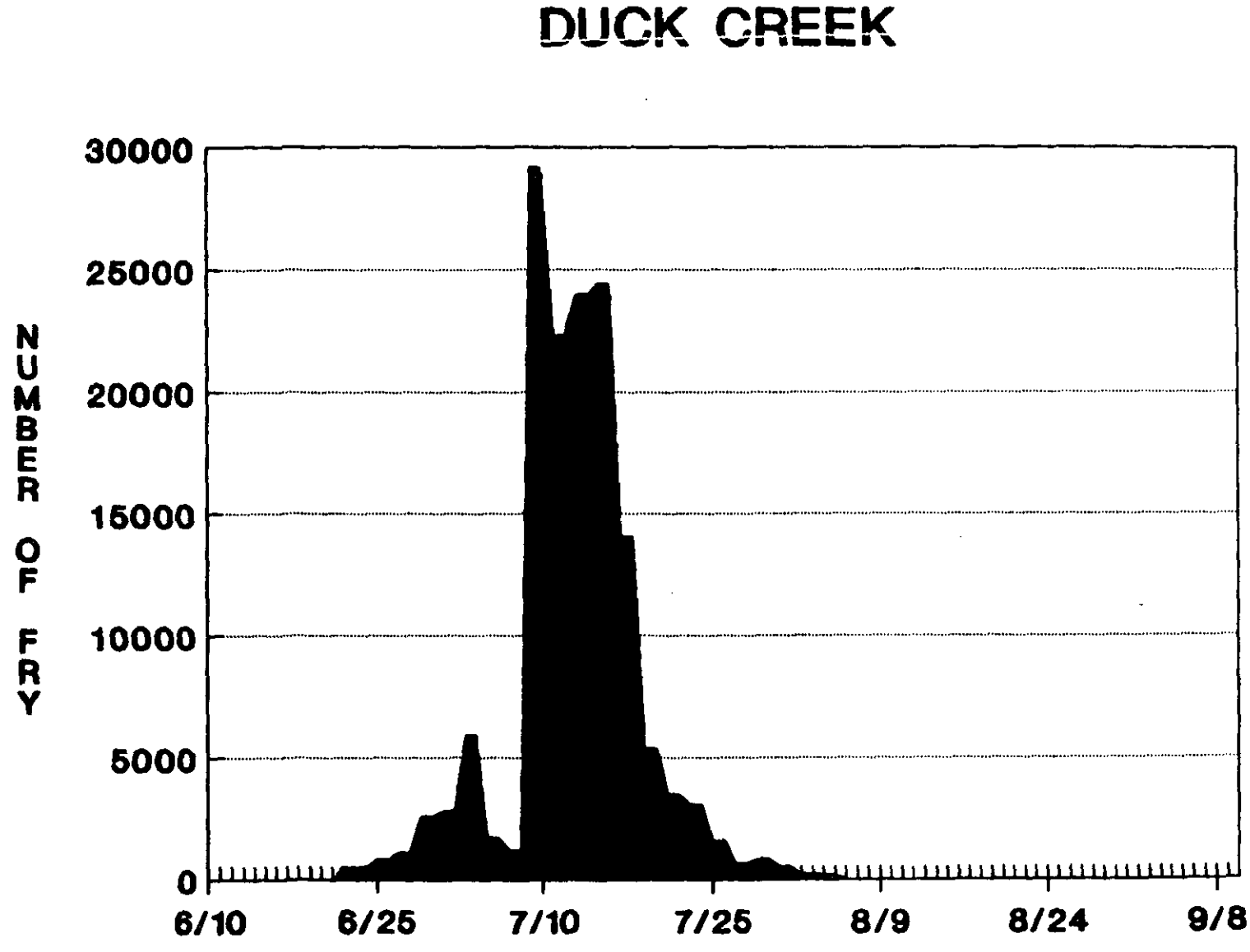

Figure 6. Estimated daily rainbow trout fry emigration at the lower Duck Creek Trap Site during 1990.

