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POTENTIAL INFLUENCE OF RECREATIONAL USE ON NELSON SPRING CREEK

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ABSTRACT

Under present angler use, we project that between 109-760 brown trout, 910-6,369 rainbow trout and 524-3,639 cutthroat trout embryos were killed as a result of wading in sections of 3 and 4 of Nelson Spring Creek (NSC) between 28 February and 6 September 1986. The impact of wading in these sections on the Yellowstone River fishery will be greatest for cutthroat trout as compared to rainbow and brown trout because they spawn during times of high angler use, low adult numbers and suitable spawning tributaries of the Yellowstone River near NSC are limited because of dewatering during summer months. Impact of wading depends upon wading frequency and stage of embryonic development. Embryo mortality resulting from human wading is highest for eyed eggs just prior to hatching and for pre-emergent fry. A slight increase in susceptability also occurs at the stage of development that corresponds to the closing of the blastopore.

Five-hundred-six trout redds were built in NSC between 1 November 1985 and 11 August 1986. Forty-eight brown trout redds, 55 rainbow trout redds and 27 cutthroat trout redds were built in sections 3, 4 and 5 of NSC that one landowner feared would receive high angler use because of the new stream access law. Based on temporal distribution of spawning and embryonic development rates specific to these sections of NSC, eggs or pre-emergent fry were in the gravel continuous from 1 November 1985 to early September 1986. It appears from tag observations that a large portion of the rainbow and cutthroat trout spawners migrating out of the Yellowstone River spawn in the lower sections of NSC.

Seventy-one people were observed fishing sections 3 and 4 between 28 February and 6 September 1986. Thirty-six percent of the 15.08 hours anglers spent fishing from within the stream channel in these sections was spent within spawning areas. The path that most fishermen took while wading in the stream was in the right one-half of sections 3 and 4 which contains 95% of the spawning areas within these two sections.

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INTRODUCTION

A 1983 Montana Supreme Court decision granted public access to all flowing waters in Montana. The ruling allows sportsmen to wade and fish non-navigable streams between the high-water marks if access was gained legally. In 1985 the Department of Fish, Wildlife and Parks was directed by the state legislature under House Bill 265 (Chapter 556, Laws of 1985) to adopt rules pertaining to the management of recreational use of rivers and streams. A process was established by which persons may petition the Fish and Game Commission to restrict public recreational use of certain waterways: 1) to protect against impacts of recreational use and 2) to limit recreational use of streams to their actual capacity. This process became effective July 12, 1985.

On July 22, 1985 William Dana, Jr. filed the first petition under this law requesting that Nelson Spring Creek be closed to recreational use without permission of the owners. Specific allegations included:

> "The creek is incapable of supporting unlimited wading in its bed because this would inevitably cause severe damage to its fragile ecosystem including its irreplaceable role as a spawning ground for Yellowstone River trout."
>
> "Unlimited wading in Nelson Spring Creek would create a strong, though with current data unquantifiable, risk of severely degrading the creek as a spawning area and if that degradation occurs there will be degradation of the Yellowstone fishery for miles up and downstream from the mouth of the creek."

On August 5, 1985 Edwin S. Nelson filed a second petition to limit access to Nelson Spring Creek. A report on these petitions with potential alternatives for action was presented to the

Montana Fish and Game Commission on September 4, 1985 (Wells, Clancy and Graham 1985). Following a public hearing the alternative course of action chosen by the commission was to conditionally extend the petition for 14 months and conduct necessary research:

1) To ascertain the amount and types of use on Nelson Spring Creek as it flows through the Nelson and Dana ranches.

2) To determine the distribution and timing of spawning and quantify the effect of wading on survival of cutthroat, brown and rainbow trout eggs. This would be done in laboratory and field tests.

3) To evaluate the sensitivity of spring creeks to damage by evaluating spring creeks under a variety of use patterns.

4) To conduct studies on the "social" carrying capacity of spring creeks. If restrictions are needed efficient and equitable methods of restricing use would be evaluated.

Minimal water level fluctuations of Nelson Spring Creek and the creeks rectangular channel form, force unauthorized recreationalists to wade portions of the creek to access fishing areas upstream without criminal trespass. The major focus of this study was to examine the potential impact of wading by either unauthorized and authorized fishermen through spawning areas on survival of trout embryos. Specific objectives were:

1) Evaluate effects of wading on brown, rainbow and cutthroat trout eggs and pre-emergent fry.

2) Document the amount, distribution and timing of brown, rainbow and cutthroat trout spawning in Nelson Spring Creek.

3) Document the amount of recreational use on lower Nelson Spring Creek.

DESCRIPTION OF STUDY AREA

Nelson Spring Creek (NSC) originates from a series of coldwater springs and parallels the Yellowstone River in a northerly direction for 1.6 miles (2.6 km) before entering the Yellowstone River at river mile 505.5 (813 km) south of Livingston, Montana (Figure 1) (Decker-Hess 1986). The creek lies entirely within Township 03 South, Range 09 East, Sections 23 and 26 of Park County. Public access to the creek is limited to floaters and waders staying within the ordinary high-water mark of the Yellowstone River and NSC or by landowner permission. Nearest public access is approximately 2 river miles (RM) (3.2km) below and 3.1 RM (5.0 km) above the confluence of NSC with the Yellowstone River (Figure 1).

Land adjacent to NSC is owned by the Edwin Nelson and William Dana, Jr. families. The upper 0.8 miles (1.3 km) and the lower 0.35 miles (0.55 km) of NSC flows through the Dana ranch; the middle 0.45 miles (0.75 km) of stream flows through the Nelson ranch. The lower 0.15 miles (0.25 km) of NSC lies within a high-water side channel of the Yellowstone River and is inundated during spring flows. Land and water uses consist of a commercial trout hatchery, a limited entry fee fishery, cattle grazing and hay production. Livestock grazing occurs on the Dana ranch during the summer months while pastures on Nelson ranch are used by livestock during the winter and the early spring calving season.

Nelson Spring Creek is fed entirely by spring water, most of which surfaces around two headwater ponds (Figure 2). Water

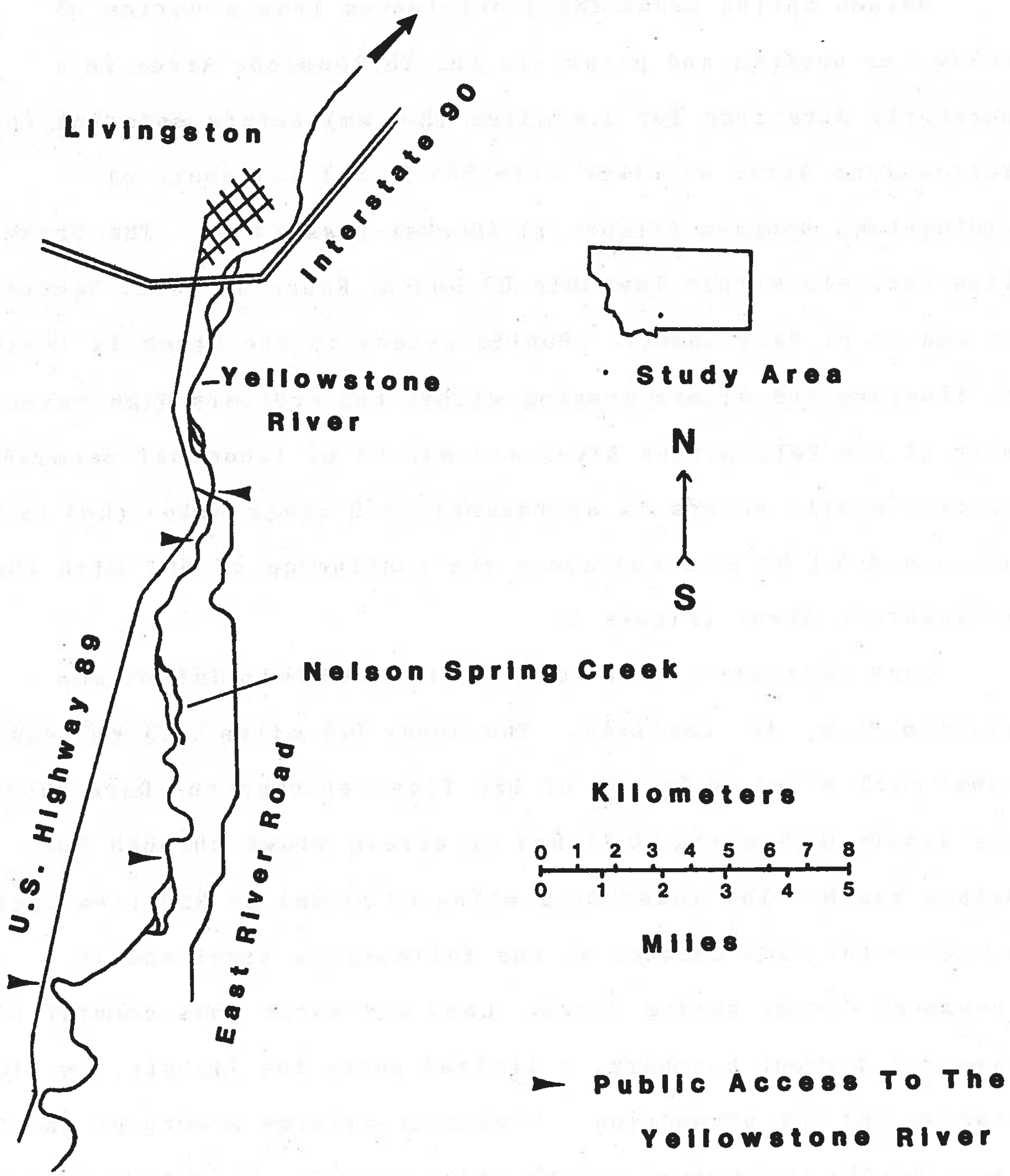

Figure 1. Location of Nelson Spring Creek relative to Livingston, Montana, Yellowstone River and nearest access areas.

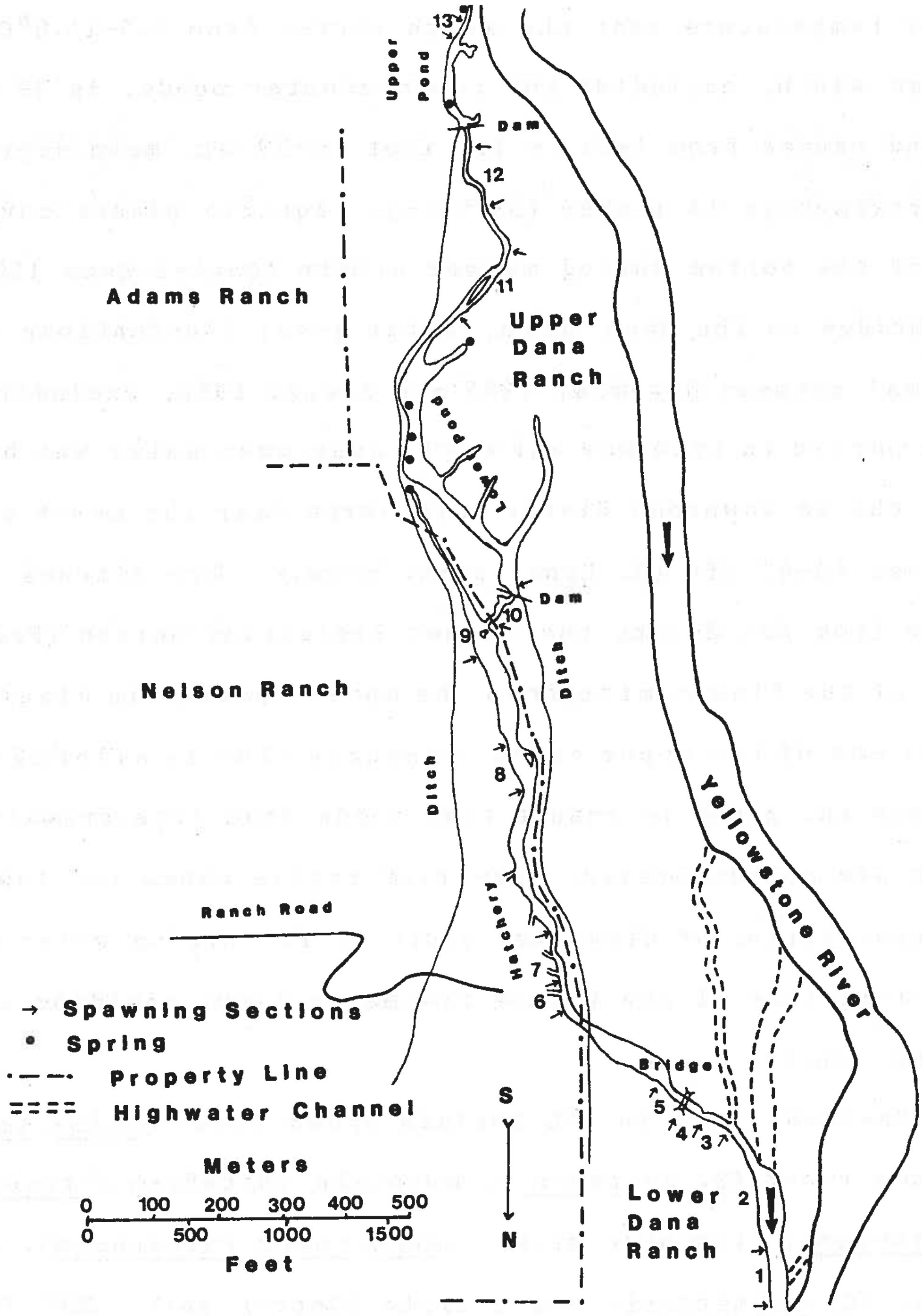

Figure 2. Nelson Spring Creek study area showing spawning sections, major springs and property lines.

temperature at the origin is a fairly constant 9-10°C, while water temperature near the mouth varies from 5.5-15.0°C. Mean stream width, excluding the two headwater ponds, is 59 feet (18 m) and ranges from 16.5 to 126 feet (5-39 m); mean depth is appproximately 14 inches (35.5 cm). Aquatic plants cover over 50% of the bottom during summer months (Decker-Hess 1986). At the bridge on the Dana ranch, water level fluctuations were minimal between November 1985 and August 1986, excluding the 3 week period in late May and early June when water was backed up from the Yellowstone River. Discharge near the mouth ranges between 40-63 cfs (A. Dana, pers. comm.). Two ditches divert water from NSC during the summer irrigation period (Figure 2). Most of the flow coming from the upper springs is diverted at the lower end of the upper pond. Adequate flow is allowed to pass between the ponds to insure that redds from late spawning rainbow trout are not dewatered. Few fish reside above the lower pond. Supersaturation of dissolved gases in the spring water result in high incidence of gas bubble trauma in trout residing near the spring source.