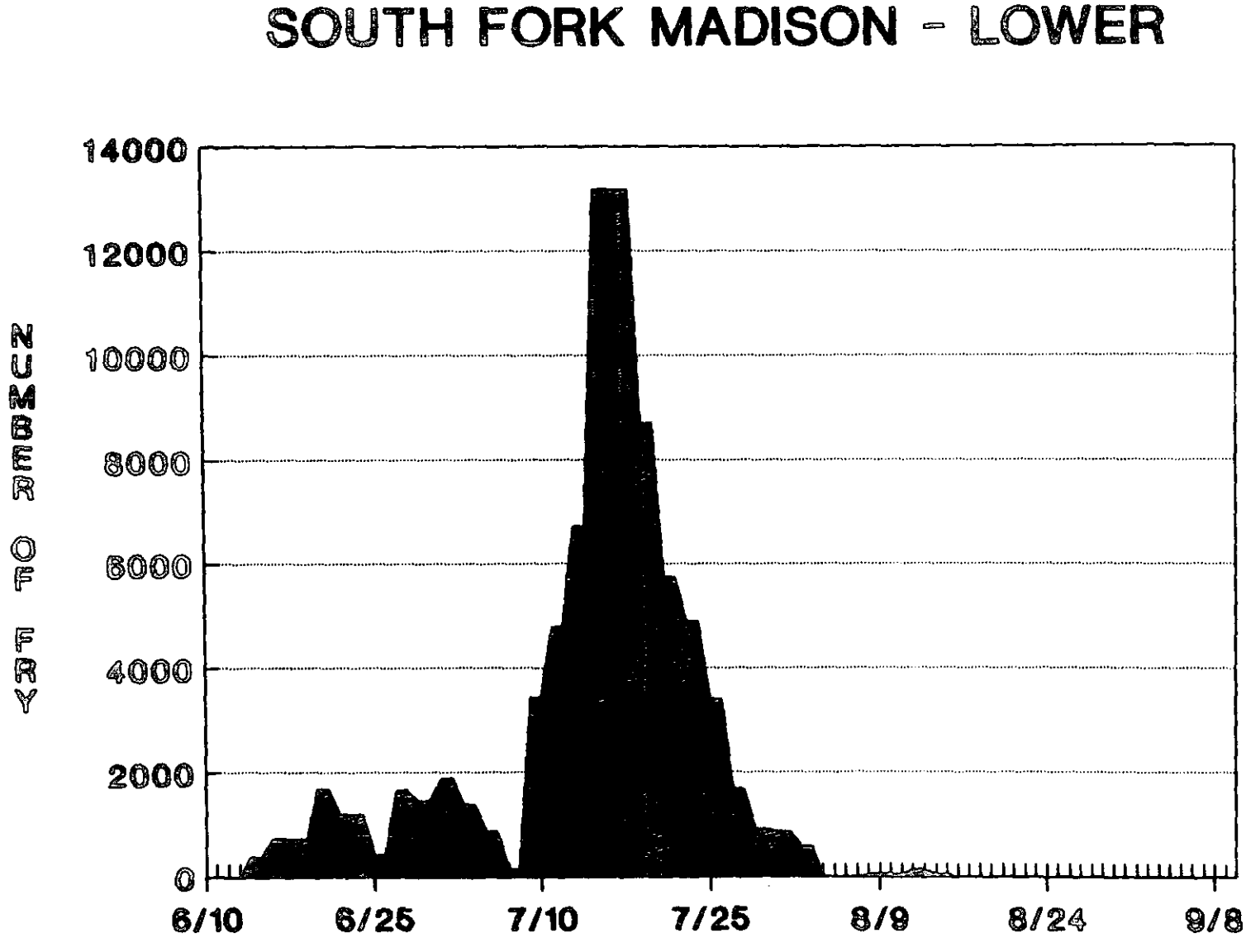

Figure 7. Estimated daily rainbow trout fry emigration at the lower South Fork Madison Trap Site during 1990.

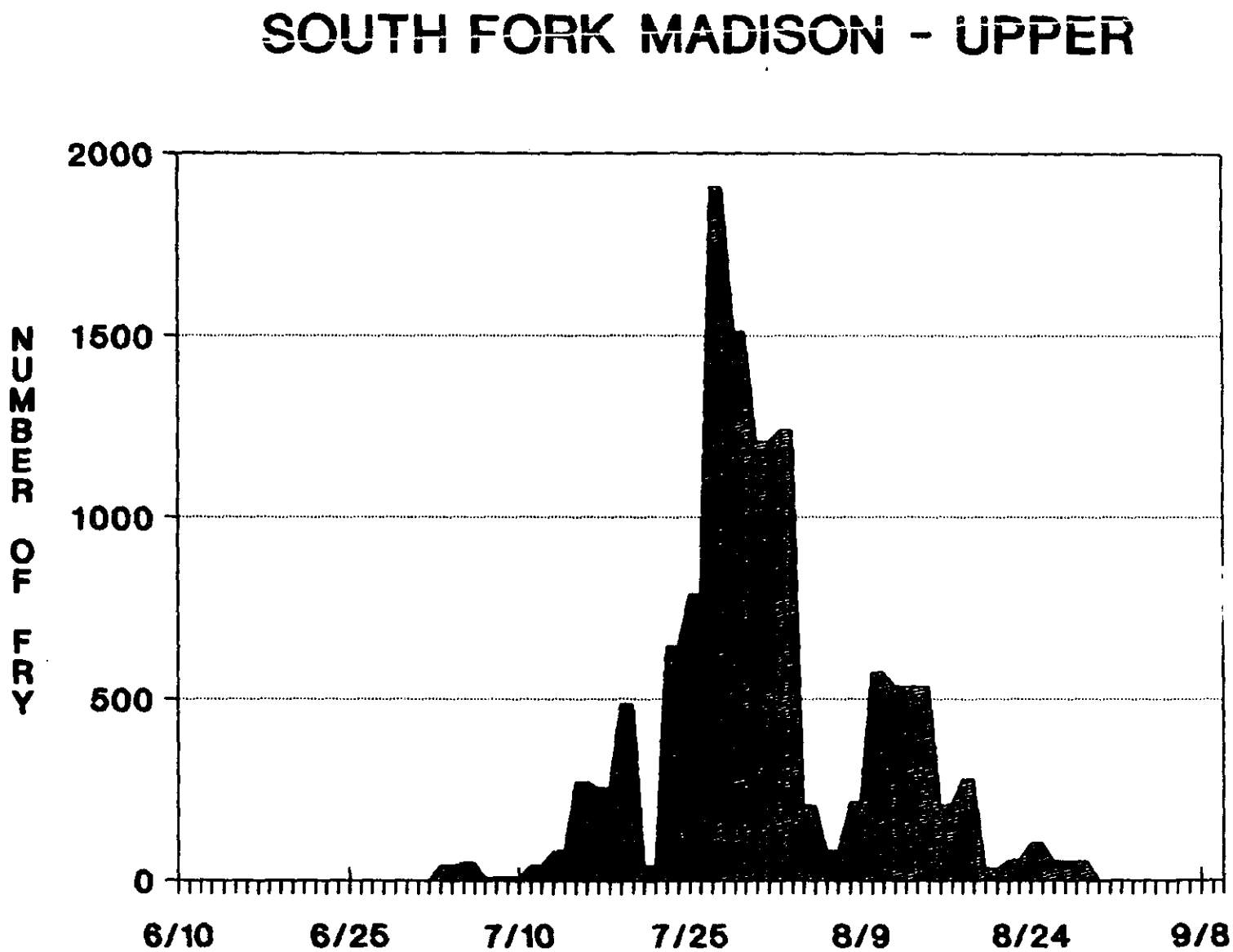

Figure 8. Estimated daily rainbow trout fry emigration at the upper South Fork Madison Trap Site during 1990.

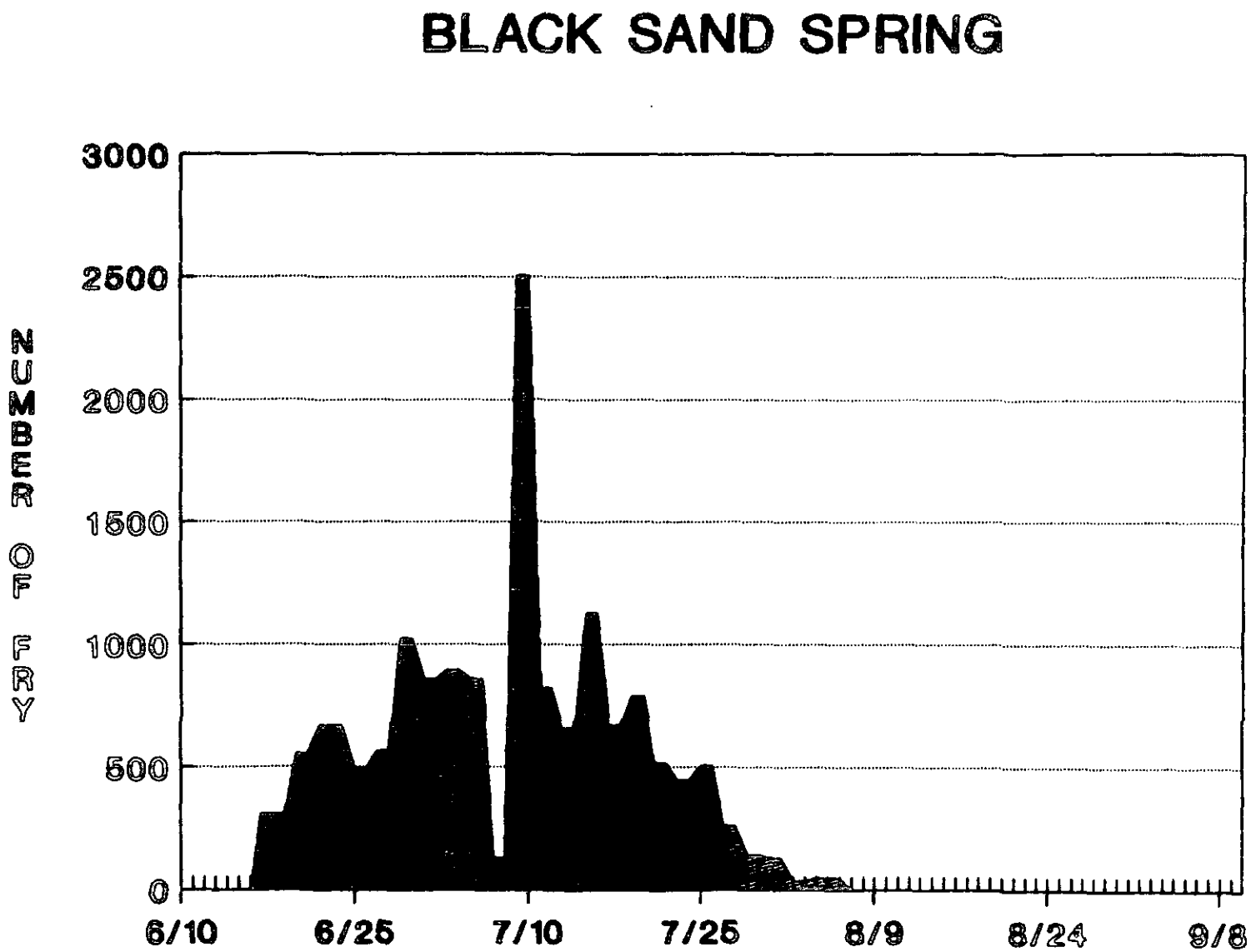

Figure 9. Estimated daily rainbow trout fry emigration at the Black Sand Spring Trap Site during 1990.