Resident fish in NSC include brown trout (Salmo trutta), rainbow trout (S. gairdneri), mountain whitefish (Prosopium williamsoni), longnose sucker (Catostomus catostomus), white sucker (C. commersoni) and sculpin (Cottus sp.). NSC is also used for spawning by migratory populations of all species with the possible exception of the sculpin. Yellowstone cutthroat trout (S. clarki bouvieri) also use NSC for spawning and juvenile rearing, but a resident adult population has not been documented. Hatchery origin rainbow trout were observed in all sections of NSC with the highest densities being observed just above the hatchery ponds in early summer. Hatchery fish were readily identified by their eroded fins during snorkeling surveys. Brook trout (Salvelinus fontinalis) are rare and have been observed in the lower headwater pond. A few carp (Cyprinus carpio) have been observed near the mouth during late spring months.

METHODS

LABORATORY

Human Wading

To evaluate effects of wading on survival of brown, rainbow and cutthroat trout eggs and pre-emergent fry, laboratory tests were conducted at the U.S. Fish and Wildlife Service Bozeman Fish Technology Center. These tests were designed to reduce variability inherent in natural stream channels. Tests were conducted in three 1.2 m (4 ft) wide x 2.4 m (8 ft)long channels, each subdivided into eight 1.2 m (4 ft) long x 0.3 m (1 ft) wide x 0.33 m (1 ft) deep chambers and filled with natural stream gravel (Figure 3). Substrate composition in each chamber simulated that found in known spawning areas of NSC as determined from the mean particle size distribution of five McNeil substrate samples (Table 1) (McNeil and Ahnell 1964). Natural stream gravel was acquired from local gravel quarries and mixed according to the size distribution in Table 1. Water flow through each chamber was 0.14 +/-0.01 liter per second (lps) for cutthroat trout and 0.145 +/- 0.06 lps for rainbow trout, while flow for brown trout was not measured. Gradient of each chamber

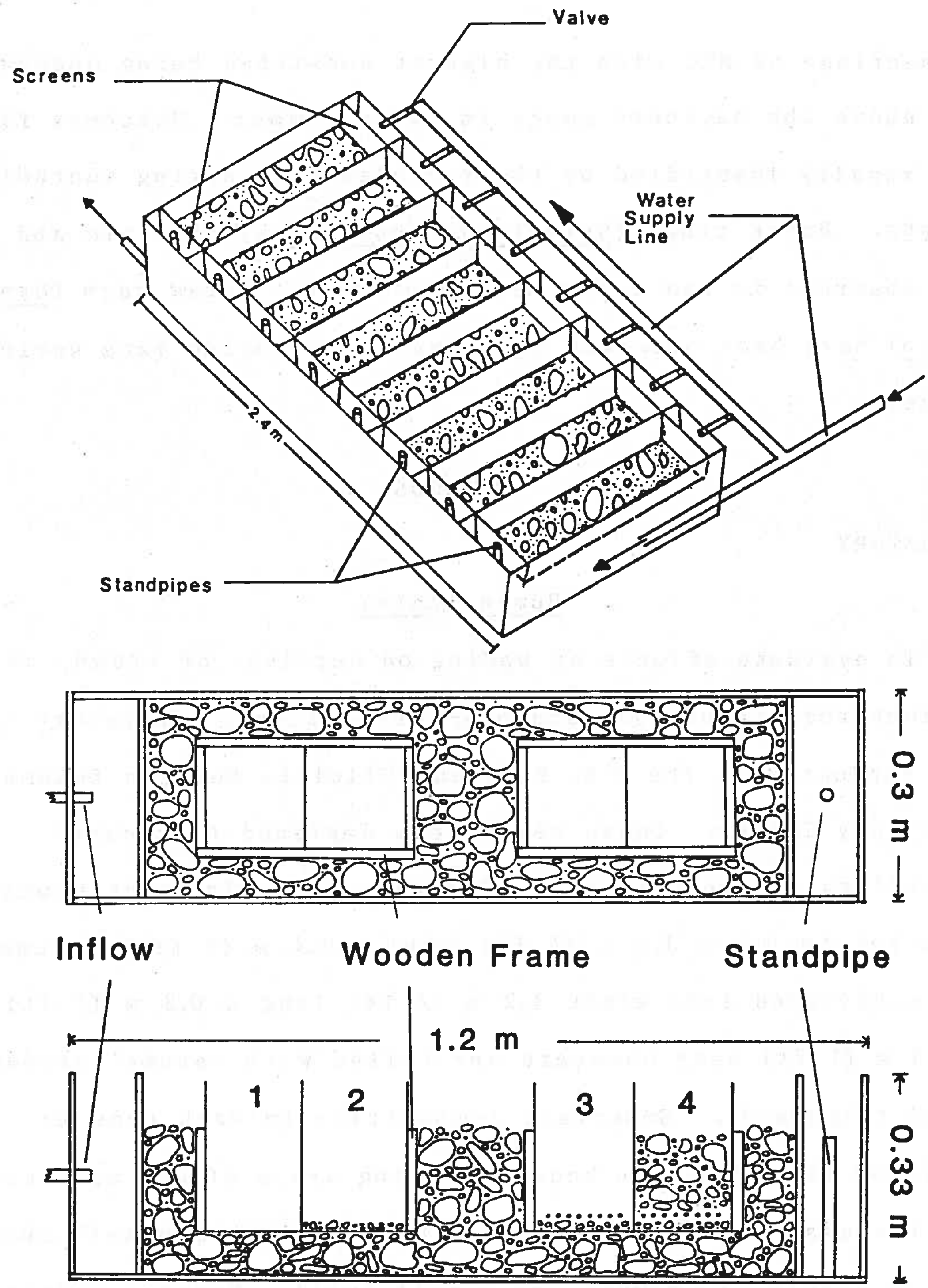

Figure 3. Diagram of the incubation chambers and the process used to plant eggs in the substrate: 1) egg baskets placed in the substrate within wooden frames. 2) 2 cm layer of substrate placed in each basket. 3) 200 eggs evenly distributed. 4) egg baskets carefully filled with substrate mixture before wooden frames are removed.

Table 1. Particle size distribution determined from the mean of five McNeil substrate samples taken from section 4 of Nelson Spring Creek, Montana, October 1985.

Particle Size Class(mm)	Percent
>38.10	30.8
19.05-38.10	32.4
12.70-19.05	9.6
6.35-12.70	10.4
4.76-6.35	2.4
2.00-4.76	5.0
0.76-2.00	3.0
0.42-0.76	3.0
<0.42	3.4

was maintained near 2%. Dissolved oxygen measurement (mg/l) were taken periodically at both the inflow and outflow. In order to predict stage of embryonic development, temperature was monitored continuously using a Taylor recording thermograph to determine daily temperature units (DTU).

To prepare for planting eggs, a 10 cm layer of gravel was placed in the bottom of each chamber (Figure 3). Two wooden frames (15.5 cm x 31 cm inside dimensions) were positioned within each chamber and the area around the frames filled with the substrate mix (Table 1). Two open-topped plastic-screen egg baskets (15.5 cm x 15.5 cm x 15.5 or 23.0 cm deep) were placed within each frame to facilitate embryo recovery; tall baskets were used for treatments that included fry emergence. Substrate mix was placed in the bottom of each egg basket to a depth of approximately 2 cm to insure embryos were not resting on exposed plastic-screen, and water was supplied to the chambers. Two hundred fertilized and water hardened brown, rainbow or cutthroat trout eggs were counted with a 100 hole plexiglass egg counter (Piper et al. 1983) and spread out evenly over the substrate mix in each egg basket. The egg baskets were then carefully filled with substrate and the wooden frames removed. Brown trout eggs were buried 3 inches (8 cm) deep, while rainbow and cutthroat trout eggs were buried 6 inches (15.5 cm) deep. Brown trout eggs were obtained from Harrison Lake, McConaughy strain rainbow trout eggs were obtained from Ennis National Fish Hatchery, while cutthroat trout eggs were obtained from two small spawning tributaries of Yellowstone Lake.

Four replicates of the following six treatments were evaluated for each species to determine the effect of human wading on embryo survival during different developmental stages (Figure 4):

Treatment 1: Wading between fertilization and eye-up.

Treatment 2: Wading between eye-up and hatching.

Treatment 3: Wading between fertilization and hatching.

Treatment 4: Wading between hatching and emergence.

Treatment 5: Wading between eye-up and emergence.

Treatment 6: Wading between fertilization and emergence.

Treatments were randomly assigned to one of the 24 chambers to reduce the effect of chamber variability observed in previous experiments (Weaver and White 1985). The only constraint was that every treatment would have at least one of its four replicates in each set of eight chambers. Each replicate consisted of two test and two control egg baskets. To eliminate possible differential survival as a result of egg location, the control or test egg baskets were located at the inlet end in two replicates and at the outlet end in the remaining two replicates.

Wading treatments were administered by one person with a weight of 165 lbs. (75 kg), except on two occassions when a person of similar weight administered the treatments. Brown trout embryos were waded on once every third day, while rainbow and cutthroat trout embryos were waded on twice daily. Wading events were applied in alternating direction to eliminate differential mortality as a result of uneven pressure distribution between the heel and toe portions of a boot. Seven days after completion of each rainbow and cutthroat trout

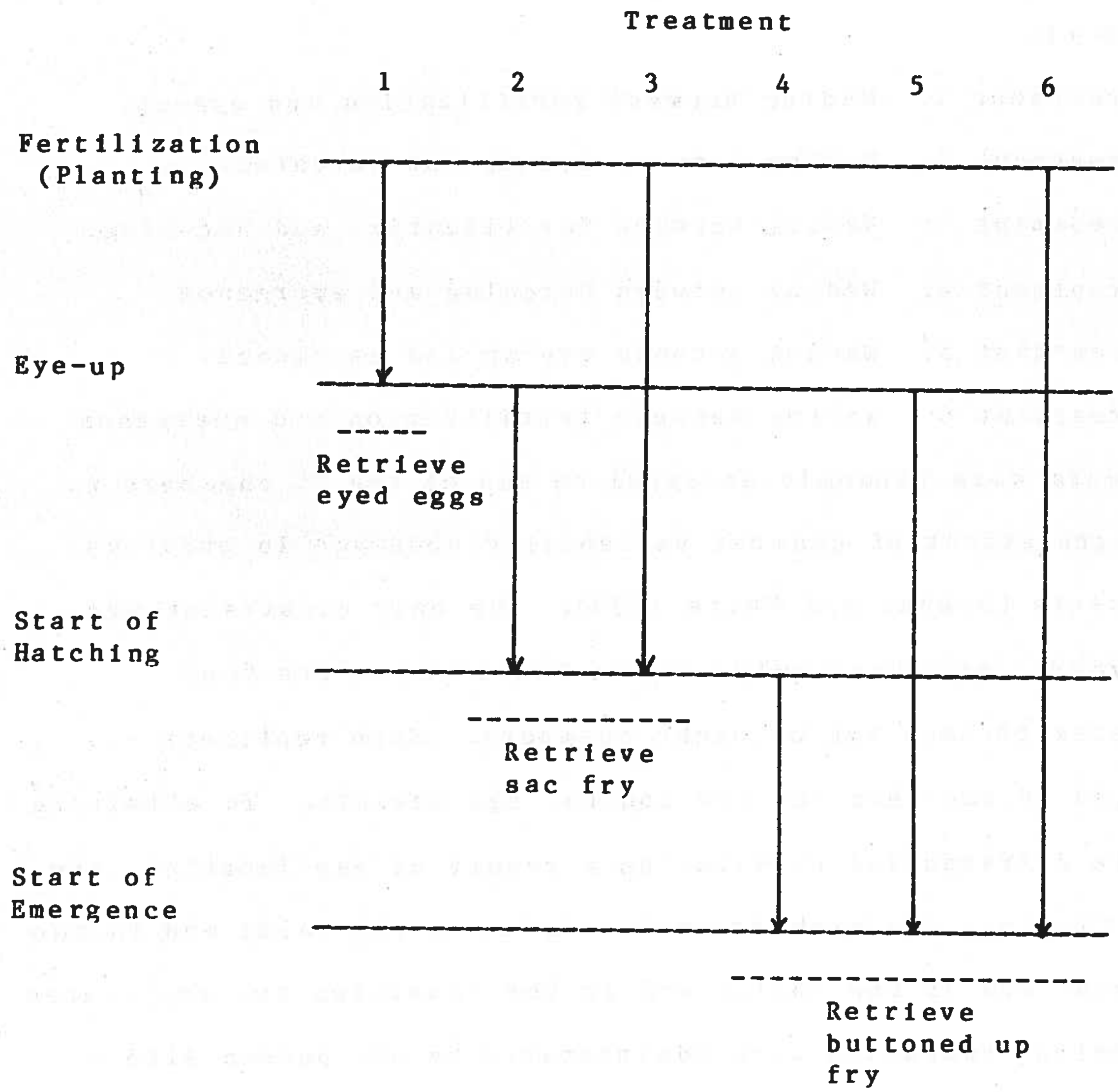

Figure 4. Diagram of treatment periods and embryo retrieval for the six human wading treatments.

treatment (which allowed for delayed mortality) egg baskets were pulled and embryos were retrieved from the substrate to determine survival in the test and control egg baskets (Figure 4). All brown trout egg baskets were pulled and embryos were retrieved after the completion of the last treatment. Contents of each egg basket were placed in a white enamel pan, and live and dead embryos were enumerated. Embryos that were not retrieved (< 200) were assumed to have decomposed after being crushed during the wading treatment.

Eggs from all female brown, rainbow or cutthroat trout were thoroughly mixed before planting to eliminate possible differential survival due to egg quality. As a check for percent fertilization and as a second control for determining nonwading-related mortality, eggs handled the same way as those planted in experimental chambers were incubated in a Heath stack. Percent survival in the Heath stack at 7 days after the start of eye-up, hatch and emergence was used to adjust survival from both control and test egg baskets. Observations of embryo development in the Heath stack were used to determine when wading treatments were initiated and terminated. A Wilcoxon's signed rank test was run on rainbow and cutthroat trout treatments to determine if adjusted survival from all control-test pairs differed statistically.

Handling Sensitivity

Sensitivity tests were conducted on pre-eyed eggs of each species to define the period of extreme sensitivity to handling and to relate this information to results of wading experiments.

Tests were conducted by gently netting a sample of 200 or 300 eggs from a Heath tray compartment and placing them in a 100 ml graduated cylinder. The graduated cylinder was covered, inverted and returned to the upright position three times; time was allowed for eggs to settle after each inversion. Handled eggs were then returned to the compartment and allowed to develope through hatching. Dead eggs were periodically picked and counted from each compartment. A new sample of 300 live eggs was handled each day until eye-up, except for cutthroat trout eggs where only 200 were handled each day. Brown trout eggs for sensitivity tests were incubated at 7.5°C and at 10.5°C, while tests on rainbow trout eggs were run at 8.1-8.4°C and 10.5°C; cutthroat trout eggs were incubated at 7.3-7.5°C. Rainbow trout eyed eggs were also handled just prior to hatching to see if a second sensitive period occurs.

Effect of Chamber Width

To determine if the narrow width (0.3 m) of the incubation chambers influenced the outcome of wading treatments, additional tests were conducted in a 0.3 m wide chamber and in a 1.0 m wide chamber (Figure 5). Substrate (Table 1) was mixed thoroughly before planting 200 eggs or pre-emergent fry. Embryos were held in the Heath stack (water temperature 7.3-8.6°C) prior to being planted in the substrate (water temperature 10.5-13.5°C). The procedure for planting was the same as diagrammed in Figure 3. Brown trout embryos were planted 3 inches (8 cm) deep. Cutthroat and rainbow trout embryos were planted 6 inches (15.5 cm) deep (Ottaway et al. 1981, Greeley 1932 and Smith 1941). Four egg

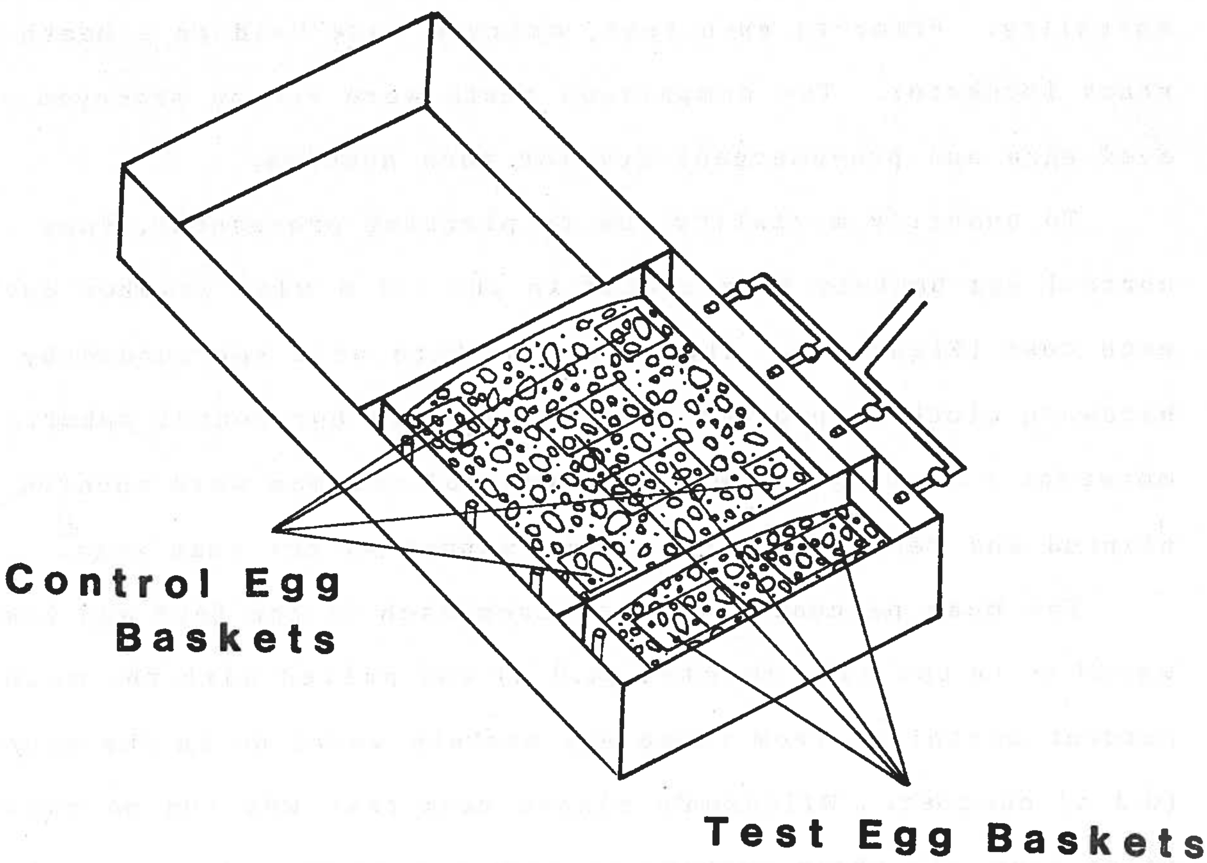

Figure 5. Diagram of the 1.0 m and 0.3 m wide incubation chambers used in the chamber width comparison tests and the location of the control and test egg baskets.

baskets were placed in each chamber (Figure 5). Embryos were planted in the substrate one day, waded on once the same day and retrieved the following day. Due to the extreme sensitivity of trout eggs to handling from day 7-15 after fertilization, eggs were planted in the substrate prior to the 7th day and retrieved after the 15th day for tests conducted during this period. Surviving eggs and pre-emergent fry were placed in a Heath stack incubator for 7 days following treatment to document delayed mortality. Prior to each test, embryos were held in a Heath stack incubator. Two comparison tests were run on pre-eyed eggs, eyed eggs and pre-emergent fry for each species.

To quantify mortality due to planting procedures, four control egg baskets were placed in the 1.0 m wide chamber during each test (Figure 5). These four baskets were surrounded by hardware cloth to protect against possible horizontal substrate movement caused by the wading. Control embryos were counted, planted and retrieved in the same manner as the test eggs.

The mean percent mortality from each of the four egg baskets waded on in the wide chamber (1.0 m) was paired with the mean percent mortality from those egg baskets waded on in the narrow (0.3 m) chamber. Wilcoxon's signed rank test was run on combined pairs from all three species to increase sample size. We assumed that differences between means were not a result of species differences. Percent mortality values were combined from the narrow (0.3 m) and wide (1.0) chamber, and a Mann-Whitney test was run to determine if there was differential mortality between test and control baskets containing embryos at various stages of development.

FIELD

Spawning Surveys

Thirteen spawning sections were identified in NSC (Figure 2). Weekly redd counts were made by walking the entire creek from 1 November 1985 to 11 August 1986 with a few exceptions: Section 13 was not identified until 19 December 1986; Sections 1 and 2 were flooded by the Yellowstone River from May 30 to July 6, 1986 and sections 11 and 12 were approximately 95% dewatered from 6 June 1986 to the end of the irrigation season. Outflow and inflow ditches to the hatchery ponds and raceways on the Nelson ranch were not censused. Accurate redd counts were difficult in section 10 (spillway pools) due to deep water. Redd locations were recorded on maps weekly to enable us to determine area of spawning riffles and to estimate the proportion of NSC that is being used for spawning. Orange rocks were placed on each redd to prevent multiple counting. In times of spawning overlap between species, an attempt was made to distinguish when the last fish of one species and the first of the second species was spawning. Stream depths were also monitored with the use of a staff gage mounted on the bridge between sections 4 and 5.

From March 1984 to July 1986, trapping and electrofishing surveys were conducted periodically by the MDFWP near the mouth of NSC to assess the relative size of the spawning run of brown, rainbow and cutthroat trout and to search for fish which had been tagged in the Yellowstone River. A 500 foot (152 m) section of the creek near the mouth was electrofished weekly or trapped daily. A box trap with wire leads was placed near the mouth to capture upstream brown and rainbow trout migrants. The trap was installed at the lower end of section 5 (just above the bridge) to monitor cutthroat trout from the Yellowstone River during the June and July high water period. Trapped fish were anesthetized, counted, measured, weighed, sexed and tagged with a red Floy-T tag prior to being returned to the stream. Spawning condition of each female trout was also noted.

Embryonic Development Specific to NSC

Brown, rainbow and cutthroat trout eggs were stripped, fertilized, water hardened and planted in the substrate in section 4 during the peak of spawning of each species. Brown trout gametes were obtained from Armstrong Spring Creek, while rainbow and cutthroat trout gametes were obtained from Nelson Spring Creek. Artificial redds were built in areas having 1 to 3 inch (2.5 to 7.6 cm) diameter gravel to insure adequate interstitial flow. One hundred eggs were placed in each of six gravel filled plastic-screen baskets and planted 4 to 8 inches (10-20 cm) in the substrate. Egg baskets were removed periodically and development observed. A Peabody Ryan model "J" thermograph was used to monitor daily temperature units (DTU), while days to eye-up, hatch and emergence were made based on observation.

Recreational Use in Sections 3 and 4

A Minolta 8 mm movie camera was placed in a streamside tree and programmed to take a single picture of sections 3 and 4 every 5 minutes during daylight hours to document fisherman use (Figure 6). Sections 3, 4 and 5 contain the spawning riffles that one of

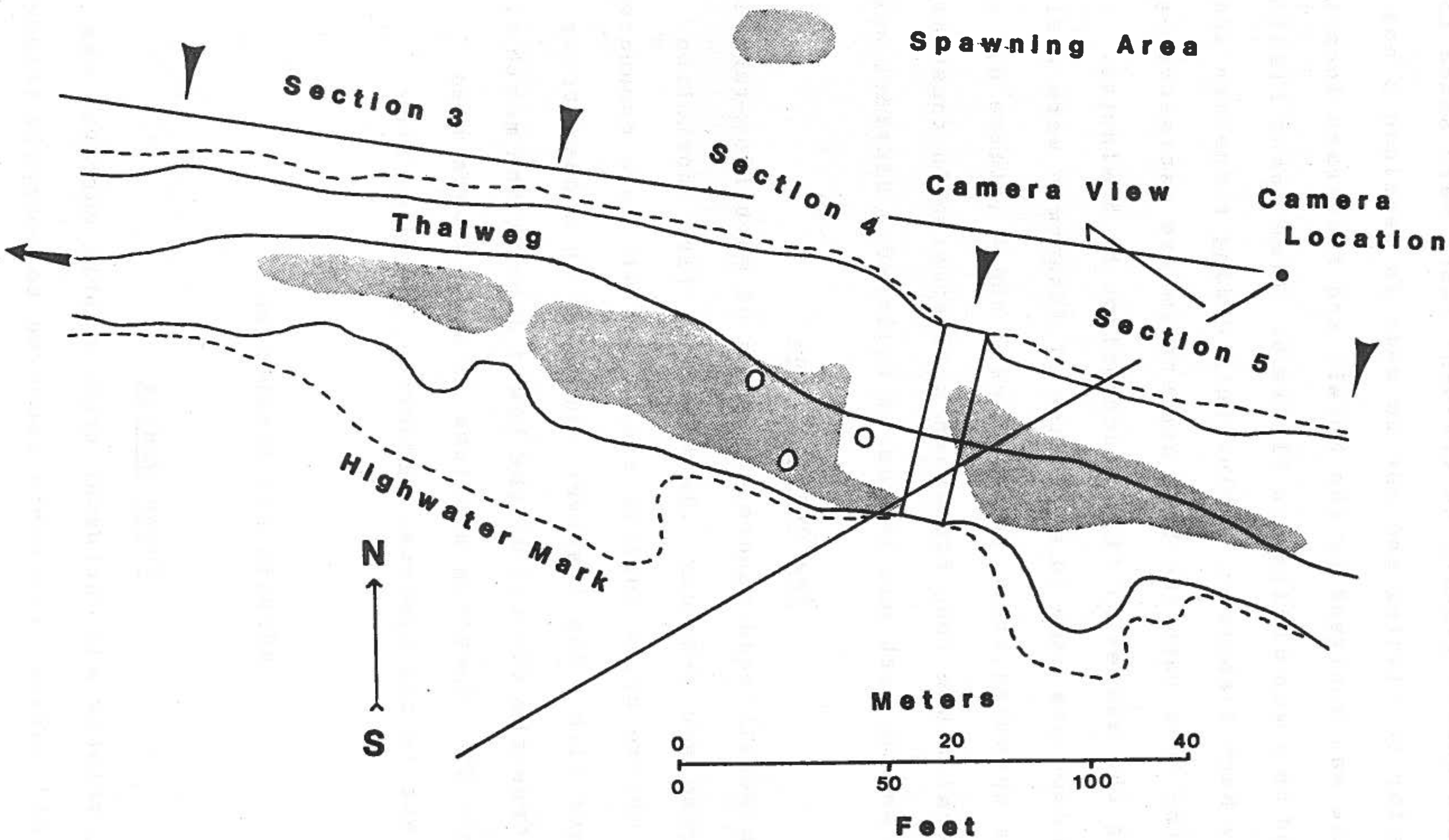

Figure 6. Location of spawning areas in sections 3,4 and 5 and the Minolta 8 mm movie camera with coverage view.

the landowners fear will be adversely impacted by unauthorized use. Invited quests fishing on the Dana ranch were asked to register prior to fishing and not to wade in sections 3 and 4. Film footage was analysed by the MDFWP, and fishermen locations were placed on a map similar to Figure 6. Time spent fishing by exclusively bank fishermen, exclusively wading fishermen and those fishing from both the bank and stream was estimated by multiplying the number of film observations by 5 minutes. A special attempt was made to determine if fishermen were wading through the spawning areas in sections 3 and 4 (Figure 6); and if so, to determine how long fishermen were staying in these areas and if the wading path was random or followed a distinct pattern.

Tag Observations

During weekly redd counts, location of each Floy-tagged trout observed was recorded. In addition, five snorkeling surveys (3 entire creek surveys and 2 partial) were conducted to locate tagged fish. The observer snorkeled in a downstream direction from the the top of the lower pond to the mouth of the creek (Figure 2). Spawning sections 11 and 12 were also snorkeled, but in the upstream direction, prior to flow reduction.