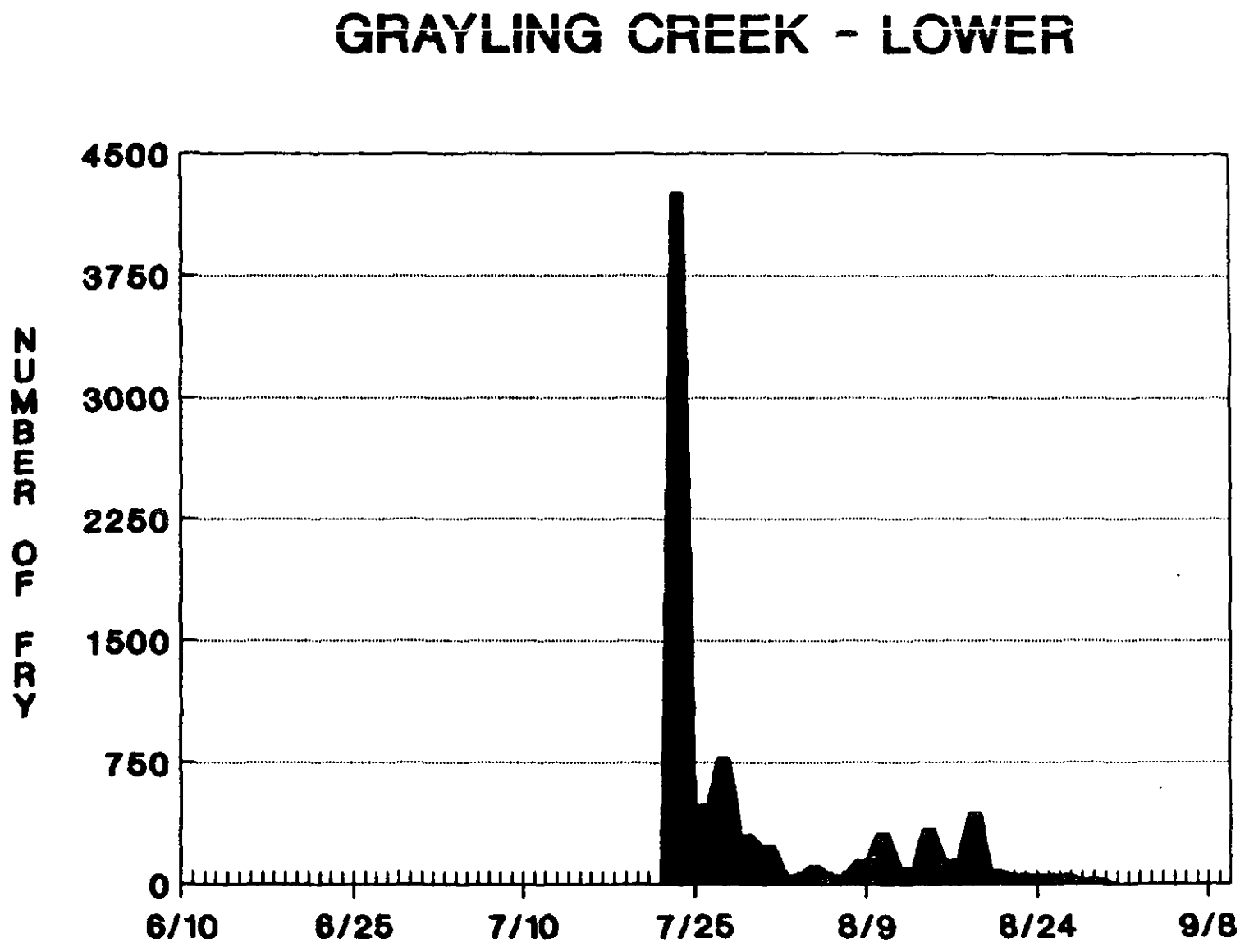

Figure 10. Estimated daily rainbow trout fry emigration at the Lower Grayling Creek Trap Site during 1990. The early part of the emigration was not sampled.

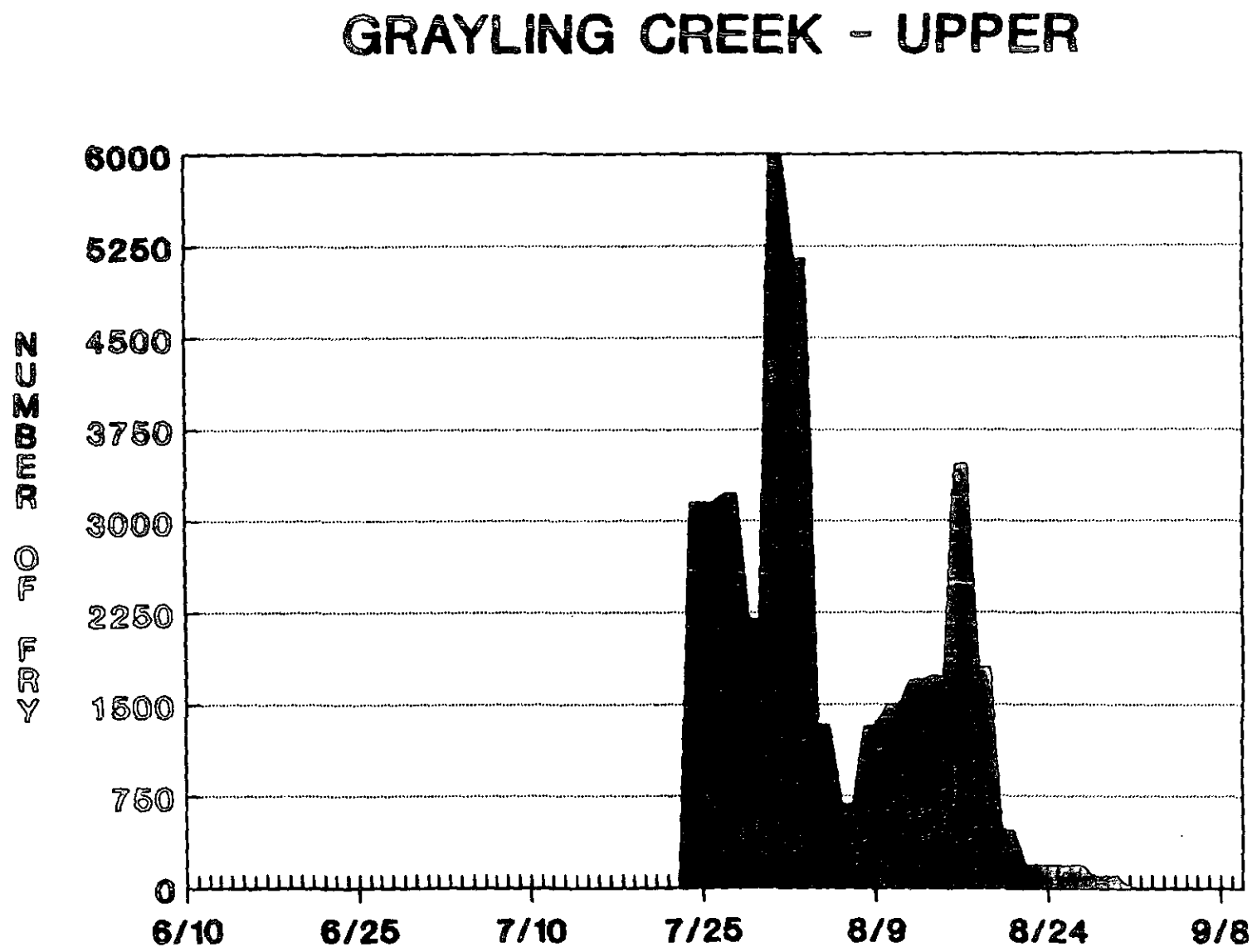

Figure 11. Estimated daily rainbow trout fry emigration at the Upper Grayling Creek Trap Site during 1990. The early part of the emigration was not sampled.