RESULTS AND DISCUSSION

LABORATORY

Human Wading

Brown, rainbow and cutthroat trout embryo survival was reduced in all wading treatments compared to controls (Figure 7). The differences were statistically significant ($P < 0.05$) for

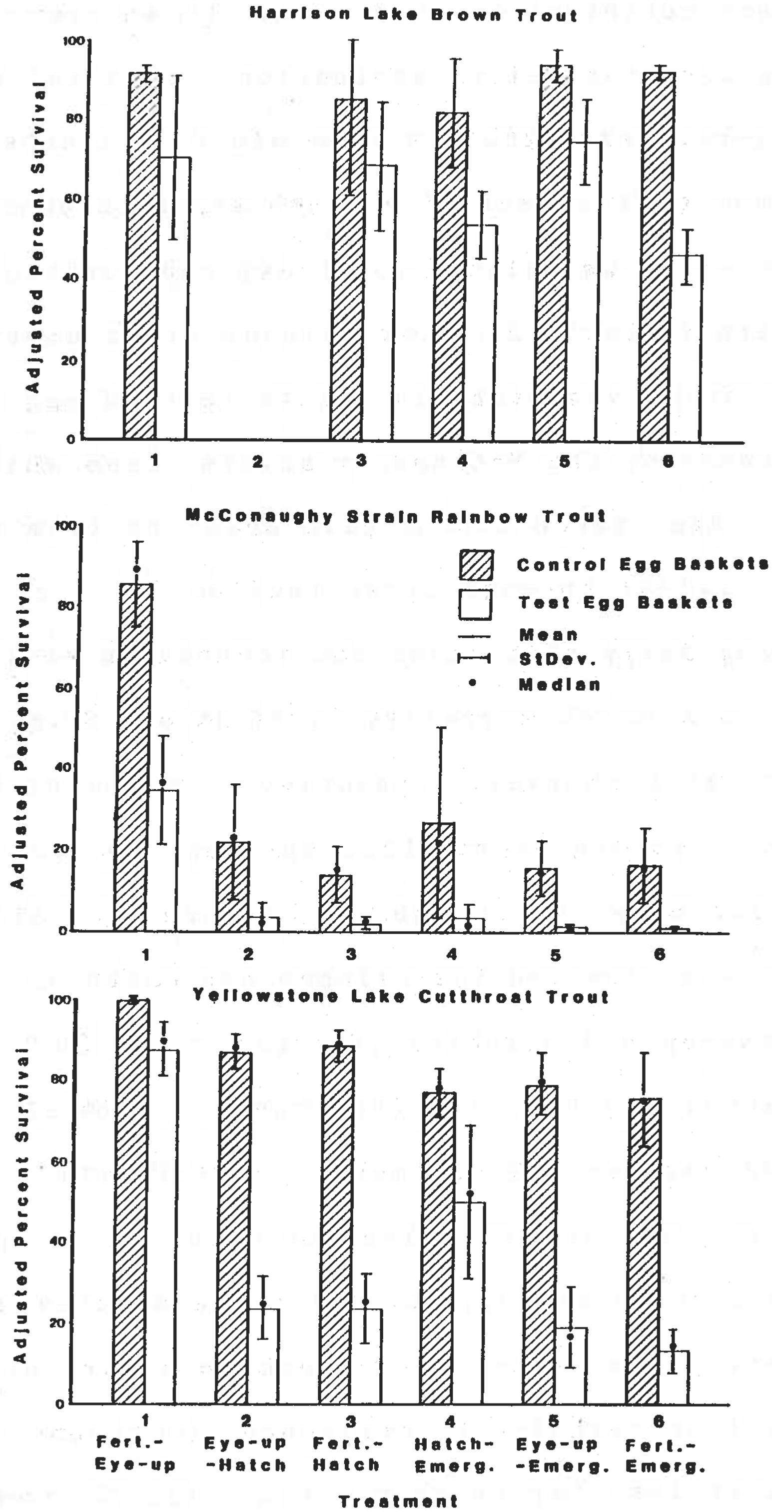

Figure 7. Adjusted survival for Harrison Lake brown trout, McConaughy strain rainbow trout and Yellowstone Lake cutthroat trout embryos in the control and test egg baskets exposed to treatments 1-6 in the laboratory. Brown trout embryos were waded on every third day; rainbow and cutthroat trout embryos were waded on twice daily.

rainbow and cutthroat trout; too few brown trout samples were available for statistical evaluation. Survival was adjusted for nonwading-related mortality determined by incubating eggs in the optimum environment of a Heath stack incubator. Heath stack embryo survival was higher for brown and cutthroat trout than for rainbow trout (Table 2). Low rainbow trout embryo survival in the Heath stack was probably due to reduced egg viability of late spawners of the McConaughy strain from which eggs were obtained. Eggs taken during peak spawning from this stock had 96% survival through first feeding (W. Orr, pers. comm.).

Wading daily throughout the incubation period (Treatment 6) resulted in a total mortality of 96.3% and 82.8% for rainbow and cutthroat trout embryos, respectively, compared to controls (Figure 7); wading every third day resulted in a total mortality of 53.2% for brown trout embryos (Figure 7). Slightly less mortality was observed for rainbow and cutthroat trout embryos between eye-up and hatching (Treatment 2 - 86.9 and 72.5%), fertilization and hatching (Treatment 3 - 88.2% and 73.6%) and eye-up and emergence (Treatment 5 - 96.3% and 76.2%) (Figure 7; Appendix A). The lowest mortality occurred in Treatment 1 (fertilization to eye-up) for all three species and was significantly less than other treatments for cutthroat trout. Mortality from hatching to emergence (Treatment 4) was considerably less for cutthroat trout (35.0%) compared to rainbow trout (90.2%).

Although the pattern of survival of embryos subjected to wading was similar, differences existed between species (Figure 7). These differences are thought to be primarily due to

Table 2. Percent survival of eggs incubated in a Heath stack incubator.

Species	Eye-up	Hatching	Emergence
Harrison Lake brown trout	.990	.964	.955
McConaughy strain rainbow trout	.909	.769	.753
Yellowstone Lake cutthroat trout	.985	.956	.941

variation in experimental conditions between experiments, but some of the observed differences could be a result of different embryonic development rates (i.e. slower developing embryos received more wading applications) (Table 3). The incubation environment during the cutthroat trout embryo experiment was the least variable of the three experiments completed, thus providing the best data.

Brown trout eggs were planted at a depth of 3 inches (8 cm) rather than 6 inches (15.5 cm) used in rainbow and cutthroat trout experiments and were also waded on every third day rather than twice daily as with the other species. Also several samples were lost during brown trout treatments due to deteriation of thread used in making egg baskets.

Poor adjusted percent survival of control and test rainbow trout embryos may have resulted from allowing too much water to flow over the surface of the substrate reducing intragravel flow and consequently reducing the amount of oxygen supplied to developing embryos. The delay in hatching exhibited by rainbow trout embryos (Table 3) probably resulted from these low oxygen concentrations (Shumway et al. 1964). Also, flow supplied to rainbow trout embryos was regulated with less precision (0.12-0.20 liters/sec.) than for cutthroat trout embryos (0.13-0.15 liters/sec.). Differences in adjusted survival for rainbow trout embryos were also observed between control egg baskets placed near the inflow of experimental chambers compared to those near the outflow; similar differences were not observed in brown and cutthroat trout experiments (Appendix A).

Table 3. Development rates (daily temperature units* and days) of the three species of trout in the laboratory.

Species	Faint Eye-Up	Hatching 1%	Hatching 50%	Hatching 100%	Start of Emergence
Harrison Lake brown trout	217.5 28 days	382.5 51 days	412.5 55 days	- -	564.4 75 days
Bighorn River brown trout	211.9 29 days	380.6 52 days	412.1 56 days	433.1 58 days	- -
McConaughy strain rainbow trout	165.7 21 days	328.5 41 days	343.9 43 days	359.5 45 days	632.4 84 days
Yellowstone Lake cutthroat trout	175.8 24 days	301.6 41 days	- -	331.5 45 days	496.5 67 days

* 1 daily temperature unit (DTU) equals 1°C above 0°C for a 24 hour period.

Periodic dissolved oxygen readings taken near the inflow and outflow ranged from 8.55-9.40 mg/l for brown trout, 8.9-9.6 mg/l for rainbow trout and 9.65-10.05 mg/l for cutthroat trout. These concentrations are within the suitable range for successful incubation (Phillips and Campbell 1961). Oxygen measurements taken near the inflow were consistently higher than those measurements taken near the outflow, but the differences never exceeded 0.10 mg/l. Intragravel oxygen measurements were not taken.

Brown and cutthroat trout embryos were incubated at water temperatures of 7.5° and 7.3-7.5°C, respectively, while rainbow trout embryos were incubated at 7.6-8-4°C. Temperature is not thought to be a factor in the poor adjusted survival of rainbow trout embryos since water temperatures were within the range suitable for incubation (1.5-15°C) (Timoshina 1972 and Kwain 1975).

The main source of mortality from human wading experiments results directly from pressure and disturbance or indirectly from Saprolegnia fungi hyphae or zoospores spreading from dead eggs (Smith et al. 1985). Susceptability of pre-emergent fry to fungus appears to be less compared to pre-eyed and eyed eggs. In our experiments, pressure placed on the substrate above the embryos by the wader (165 lbs or 75 kg) was equivalent to 460 g/cm^2 if all the body weight was evenly distributed over one boot, 644 g/cm^2 over the toe portion and 1,613 g/cm^2 over the heel portion.

Compaction of the substrate might indirectly result in embryo mortality. Constriction of the interstitial spaces resulting from human compaction could theoretically restrict the intragravel flow. Coble (1961) showed a close relationship between apparent velocity and dissolved oxygen concentrations in intragravel water. Incubating embryos require higher levels of dissloved oxygen as they progess through development (Alderdice et al. 1958). If compaction results in large reduction in intragravel flow, embryo survival could be reduced. To our knowledge, no one has evaluated the effect of substrate compaction from wading on embryo survival. Research reported by Gangmark and Broad (1956) provided the closest comparison to our work. They assessed the effect of horizontal bedload movement caused by floods on embryo survival. Embryos planted in egg canisters within the substrate showed high mortality after bedload movement.

Substrate compaction from multiple wading events occurring during developmental periods when embryos are resistent to crushing and insensitive to movement might aid in the protection of embryos from wading during sensitive periods. Mortality in cutthroat trout resulting from Treatment 2 (34 wading events between eye-up and hatching) and Treatment 3 (82 wading events between fertilization and hatching) was approximately the same and only twice as high, respectively, as the mortality resulting from one wading event just prior to hatching (Figure 8). Substrate compaction of 0.5 to 0.75 inches (1.25 -1.90 cm) was observed in each treatment area as compared to the control portion of experimental chambers. It took approximately seven to

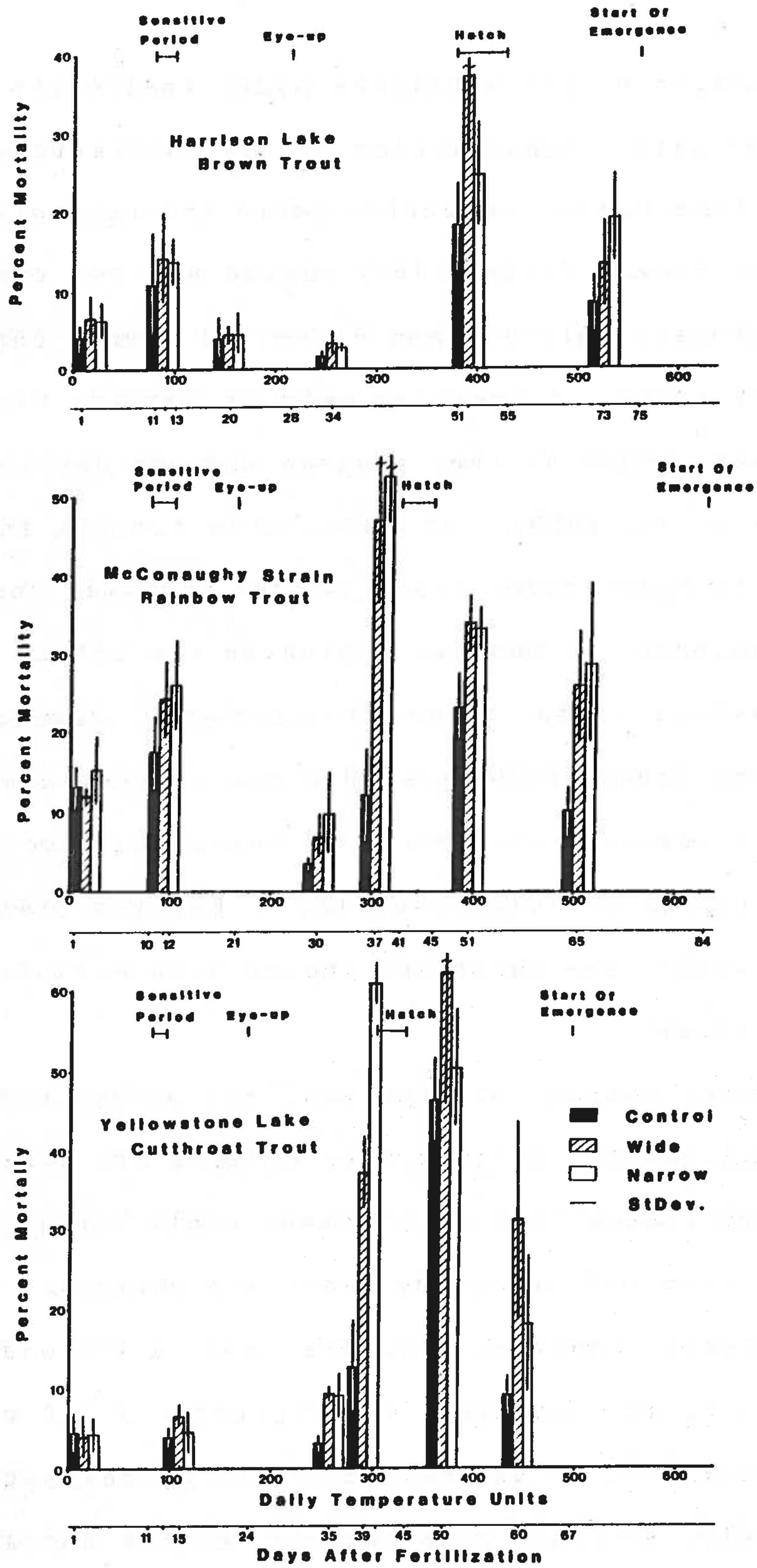

Figure 8. Comparison of percent mortality of Harrison Lake brown trout, McConaughy strain rainbow trout and Yellowstone Lake cutthroat trout embryos between control egg baskets and those exposed to one wading event in the wide (1.0 m) and narrow (0.3 m) chambers in relation to daily temperature units, stage of development and days after fertilization.

eight wading events to compact the substrate to the point where no further compaction was evident.

Handling Sensitivity

The peak sensitive period (highest mortality from handling) for brown and rainbow pre-eyed eggs occurred at the stage of embryonic development corresponding to 80-100 daily temperature units (DTU) (Figure 9), whereas it occurred between 80-95 DTU for cutthroat trout (Figure 9). Pre-eyed eggs incubated at 10.5°C exhibited peak handling sensitive at similar DTU to those incubated at lower temperatures (Figure 9). Onset of the sensitive period for cutthroat trout embryos was more gradual than for rainbow and brown trout embryos. No increase in mortality occurred for eyed eggs of rainbow trout handled prior to hatching (Figure 9).

Sensitivity of developing salmonid embryos to handling has been studied by numerous researchers during every stage of development prior to hatching. Leitritz and Lewis (1976) observed that the sensitive period of trout embryos begins between 24 to 48 hours after fertilization and lasts until embryos are eyed. Handling steelhead and rainbow trout embryos during early development showed that peak sensitivity occurs between 90-110 DTU (Johnson et al. 1983 and Johnson et al. Manuscript). Jensen and Alderdice (1983) exposed developing coho salmon embryos to a series of shock intensities (various drop heights) between fertilization and hatching and found higher mortality between 100-120 DTU (when the blastopore is closing) than before and after this period of development. Shock

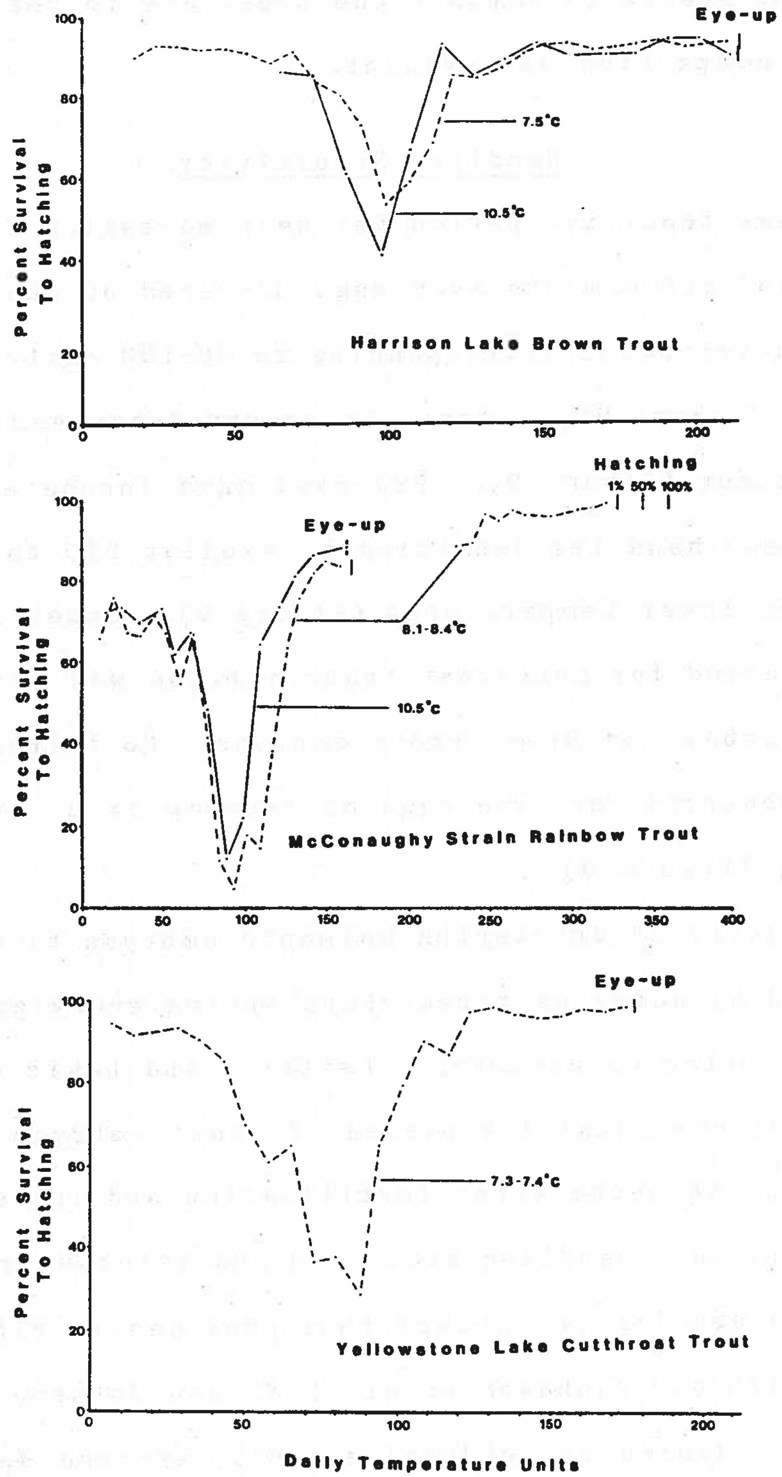

Figure 9. Percent survival to hatching of Bighorn River brown trout, McConaughy strain rainbow trout and Yellowstone Lake cutthroat trout embryos incubated at various water temperatures and handled daily between fertilization and eye-up. Rainbow trout eyed eggs were also handled prior to hatching. Each point represents survival from a known number of eggs.

treatments administered to eyed-eggs by Jensen and Alderdice (1983) resulted in low mortality up until 2 days prior to 50% hatch. Rosenberg (1985) subjected coho salmon eggs to physical shock at various stages between eye-up and hatching and found no detectable differences in sensitivity.

Effect of Chamber Width

Dimensions of incubation chambers (narrow (0.3 m) vs. wide (1.0 m)) had no significant effect ($P > 0.05$) on embryo mortality from one wading event. Differences in embryo mortality between wide and narrow chambers were small until the week prior to hatching (Figure 8; Appendix B). From just before hatching to emergence, differences were larger, but neither the wide nor the narrow chamber consistently exhibited higher mortality. These results support the predictions of two Montana State University physicists (D. Robiscoe and G. Caughlan, pers. comm.) that width of channel should not influence the results since force applied to the substrate surface would continue in a vertical plane rather than dispersing horizontally. Therefore, the narrow width of incubation chambers should not have affected our results.

Our data show that throughout the developmental process, fish embryos progress through several stages which change their vulnerability to human wading. Following spawning, the permeable chorin (egg shell) allows the perivitilline space to fill with fluids (water hardening). The chorion also hardens, thus protecting the embryo in the early, more vulnerable stages (Blaxter 1969). During the stage of development that corresponds to the closing of the blastopore (approximately a third of the way between fertilization and eye-up), embryos become extremely sensitive to handling (Leitritz 1972, Johnson et al. 1983 and Manuscript). Inside the hardened chorion and fluid filled perivitilline space, the developing embryo can rotate freely within the chorion to minimize environmental disturbances, but the embryo is usually bouyed in a dorsal position by clusters of lipid droplets (Knight 1963). Halfway to hatching, softening of the chorion begins. Hayes (1949) states that conclusive evidence on what causes the chorion to start softening this early is lacking. A few days prior to hatching, an enzyme is secreted into the perivitilline fluid from the ectodermal gland near the gills finishes softening the chorion for hatching.

Hayes (1949) and Hein (1907) as cited in Hayes (1949) showed that susceptibility of eggs to crushing follows a distinct pattern. It takes less than 0.25 kg to crush salmon and trout eggs prior to water hardening compared to 3 to 5 kg after water hardening. As hatching nears, it takes less and less weight to crush the eggs. Less than 1 kg is required to crush an egg just prior to hatching (Hayes 1949 and Hein 1907).

Results from the tests we ran on the effect of one wading event on embryo survival showed similar trends to those reported in the literature. Differences in mortality between control and test egg baskets (one wading event) ranged from 0 to 36.5% (mean = 11.2%) depending on stage of embryonic development (Figure 8; Appendix B). Eggs were never waded on before water hardening. Since water hardening only takes about 20 minutes (Leitritz and Lewis 1976), few trout redds would likely be affected by human wading during this stage of development. Brown and rainbow trout eggs that were waded on just before, during and just after the closing of the blastopore (Figures 8) showed an insensitive, sensitive, insensitive pattern similar to that observed in handling tests (Figures 9). Rainbow trout pre-eyed eggs waded on during the peak sensitive period (as defined by the handling tests) showed significantly higher ($P < 0.05$) mortality in test egg baskets as compared to the controls, while no significant difference was observed for brown trout embryos waded on once during the same stage of development. Wading on cutthroat trout embryos less than 2 days following the sensitive period had minimal effect on mortality (Figure 8). Mortality from one wading event was not as high as mortality from a single handling test during the peak sensitive period. The difference in mortality is probably a result of eggs being more sensitive to handling than to compaction.

Prior to hatching, when the chorion softening enzymes are being released, one wading event resulted in a large increase in mortality (Figure 9). High mortality was also observed in pre-emergent fry tests. Pre-emergent fry were also more sensitive to being placed in the substrate than were eggs (Figure 8). Embryos of all three species had significantly higher mortality ($P < 0.05$) from one wading event compared to the controls when wading occurred between the time the egg shell started to soften and emergence. Temperature differences between the Heath stack incubator (7.3-8.6^{o}C) and experimental chamber (10.5-13.5^{o}C) were assumed not to influence mortality (Peterson et al. 1977).

Post et al. (1974) subjected embryos in artificial redds to physical shock simulating four magnitudes of underground nuclear detonations, These tests resulted in no significant differences in embryo survival. Similar results were reported by Lloyd and Marshall (1986) from test detonations near a natural stream simulating siesmic detonations used in oil and gas exploration. Sheng (1985) concluded that the sensitivity of chum salmon embryos in the substrate to electrical shock from a back pack electroshocker was similar to the mechanical shock sensitivity curve developed by Jensen and Alderdice (1983).

FIELD

Spawning Surveys

Weekly redd counts were started the day (1 November 1985) the first spawning activity was observed in section 4 (Figure 10). Some brown trout redds constructed before 1 November 1985 in the other 12 sections may have been missed (Figure 2). Seventy-five percent of the entire creeks spawning took place in sections 4, 9, 11 and 12. Sections 3, 4 and 5 (the sections feared by one of the landowners to be adversely impacted by uninvited fishermen) contributed 2.5%(13), 20.5%(104) and 2.5%(13) of the redds in the entire creek, respectively, while sections 11 and 12 contributed 10.9%(55) and 29.1%(147), respectively (Table 4). Forty-eight of the redds located in sections 3, 4 and 5 were thought to be made by brown trout, 55 by rainbow and 27 by cutthroat trout. The most productive spawning section on the Nelson Ranch (section 9) contributed 12.5%(64) of the redds in the entire creek and 23%(9) of the cutthroat trout

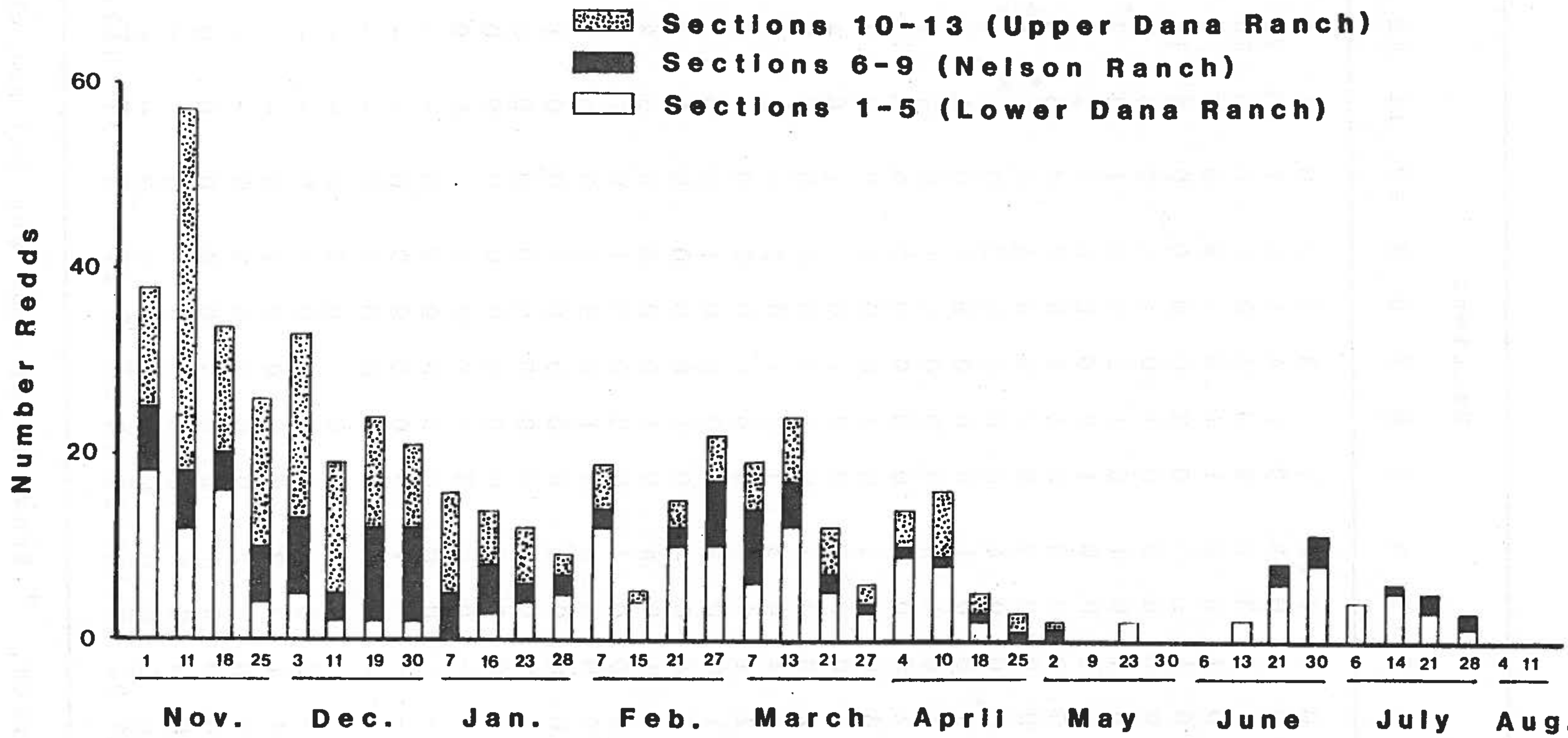

Figure 10. Weekly redd counts on Nelson Spring Creek, Montana made from 1 November 1985 to 11 August 1986.

Table 4. Weekly redd counts in Nelson Spring Creek, Montana from 1 November 1985 to 11 August 1986.

Month	Day	Sections 1	2	3	4	5	6	7	8	9	10	11	12	13	Total
November	1	0	3	2	12	1	1	3	1	2	0	4	9	-	38
	11	0	3	0	9	0	1	4	1	0	1	10	28	-	57
	18	1	3	3	6	3	0	3	0	1	0	4	10	-	34
	25	0	1	0	2	1	1	0	1	4	0	7	9	-	26
December	3	0	1	1	3	0	2	0	0	6	0	6	14	-	33
	11	0	0	0	3	0	1	0	1	1	0	6	8	-	20
	19	0	1	0	1	0	1	1	2	6	1	2	7*	2	24
	30	0	1	0	0	1	2	0	2	6	0	2	6	1	21
January	7	0	0	0	0	0	1	2	0	2	0	5	5	1	16
	16	0	0	0	3	0	1	0	0	4	0	1*	5+	0	14
	23	0	0	0	4	0	0	0	0	2	0	1*	4*	1	12
	28	4*	0	0	1	0	0	0	0	2	0	0	2	0	9
Febuary	7	5	0	1	6	0	0	0	1	1	0	0	5	0	19
	15	2	0	0	2	0	0	0	0	0	0	0	0	1	5
	21	8	0	0	2	0	1	0	0	1	0	0	3	0	15
	27	4	0	0	6	0	0	2	0	5	1	0	4	0	22
March	7	2	0	0	4	0	1	1	0	6	0	0	5	0	19
	13	3	1	0	5	3	2	1	0	2	0	1	6	0	24
	21	2	1	0	2	0	0	0	0	2	0	1	4	0	12
	27	1	0	0	2	0	0	0	0	1	0	0	2	0	6
April	4	1	4	0	4	0	1	0	0	0	0	1	3	0	14
	10	1	1	0	6	0	1	0	0	0	0	3	4	0	16
	18	0	0	0	2	0	0	0	0	1	0	1	1	0	5
	25	0	0	0	0	0	1	0	0	0	0	0	2	0	3
May	2	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	0	0	0	2	0	0	0	0	0	0	0	0	0	2
	30	-	-	0	0	0	0	0	0	0	0	0	0	0	0
June	6	-	-	0	0	0	0	0	0	0	0	-	-	-	0
	13	-	-	1	1	0	0	0	0	0	0	-	-	-	2
	21	-	-	2	3	1	0	0	0	2	0	-	-	-	8
	30	-	-	2	3	3	0	1	0	2	0	-	-	-	11
July	6	-	0	0	4	0	0	0	0	0	0	-	-	-	4
	14	1	1	0	3	0	0	0	0	1	0	-	-	-	6
	21	0	0	1	2	0	0	0	0	2	0	-	-	-	5
	28	0	0	0	1	0	0	0	0	2	0	0	0	0	3
August	4	0	0	0	0	0	0	0	0	0	0	-	-	-	0
	11	0	0	0	0	0	0	0	0	0	0	-	-	-	0
Total		35	21	13	104	13	18	18	9	64	3	55	147	6	506

* Rainbow trout redd, + Brown trout redd and (-) not checked.

redds (Figure 11).