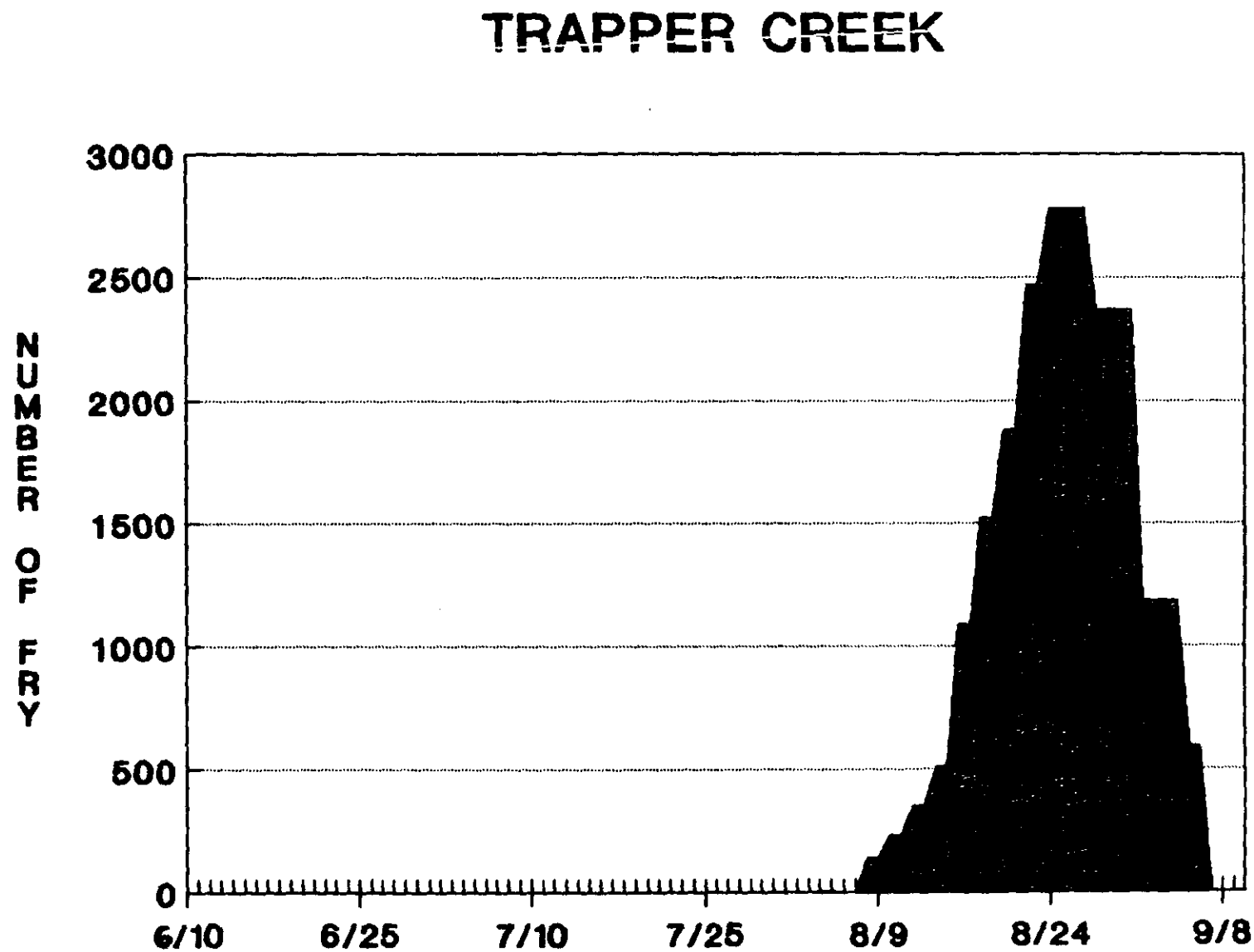

Figure 12. Estimated daily rainbow trout fry emigration at the Trapper Creek Site during 1990.

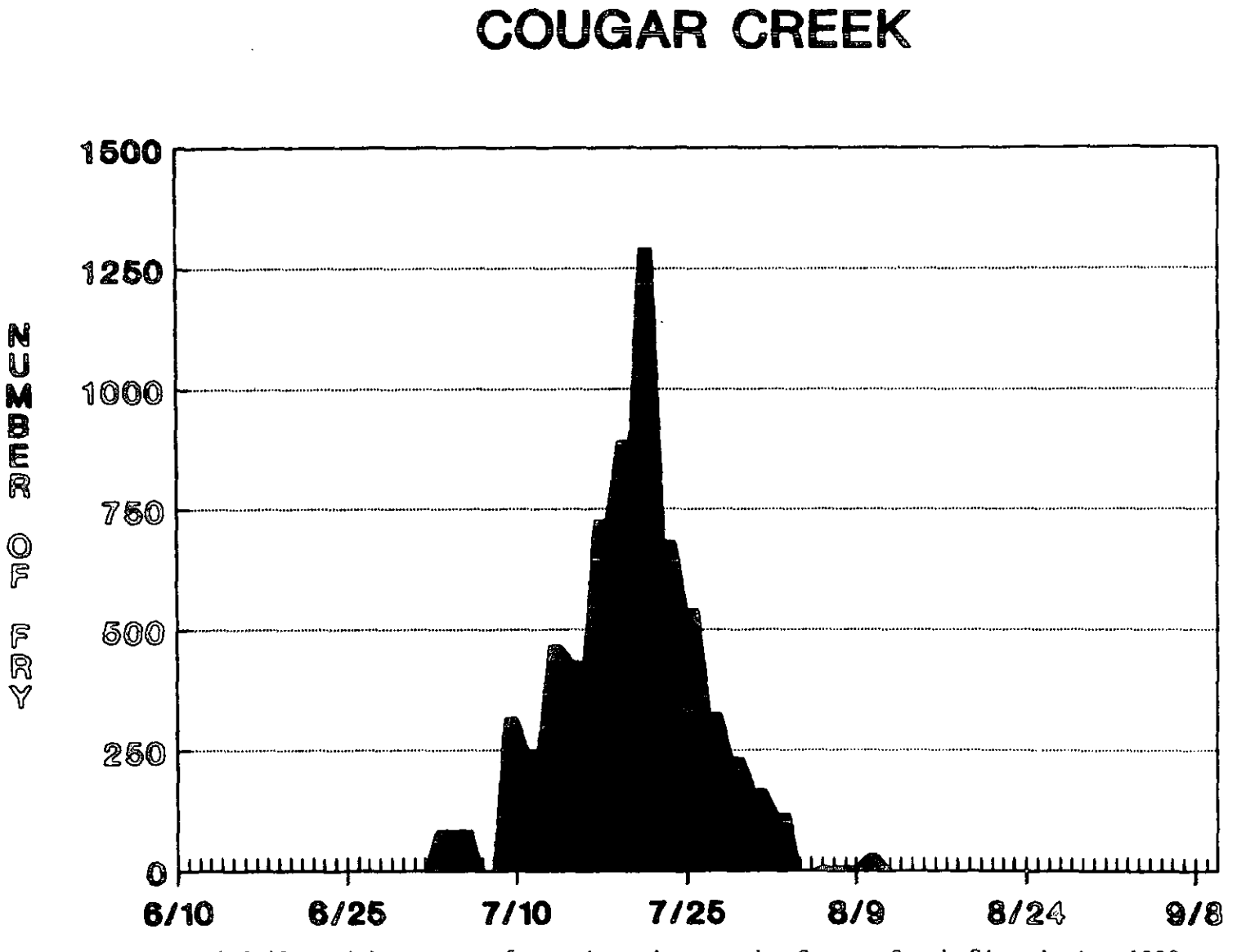

Figure 13. Estimated daily rainbow trout fry emigration at the Cougar Creek Site during 1990.