Spawning areas made up 4.5% of the creeks surface area, excluding the area of two headwater ponds (Table 5). Sections 11 and 12 contained the most spawning area for rainbow and brown trout (Table 5). Sections 11 and 12 were unavailable for cutthroat trout to spawn in because of reduced flow resulting from an irrigation diversion. Brown trout were observed spawning from 1 November 1985 to 16 January 1986; rainbow trout from 19 December 1985 to 23 May 1986 and cutthroat trout from 13 June 1986 to 28 July 1986. Rainbow and brown trout spawning appeared not to overlap in sections 1-5, whereas in the upper 8 sections spawning overlapped (Table 4). There were 3 weeks between the time rainbow trout finished spawning and cutthroat trout began. Brown and rainbow trout used the entire creek for spawning, whereas cutthroat trout spawning was concentrated in sections 3, 4 and 9 (Table 4).

Rainbow trout trapping data from 1984 and 1986 indicates that the spawning migration from the Yellowstone River continued longer in 1984 (Table 6). In 1986 the run peaked between 3 March and 10 March, while the peak of spawning in sections 1-5 occurred between 7 March and 13 March (Figure 10). Electrofishing data from the last 3 years indicate that most Yellowstone River cutthroat trout spawners migrate into NSC between mid-June and mid-July. Trapping in 1986 was terminated 4 July, but spawning continued until 28 July with peak spawning between 21 June and 21 July. It appears that brown trout start running up NSC in early November to spawn which coincides with the peak of spawning in sections 1-5.

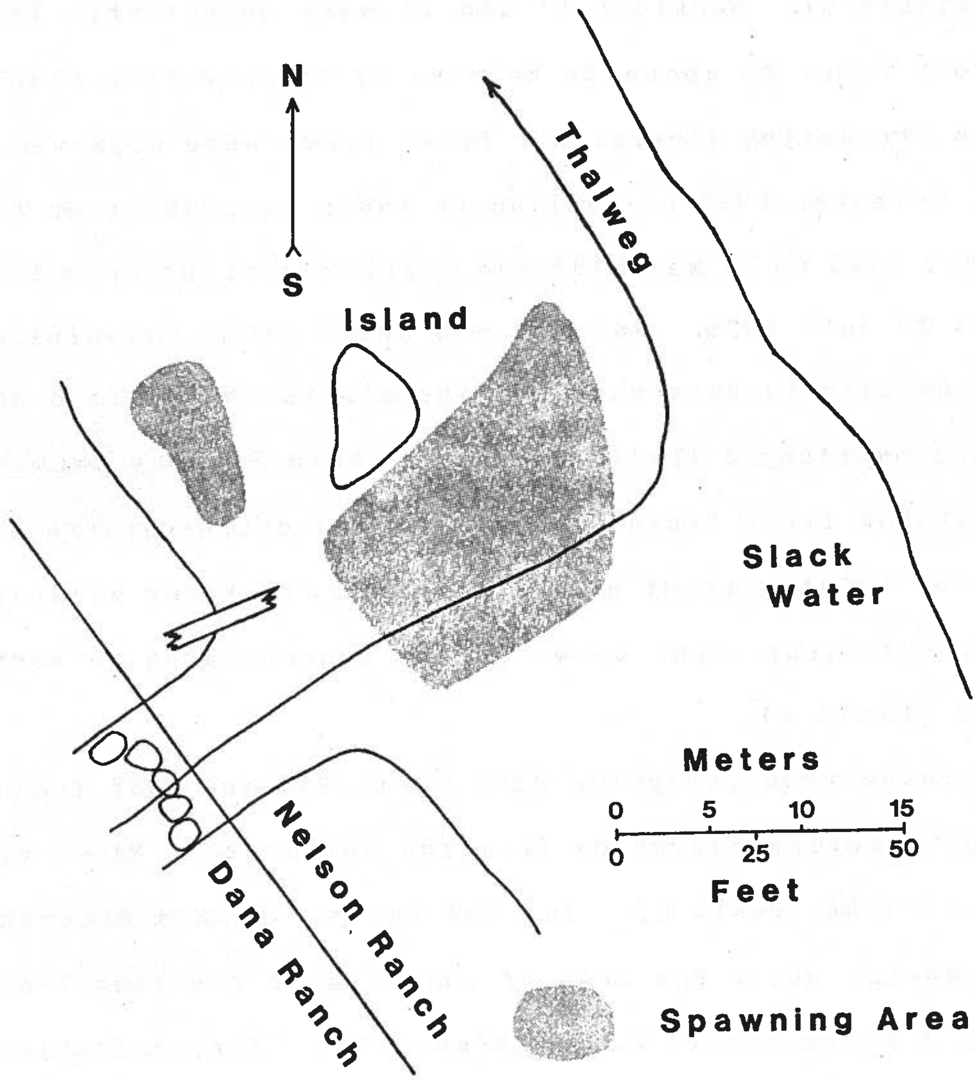

Figure 11. Map of spawning section 9 located on the Nelson Ranch.

Table 5. Area (m^2) of all 13 spawning sections in Nelson Spring Creek, Montana.

Section	Area(m^2)	Percent of total area(m^2)*
1	34.20+	0.1
2	148.46	0.5
3	47.44	0.1
4	190.24	0.6
5	128.44	0.4
6	47.57	0.1
7	103.81	0.3
8	10.75	<0.1
9	198.72	0.6
10	30.81	0.1
11	251.67	0.7
12	278.74	0.8
13	40.92	0.1
Total	1,511.77 m^2	4.5%

* total area excluding the area of the two headwater ponds.
+ approximately 30 m^2 of spawning substrate was lost as a result of the Yellowstone River re-routing during high spring flows.

Table 6. Trapping and electrofishing data (collected near the mouth of Nelson Spring Creek) from fall 1984 to summer 1986 on brown, rainbow and cutthroat trout migrating from the Yellowstone River (Clancy 1984, 1985 and pers. comm.).

Species	Year	Method	Dates	Males	Females	Temp.(^{o}F) (Max-Min.)	Spawning condition of females
LL	1984	ELFH	10/16	-	-	-	green
			10/29	-	-	52-46	green
			11/7	17	12	52-44	some ripe
			11/13	18	11	-	some ripe
	1986	TRAP	10/11-22	0	0	-	-
			10/23-30	1	1	-	green
			11/1-10	7	3	-	green
RB	1984	TRAP	3/20-30	19	10	56-44	50% ripe
	1986	TRAP	1/29-31	18	4	47-?	most green
			2/1-10	13	4	51-42	most green
			2/11-20	0	4	50-40	green
			2/21-28	17	14	53-45	33% ripe
			3/1-10	26	11	-	33% ripe
			3/11-20	12	14	-	50% ripe
			3/21-30	1	6	-	ripe-spent
			4/1-	-	-	-	spent
CT	1984	ELFH	6/25	2	3	-	ripe
			7/2	3	0	-	-
			7/9	5	6	-	ripe
			7/16	3	7	-	spent
			7/23	3	2	-	spent
	1985	ELFH	6/3	1	0	-	-
			6/12	2	2	-	green
			6/19	0	1	-	ripe
			6/27	9	6	-	ripe
			7/5	9	5	-	ripe
			7/9	5	3	-	spent
			7/17	3	3	-	spent
	1986	ELFH	6/17	1	0	-	-
			6/25	1	4	-	most green
			6/30	4	2	-	spent
			7/7	1	4	-	ripe
			7/14	1	1	-	spent
	1986	TRAP	6/11-20	2	1	61-50	-
			6/21-30	15	6	61-50	green
			7/1-4	8	7	63-50	ripe

RB = Rainbow trout, CT = Cutthroat trout and LL = Brown trout. ELFH=electrofishing and TRAP=trapping.

Nelson Spring Creek is an important spawning area for both cutthroat and rainbow trout (C. Clancy, pers. comm.). Yellowstone River cutthroat trout in the Livingston area are exclusively tributary spawners, while rainbow trout are primarily tributary spawners. Rainbow trout migrate long distances up and down the Yellowstone River to spawn in NSC. Nelson Spring Creek is the best cutthroat trout spawning stream known to occur in the Livingston area (from NSC to the mouth of the Shields River). Several channels of Armstrong Spring Creek are used by cutthroat trout for spawning. MDFWP speculates that one-third of the mature cutthroat trout in this section of the Yellowstone River spawn in these channels compared to two-thirds in NSC (C. Clancy, pers. comm). Due to the fact that Yellowstone River brown trout are mostly main-stem and side-channel river spawners, the importance of NSC to the Yellowstone River brown trout population is not nearly so great.

Water level fluctuations on the Dana ranch (between section 4 and 5) ranged from 7 1/2 to 10 5/8 inches from 18 November 1985 to 28 August 1986 (Figure 12), excluding a 3 week period in late May and early July when the water level at the bridge rose to approximately 16 inches (40.5 cm). The high water mark upstream from section 2 caused by the flooding Yellowstone River (Figure 6) is not considered the "ordinary high water mark" as defined in House Bill 265 because of the lack of permanent physical characteristics (Campbell and Waltermire 1985).

Embryonic Development Specific to NSC

Brown trout eggs planted in the substrate in section 4 of

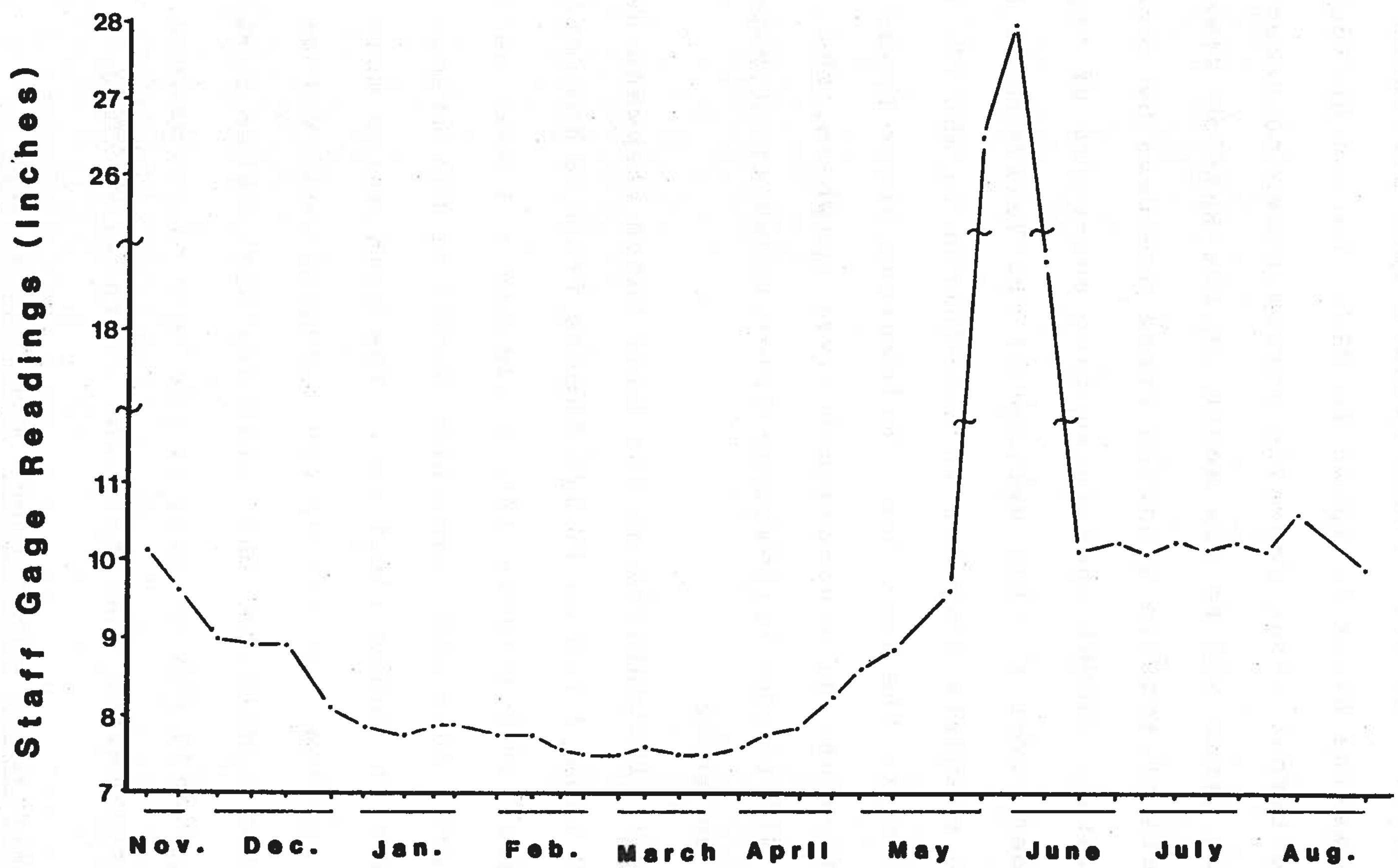

Figure 12. Weekly staff gage readings (inches) taken between sections 4 and 5 (on bridge) of Nelson Spring Creek, Montana.

NSC on 1 November 1985 took 33 days to eye-up and 66 days to hatch (Table 7). We were unable to estimate the number of days to emergence. The high mortality in brown trout egg baskets before hatching and complete mortality prior to emergence was thought to be related to trampling by whitetail deer. Rainbow and cutthroat trout eggs were planted in the substrate 13 March and 2 July 1986, respectively. Eye-up, hatch and emergence occurred at 19, 39, and 68 days for rainbow trout, respectively, while it took 14, 26 and 47 days for cutthroat trout (Table 7). Water temperature in the late afternoon during the summer months quit often rises above 13.5°C. Cutthroat trout eggs in hatcheries start to exhibit reduced survival between 13.5-14.5°C (M. Hamilton, pers. comm.). It is possible that cutthroat survival in NSC could be considerably lower than the survival we observed in the laboratory. Inherent species differences and large variations in weekly stream temperature units (Figure 13) resulted in varying rates of embryonic development rates in NSC. Based on the development rates, weekly temperature units and the distribution of spawning of all three species in section 4 (Table 5), it appears that there were eggs or fry in the gravel continuously from 1 November 1985 to early September 1986.

Tag Observations

Our observations indicate that sections 1-5 (lower Dana ranch) are the most important spawning areas for Yellowstone River rainbow and cutthroat trout. Only 12 Yellowstone River brown trout spawners were trapped and tagged at the mouth of NSC and only one of these fish was subsequently observed (Table 8).

Table 7. Embryo development rates (daily temperature units* and days) of brown, rainbow and cutthroat trout in Nelson Spring Creek, Montana.

Species	Date Planted	Predicted Eye-up	Predicted Hatching	Predicted Emergence	Egg Source
Brown trout	11/2/85	12/5/85 (33 days)	1/7/86 (66 days)	---+	Armstrong Spring Creek
Rainbow trout	3/13/86	4/1/86 (19 days) (168 DTU)	4/21/86 (39 days) (352 DTU)	5/20/86 (68 days) (641 DTU)	Nelson Spring Creek
Cutthroat trout	7/2/86	7/16/86 (14 days) (158 DTU)	7/28/86 (26 days) (294 DTU)	8/14/86 (47 days) (478 DTU)	Nelson Spring Creek

* 1 daily temperature unit (DTU) equals 1°C above 0°C for 24 hour period.
\+ No surviving pre-emergent fry.

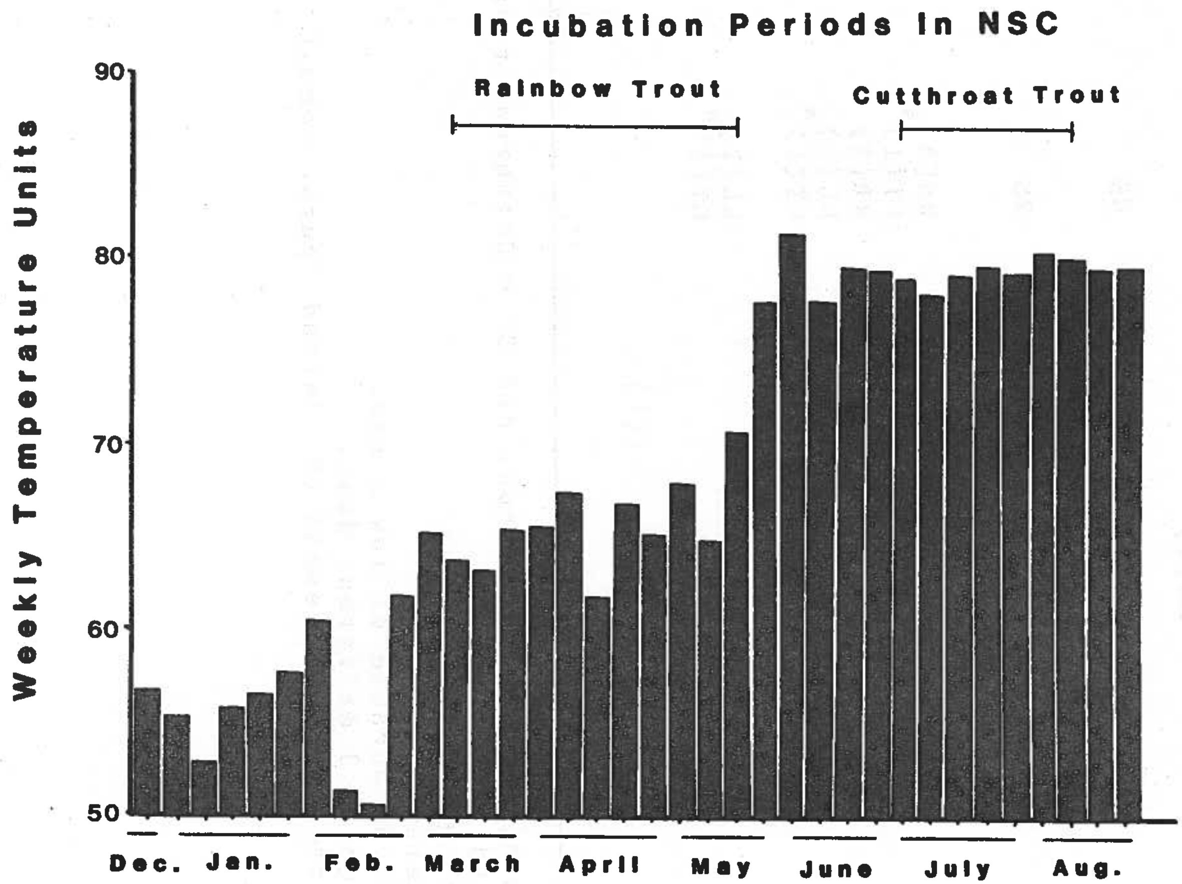

Figure 13. Weekly temperature units that developing embryos were exposed to in sections 3, 4 and 5 of Nelson Spring Creek, Montana.

Table 8. Tag observations made in Nelson Spring Creek, Montana from 18 November 1985 to 4 August 1986 by way of streamside and underwater observations.

Date	Stream-side Obs.	Under-water Obs.	Sections 1-5	6-9	10-Lower Pond	11-12
11/18/85	X		LL(1)			
1/6/86	X					?(1)
1/16/86		X	NS	NS	NS	0
2/15/86	X					RB(1)
2/27/86	X					?(1)
2/27/86		X	RB(12)	NS	NS	NS
3/7/86	X		?(2)			
3/21/86	X		?(2)			
4/4/86		X	RB(11)	RB(1)	RB(3) CT(1)*	0
4/10/86		X	RB(3)	0	RB(3) LL(1) CT(1)*	0
6/13/86	X		CT(1)	CT(1)+		
7/6/86		X	CT(2) RB(2)	0	LL(1) CT(1)*	NW
7/14/86	X		CT(1)			
8/4/86	X		CT(1)	?(1)		

LL = Brown trout, RB = Rainbow trout and CT = Cutthroat trout.
? = unidentified.
( ) = Number tagged fish sighted.
NS = Not snorkeled.
NW = Not snorkeled because of low water.
* Same fish sighted 3 different days.
+ Sighted in ditch below raceways (R. Nelson, pers. comm.)

Tagged rainbow trout were observed in every spawning section, except for section 13, with most observations (28) made in sections 1-5 (Table 8; Figure 2). Five of six cutthroat trout observations were also made in sections 1-5; the sixth fish was observed just upstream of section 6. Cutthroat trout were not observed above the lower headwater pond because of reduced flow in sections 11 and 12 due to an irrigation diversion. Tagged brown trout were observed in the lower pond up to 7 months after brown trout spawning had been completed; one tagged cutthroat trout was observed in the lower pond on three occasions.

Recreational Use in Sections 3 and 4 of NSC

Seventy-one anglers were photographed fishing sections 3 and 4 of NSC between 28 February and 30 August 1986 (Table 9). Of these anglers, 16 fished exclusively from the bank, 20 fished from the bank and while wading and 35 fished exclusively while wading. We estimated that fishermen spent 15.08 hours (181 picture frames) fishing sections 3 and 4 while wading and 5.75 hours (69 picture frames) while standing on the bank for a total of 20.83 hours. Thirty-six percent of the time spent wading in the stream was in spawning areas. Most wading anglers (85%) in sections 3 and 4 waded up the right half of the stream (facing upstream). This portion of the channel includes approximately 95% of the spawning area within these sections. A small portion (15%) of the observed fishermen were wading on the left hand side of the stream. Using redd locations that were mapped weekly, we estimate that 7 of 10 brown trout redds, 33 of 52 rainbow trout redds and 13 of 23 cutthroat trout redds located in the area of

Table 9. Estimated amount of fisherman use on lower Nelson Spring Creek (sections 3 and 4) from exclusively bank, bank & wading and exclusively wading fishermen.

	Dana Register	Camera Coverage			Spawning Surveys
Week	# Registered Anglers	# Bank Anglers (a)*	# Bank & Wading Anglers (a,b,c)*	# Wading Anglers (b,c)*	Est. # of Redds with dev. embryos (d,e,f)*
2/28-3/1	0	0	3(10,35,15)	0	(7,15,0)
3/2-3/8	4	1(5)	0	0	(7,18,0)
3/9-3/15	2	0	2(15,10,10)	0	(6,21,0)
3/16-3/22	0	0	0	4(60,35)	(4,23,0)
3/23-3/29	4	0	0	0	(1,23,0)
3/30-4/5	3	1(30)	0	1(5,5)	(0,23,0)
4/6-4/12	2	0	1(5,5,5)	0	(0,25,0)
4/13-4/19	0	0	0	0	(0,22,0)
4/20-4/26	1	0	0	0	(0,20,0)
4/27-5/3	9	0	0	0	(0,19,0)
5/4-5/10	5	1(15)	0	1(10,0)	(0,18,0)
5/11-5/17	8	0	0	1(30,25)	(0,15,0)
5/18-5/24	6	0	0	1(5,5)	(0,12,0)
5/25-5/31	4	0	1(5,20,15)	0	(0,10,0)
6/1-6/7	10	1(15)	5(45,60,20)	0	(0,9,0)
6/8-6/14	12	2(25)	1(5,5,5)	1(60,0)	(0,6,1)
6/15-6/21	7	1(25)	2(15,35,10)	3(130,55)	(0,3,4)
6/22-6/28	7	0	1(5,30,5)	7(165,40)	(0,1,8)
6/29-7/5	20	0	1(5,30,5)	2(15,15)	(0,1,10)
7/6-7/12	20	1(5)	1(15,45,20)	0	(0,1,11)
7/13-7/19	26	2(25)	0	3(15,0)	(0,1,13)
7/20-7/26	44	3(25)	1(5,5,0)	6(90,25)	(0,0,13)
7/27-8/2	22	0	0	2(10,0)	(0,0,12)
8/3-8/9	13	0	0	2(25,10)	(0,0,9)
8/10-8/16	28	2(35)	0	0	(0,0,5)
8/17-8/23	31	1(15)	0	0	(0,0,3)
8/24-8/30	14	0	1(5,5,5)	1(5,0)	(0,0,2)
8/31-9/6	22	-	-	-	(0,0,0)
Total	296	16(220)	20(125,280,115)	35(625,215)	(7,33,13)

* a = estimated # of minutes fishing from the bank.
b = estimated # of minutes fishing from within the stream channel.
c = estimated # of minutes fishing from within spawning areas.
d,e and f = estimated # of brown, rainbow and cutthroat trout redds with incubating embryos laying within the area frequently waded through by anglers.

heavy human use were probably impacted by human wading after 28 February 1986. Using 68 and 47 day incubation periods for rainbow and cutthroat trout embryos (Table 7) and assuming 100 days for brown trout, no more than 7 brown trout redds, 25 rainbow trout redds and 13 cutthroat trout redds contained embryos at any given time (Table 9).

Wading in spawning areas of sections 3 and 4 was also observed by livestock (horses and cows) and whitetail deer. Livestock were observed wading 16 times within the stream and 1 time within spawning areas. Whitetail deer were observed 2 times within the stream and 2 times within spawning areas. The heaviest deer use of the stream channel was during fall and winter months when brown and rainbow trout were spawning and cameras were not operational.

Without knowing if each angler waded on a redd(s) or the stage of embryo development at the time of wading, it is difficult to predict how much wading-related embryo mortality occurred in NSC. There is a need to make projections regarding impact of present recreational use on NSC and the Yellowstone River fishery. To do this, it is necessary to make several assumptions:

1) The redd of each Yellowstone River trout contained 1,325 eggs.

2) 20% of eggs deposited in the substrate died of natural causes.

3) 5-15% of the redds located in heavy use areas received one wading event for every 5 minutes of wading within the spawning areas.

4) 30-70% of all embryos within a given redd were waded on.

5) Mean embryo mortality was 11.2% (range of 0-36.5%) from one wading event (Figure 8).

Using these assumptions we estimate that 109-760 brown trout embryos died as a result of human wading in sections 3 and 4 after 28 February 1986 (Table 10). Although fishing during winter is light, this is probably an underestimate of mortality since brown trout spawning began 1 November 1985, approximately 17 weeks before the camera was operational. However, since brown trout numbers are large in the Yellowstone River in the vicinity of NSC (80 fish/mile > 16") and since river brown trout are mostly main-stem and side-channel spawners, human wading in NSC is not expected to adversely influence the river population. Also, since only 23% of the 230 brown trout redds observed in NSC were located below section 5, wading-related mortality would not be expected to have a significant impact on the resident brown trout population.

Human wading documented in sections 3 and 4 of NSC during 1986 is estimated to have resulted in the mortality of 910-6,369 (1.7-11.6%) rainbow trout embryos (Table 10). The total number of rainbow trout (237) and brown trout (230) redds observed in NSC was similar, however, more Yellowstone River rainbow trout used NSC than did Yellowstone River brown trout (Table 6); most river spawners appear to spawn in the impacted section.

Population estimates of rainbow trout in the Livingston area are the highest (80 fish/mile > 16") documented between Corwin Springs (10 fish/mile > 16") and Springdale (44 fish/mile > 16") (Clancy 1985). Data collected by MDFWP suggest that Armstrong Spring Creek is used considerably more for rainbow trout spawning

Table 10. Projected percent (number) embryo mortality in sections 3 & 4 of Nelson Spring Creek, Montana under present use conditions within the spawning areas.

species	# redds potentially affected	% of embryos in redds waded on	% redds waded on / 5 min. wading interval 5%	10%	15%
			%(No.)	%(No.)	%(No.)
Brown Trout	7	30%	0.2%(109)*	0.5%(218)	0.7%(326)
		50%	0.4%(181)	0.8%(362)	1.2%(543)
		70%	0.6%(253)	1.1%(507)	1.7%(760)
Rainbow Trout	33	30%	1.7%(910)	3.3%(1,820)	5.0%(2,730)
		50%	2.8%(1,517)	5.5%(3,034)	8.3%(4,551)
		70%	3.9%(2,123)	7.7%(4,246)	11.6%(6,369)
Cutthroat Trout	13	30%	2.1%(524)	4.3%(1,048)	6.4%(1,572)
		50%	3.6%(873)	7.2%(1,746)	10.7%(2,619)
		70%	5.0%(1,213)	10.0%(2,426)	14.9%(3,639)

* Example calculation: Brown trout for 30% of embryos waded on and 5% redds waded on (Table 9 and Assumptions 1-5):

(A) Week	(B) # redds w/ dev. embryos	(C) # live embryos/ redd(80% x 1,325)	(D) # 5 min. intervals spent in spawning areas	(E) # redds waded on (5%xDxB)	(F) # embryos waded on (30%xExC)	(G) # embryos killed (11.2%xF)
2/28-3/1	7	1,060	3	1.05	333.9	37.4
3/2-11	7	1,060	0	0	0	0
3/9-15	6	1,060	2	0.6	190.8	21.4
3/16-22	4	1,060	7	1.4	445.2	49.9
3/23-29	1	1,060	0	0	0	0
3/30-4/5	0	1,060	1	0	0	0
						Σ 108.7(109)

109 killed embryos / (1,325(fecundity) x 80%(embryo survival) x 42 brown trout redds in sections 3 and 4) = 0.24%

than is NSC; other tributaries in the area are apparently not used. Rainbow trout are also known to spawn in side channels of the Yellowstone River, but not to the same extent as brown trout.

To estimate the overall effect of rainbow trout mortality due to wading in NSC, it is necessary to project survival from the time of emergence until the fish return to spawn. In general, less than 10% of the trout fry that emerge survive through the first year of life (Allen 1951 and Elliott 1985). Annual mortality after the first year decreases. Annual mortality rates ranging from 38-58% for age II+ trout in the Yellowstone and Madison Rivers have been reported (Vincent (In Press) and C. Clancy, pers. comm.).