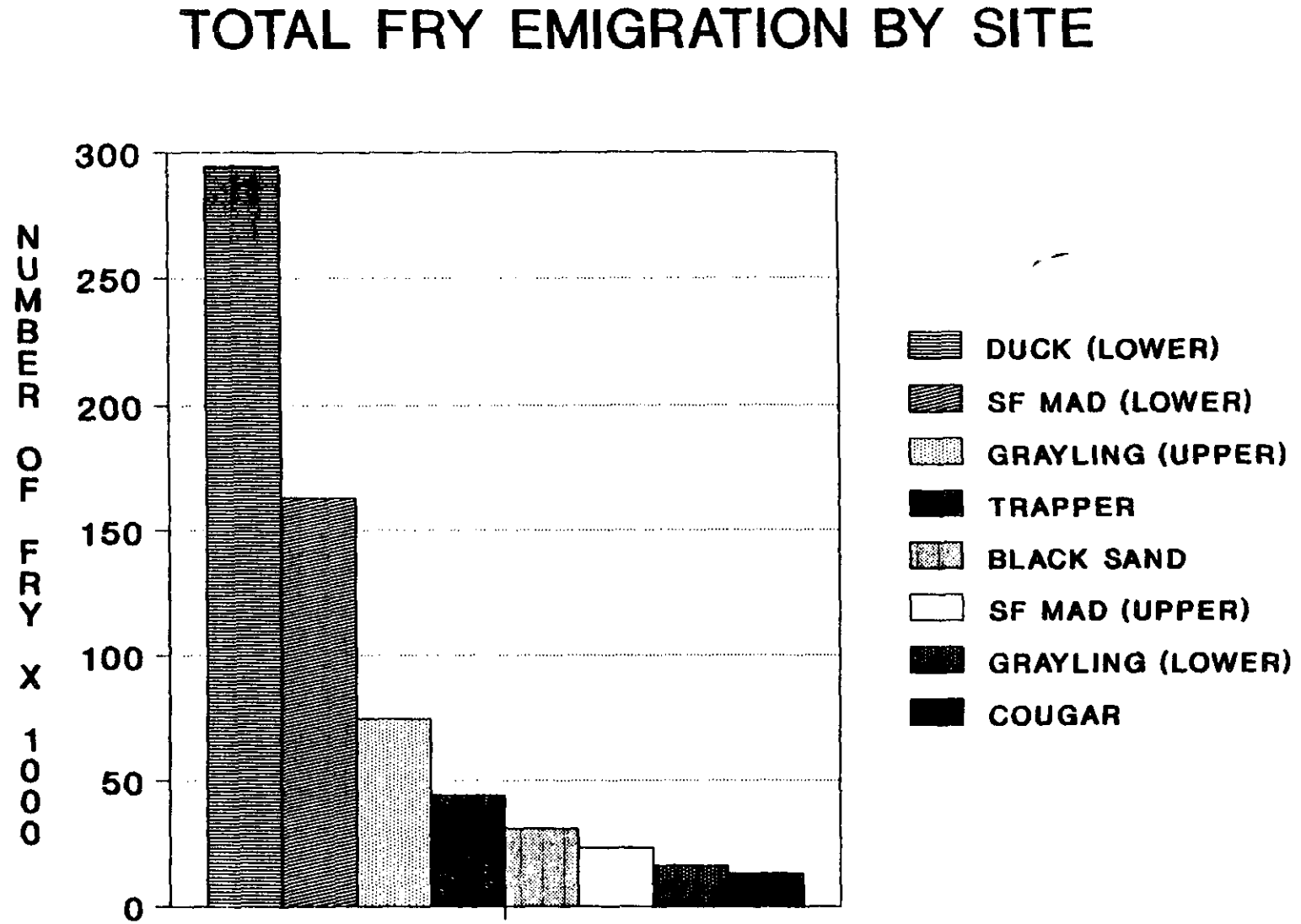

Figure 14. Total estimated fry emigration at each of eight trap sites on tributaries to Hebgen Resevoir during 1990.

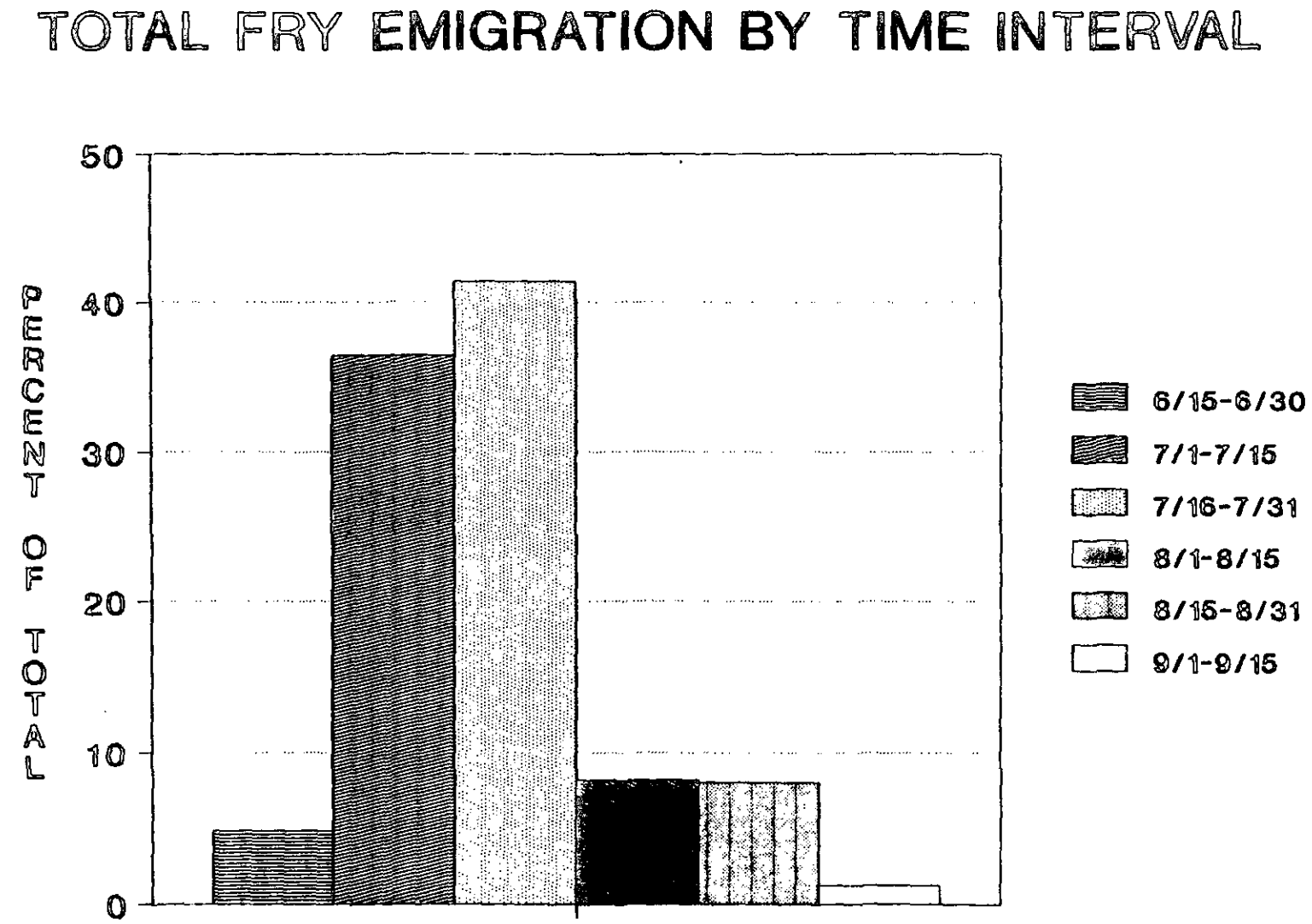

Figure 15. Distribution of emigrating rainbow trout fry from Hebgen Lake tributaries by 2-week time intervals during 1990.

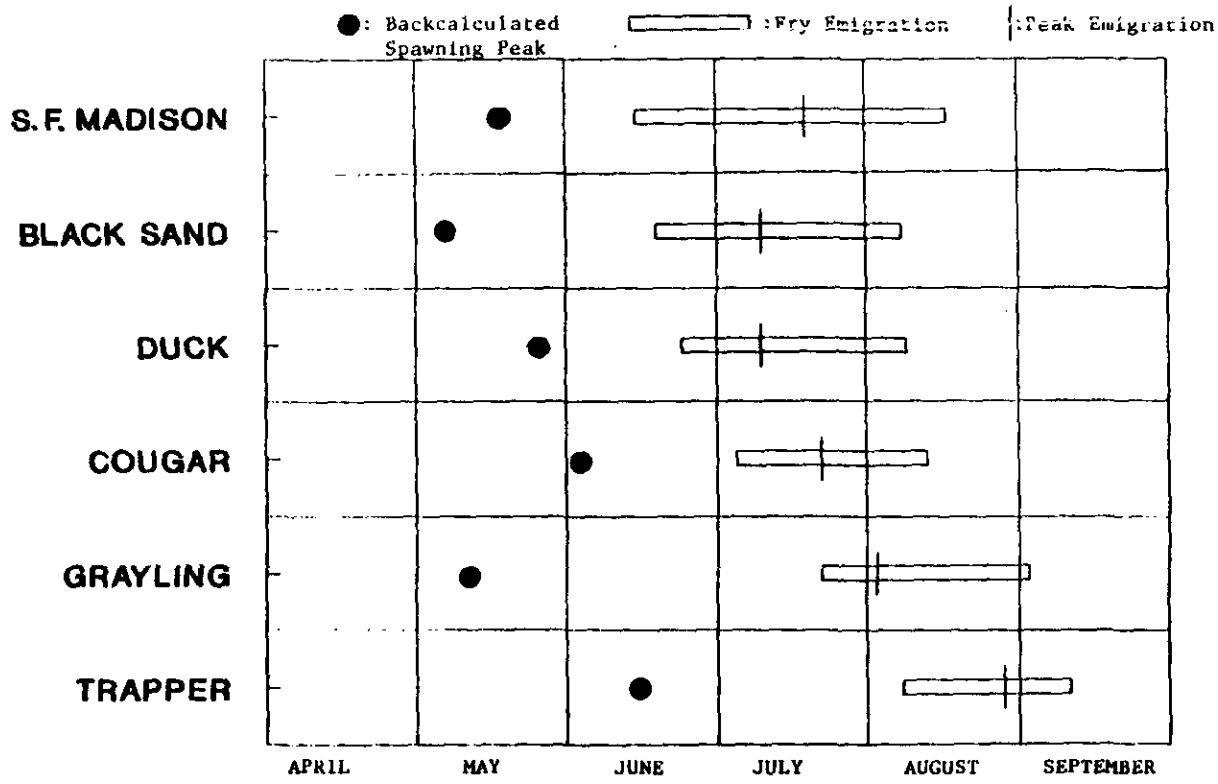

Figure 16. Timeline of estimated 1990 spawning and fry emigration period for rainbow trout in selected streams that are tributaries of Hebgen Lake. Spawning period peak based on backcalculation of 1,080 temperature units from peak emigration.