Assuming no wading-related mortality and using an annual mortality rate of 50%, 40 rainbow trout (one-half females) would reach maturity at age IV (Javorsky 1984). Based upon our "worst case" projection of wading-related mortality and the numbers of large rainbow trout in the Yellowstone River in the vicinity of NSC, it appears unlikely that the present level of wading-related mortality below section 5 in NSC would have significant impact on the Yellowstone River or NSC populations of rainbow trout.

The cutthroat trout population in the Yellowstone River from the mouth of the Shields River to NSC is low (29 fish/mile > 12") compared to the 125 fish/mile > 12" in the Corwin Springs area and 98 fish/mile > 12" in the Springdale area (Clancy 1985). This is probably due to a combination of factors including recruitment and overfishing.

Yellowstone cutthroat trout are not known to spawn in the main-stem Yellowstone River and the principal spawning area in the Livingston vicinity is NSC. Cutthroat trout spawning also occurs in Armstrong Spring Creek, but Clancy (pers. comm.) speculates that only one-third of the spawning occurs there. Clancy (1984) reported that recruitment of two year olds was highest in areas of the Yellowstone River having the best spawning tributaries nearby. Dewatering of tributaries in Paradise Valley and the Livingston area has affected recruitment of Yellowstone cutthroat trout into the Yellowstone River (Berg 1975). Due to the limited spawning area available to cutthroat trout in the Livingston vicinity, wading-related mortality would have a larger impact on Yellowstone River cutthroat trout populations than on brown or rainbow trout populations.

Only 39 cutthroat trout redds were observed in NSC during 1986. Of these, 13 (33%) may have been affected by wading. Using the "worst case" projection (Table 10), 14.9% or 3,639 embryos would succumb due to wading-related mortality. With no wading-related mortality and assuming 90% mortality during the first year of life and an annual mortality of 50% for age II and a 62% mortality for ages III and older (1982-83 data, C. Clancy, pers. comm.), 26 additional fish (13 females) would reach maturity (age IV). Because of the limited spawning area in the vicinity of NSC, 13 additional females (a 33% increase over 1986) recruited to the spawning population annually would theoretically improve recruitment to the Yellowstone River.

Wading-related mortality of cutthroat trout embryos in NSC in 1986 was probably not larger than in past years. Elimination of wading on cutthroat trout redds would provide more cutthroat trout recruits to the Yellowstone River fishery. However, due to the present five-fish limit and the vulnerability of cutthroat trout to angling (Vincent and Clancy 1980), population increase would be slow. Angling probably has a much larger affect on the present cutthroat trout population structure in this portion of the Yellowstone River than does wading. Johnson and Bjornn (1978) estimated annual cutthroat trout mortality at 0.62 in 1969 and 0.71 in 1970 prior to initiating trophy-fish regulations (13" minimum size-3 fish limit), as compared to 0.47 in 1974 and 0.56 in 1975 after regulations were instituted.

SUMMARY

1) Impact of wading depends upon wading frequency and stage of embryonic development. Brown, rainbow and cutthroat trout embryo survival was reduced in all wading treatments compared to controls. Embryo mortality resulting from human wading is highest for eyed eggs just prior to hatching and pre-emergent fry. Pre-eyed and eyed eggs waded on after water hardening and prior to softening of the egg shell are less susceptable to human wading. A slight increase in susceptibility also occurs at the stage of development that corresponds to the closing of the blastopore (between 7 and 15 days). Mortality was considerably higher for those pre-eyed eggs handled daily during this same period compared to those that were waded on.

2) Width of experimental chambers had no detectable effect on embryo mortality in wading experiments.

3) One-hundred-thirty of the 506 trout redds built in NSC between 1 November 1985 and 11 August 1983 were in sections 3, 4 and 5. Forty-eight of those redds were thought to be made by brown trout, 55 by rainbow trout and 27 by cutthroat trout.

4) Seven of 10 brown trout redds, 33 of 52 rainbow redds and 13 of 23 cutthroat trout redds located in the area of heavy human use were probably impacted by human wading after 28 February 1986.

5) Brown trout were observed spawning in sections 3, 4 and 5 from 1 November 1985 to 30 December 1985; rainbow trout from 16 January 1986 to 23 May 1986 and cutthroat from 13 June 1986 to 28 July 1986. Peak spawning migration of Yellowstone River trout into NSC in 1985 was early November for brown trout; early March (1986) for rainbow trout and late June(1986) for cutthroat trout.

6) Days to eye-up, hatch and emergence in NSC for rainbow and cutthroat trout in 1986 were 19, 39 and 68 and 14, 26 and 47, respectively. It took brown trout embryos 33 and 66 days to reach eye-up and hatch, respectively.

7) Based on embryonic development specific to NSC and the timing of spawning for all three species of trout, there were eggs or pre-emergent fry in the gravel continuously from 1 November 1985 to early September 1986 in sections 3, 4 and 5.

8) Based on tagged fish observations, it appears that a large portion of the runs of rainbow and cutthroat trout migrating into NSC from the Yellowstone River spawn in sections 1-5.

9) Seventy-one people were observed fishing sections 3 and 4 of NSC between 28 February and 30 August 1986. Sixteen bank fishermen (exclusively) spent 3.67 hours fishing sections 3 and 4 and wading fishermen (exclusively) spent 10.41 hours, while fishermen fishing from both the bank and within the stream spent 6.75 hours for a total of 20.83 hours. Thirty-six percent of the time spent fishing from within the stream channel (5.50 hours) was also spent within spawning areas.

10) The path that most fisherman took while wading in the stream was in the right one-half of sections 3 and 4 which contains 95% of the spawning areas.

11) Of the three trout species examined, the present level of angler wading in Nelson Spring Creek is not expected to have measurable impact on brown or rainbow trout populations of the Yellowstone River or NSC. Spawning of neither species is restricted to tributaries and population levels (fish > 16") are high relative to most other sections of the Yellowstone River. Wading-related mortality, however is expected to have a negative impact on the Yellowstone River cuttthroat trout population because they spawn during times of high angler use, adult numbers (fish > 12") are low, and NSC is the principal spawning area for cutthroat trout in the Livingston vicinity. Although wading impacts are thought to be negative, angler harvest probably has a larger affect on the present cutthroat trout population structure in this portion of the Yellowstone River than does wading.

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APPENDIX A

ADJUSTED SURVIVAL DATA FROM TREATMENTS 1-6 FOR ALL THREE SPECIES

Appendix A. Adjusted survival for Harrison Lake brown trout, McConaughy strain rainbow trout and Yellowstone Lake cutthroat trout embryos in the control and test egg baskets exposed to Treatments 1-6 in the laboratory.

Harrison Lake Brown Trout

Treatment	Control Location	Control Adjusted Survival(%)	Test Adjusted Survival(%)
1	Front	89.5	80.0
	Front	89.0	73.0
	Rear	92.5	72.0
	Rear	93.0	91.0
	Front	93.5	35.5
	Mean	91.5	70.3
	StDev.	2.1	20.9
3	Rear	96.0	77.5
	Front	100.0	74.0
	Rear	50.0	44.0
	Front	93.5	78.0
	Mean	84.9	68.4
	StDev.	23.4	16.4
4	Front	72.0	59.5
	Rear	91.0	48.0
	Mean	81.5	53.8
	StDev.	13.4	8.1
5	Front	99.0	85.0
	Front	94.0	82.0
	Rear	91.0	66.5
	Rear	91.0	64.0
	Mean	93.8	74.4
	StDev.	3.8	10.7
6	Rear	90.5	40.5
	Rear	93.5	46.0
	Front	92.5	54.0
	Mean	92.2	46.8
	StDev.	1.5	6.8

Appendix A. (Continued).

McConaughy Strain Rainbow Trout

Treatment	Control Location	Control Adjusted Survival(%)	Test Adjusted Survival(%)
1	Rear	94.0	46.5
	Rear	93.0	56.0
	Front	89.0	17.0
	Front	72.5	22.0
	Rear	65.5	38.5
	Rear	87.5	38.0
	Front	90.5	24.0
	Front	89.0	34.0
	Mean	85.1	34.5
	StDev.	10.4	13.1
	Median	89.0	36.0
2	Front	26.0	0.0
	Front	17.5	0.5
	Rear	2.0	2.0
	Rear	2.5	0.5
	Front	38.0	0.0
	Front	17.0	7.0
	Rear	38.5	6.5
	Rear	30.0	6.0
	Mean	21.4	2.8
	StDev.	14.3	3.1
	Median	21.75	1.25
3	Rear	7.0	2.0
	Rear	8.0	3.5
	Front	21.5	2.0
	Front	12.5	2.5
	Rear	16.5	0.0
	Rear	3.5	0.0
	Front	22.0	0.5
	Front	18.0	2.0
	Mean	13.6	1.6
	StDev.	7.0	1.3
	Median	14.5	2.0

Appendix A. (Continued).

McConaughy Strain Rainbow Trout

Treatment	Control Location	Control Adjusted Survival(%)	Test Adjusted Survival(%)
4	Front	22.0	0.0
	Front	6.5	0.0
	Rear	56.5	8.5
	Rear	55.0	4.5
	Front	48.5	5.5
	Front	21.0	2.0
	Rear	1.5	0.0
	Rear	0.5	0.0
	Mean	26.4	2.6
	StDev.	23.8	3.3
	Median	21.5	1.0
5	Front	27.0	2.0
	Front	23.0	0.0
	Rear	12.0	1.5
	Rear	11.5	0.0
	Front	6.0	0.5
	Front	18.5	0.0
	Rear	16.0	0.0
	Rear	14.0	0.5
	Mean	16.0	0.6
	StDev.	6.7	0.8
	Median	15.0	0.5
6	Rear	22.0	1.5
	Rear	10.0	0.0
	Rear	4.5	0.5
	Rear	8.0	0.5
	Front	26.5	0.5
	Front	25.0	1.5
	Front	8.5	0.0
	Front	26.0	0.0
	Mean	16.3	0.6
	StDev.	9.4	0.6
	Median	16.0	0.5

Appendix A. (Continued).

Treatment	Control Location	Control Adjusted Survival(%)	Test Adjusted Survival(%)
		Yellowstone Lake Cutthroat Trout	
1	Front	98.5	88.5
	Front	99.0	92.0
	Rear	100.0	85.5
	Rear	98.5	93.5
	Rear	100.0	73.5
	Rear	99.5	90.5
	Front	100.0	82.0
	Front	100.0	92.0
	Mean	99.4	87.2
	StDev.	0.7	6.7
	Median	99.75	89.5
2	Front	93.5	34.5
	Front	81.0	28.0
	Rear	89.5	22.5
	Rear	88.0	21.0
	Front	83.5	13.5
	Front	87.0	14.5
	Rear	82.0	32.0
	Rear	90.5	25.0
	Mean	86.9	23.9
	StDev.	4.4	7.6
	Median	87.5	23.75
3	Rear	83.0	29.5
	Rear	85.0	20.0
	Front	92.0	13.5
	Front	92.0	37.5
	Rear	88.5	26.0
	Rear	88.0	11.0
	Front	84.0	19.5
	Front	93.5	29.0
	Mean	88.3	23.3
	StDev.	4.0	8.9
	Median	88.25	23.0

Appendix A. (Continued).

Treatment	Control Location	Control Adjusted Survival(%)	Test Adjusted Survival(%)
		Yellowstone Lake Cutthroat Trout	
4	Rear	70.0	42.0
	Rear	67.5	51.5
	Front	77.0	62.0
	Front	78.5	71.0
	Front	80.0	22.5
	Front	73.0	25.5
	Rear	85.5	72.5
	Rear	82.5	52.5
	Mean	76.8	49.9
	StDev.	6.2	19.0
	Median	77.75	52.0
5	Front	70.0	18.5
	Front	79.0	23.0
	Rear	79.0	5.0
	Rear	94.5	12.0
	Front	74.0	13.5
	Front	82.0	30.5
	Rear	66.5	34.5
	Rear	79.5	12.0
	Mean	78.1	18.6
	StDev.	8.5	10.1
	Median	79.0	16.0
6	Rear	87.5	11.0
	Rear	78.5	16.0
	Rear	55.5	18.0
	Rear	70.5	3.5
	Front	67.5	18.5
	Front	89.5	10.5
	Front	82.5	16.0
	Front	69.0	9.5
	Mean	75.1	12.9
	StDev.	11.5	5.2
	Median	74.5	13.5

APPENDIX B

MORTALITY DATA FROM CHAMBER COMPARISON TESTS

Appendix B. Percent mortality for Harrison Lake brown trout, McConaughy strain rainbow trout and Yellowstone Lake cutthroat trout embryos in the control egg baskets as well as those that were exposed to one wading event in the wide (1.0 m) and narrow (0.3 m) chambers at various stages of development.

Harrison Lake and Bighorn River Brown Trout*

Test	Daily Temp. Units		Percent Mortality		
			Control	1.0 Meter	0.3 Meter
1	7.5		5.0	3.5	4.5
			2.5	10.5	8.0
			---	4.5	4.0
			---	6.5	8.0
		Mean	3.8	6.3	6.1
		StDev.	1.7	3.1	2.2
2*	86.7		20.0	12.5	17.0
			4.5	22.5	12.0
			10.5	14.5	15.5
			8.0	9.0	10.5
		Mean	10.8	14.6	13.8
		StDev.	6.6	5.7	3.0
3	154.5		2.0	5.0	6.5
			6.0	3.5	7.0
			---	4.0	1.5
			---	6.0	3.0
		Mean	4.0	4.6	4.5
		StDev.	2.8	1.1	2.7
4	255.0		1.5	2.5	2.5
			1.0	1.5	3.0
			2.5	4.0	3.5
			0.5	5.0	2.0
		Mean	1.4	3.3	2.8
		StDev.	0.9	1.6	0.6
5	390.0		24.0	45.5	26.0
			22.0	37.0	33.5
			12.5	23.5	17.0
			14.5	43.5	23.0
		Mean	18.3	37.4	24.9
		StDev.	5.6	9.9	6.9
6	525.3		12.6	8.6	26.7
			8.2	21.5	23.6
			3.5	12.9	14.6
			10.1	10.8	12.6
		Mean	8.6	13.5	19.4
		StDev.	3.8	5.6	6.8

Appendix B. (Continued).

			McConaughy Strain Rainbow Trout		
Test	Daily Temp. Units		Control	Percent Mortality 1.0 Meter	0.3 Meter
1	3.5		9.0	13.5	10.0
			14.0	10.5	18.5
			14.5	12.5	10.0
			15.0	11.0	18.0
		Mean	13.1	11.9	14.1
		StDev.	2.7	1.4	4.8
2	94.1		16.0	19.0	26.5
			24.0	21.0	19.5
			17.0	27.5	26.5
			13.0	29.5	33.5
		Mean	17.5	24.3	26.5
		StDev.	4.7	5.0	5.7
3	247.6		3.0	5.5	9.0
			4.0	5.5	8.5
			3.0	11.5	5.5
			4.5	6.0	17.5
		Mean	3.6	7.1	10.1
		StDev.	0.8	2.9	5.2
4	303.6		10.5	54.0	55.5
			8.0	35.5	44.0
			8.0	58.5	56.5
			23.0	43.5	55.5
		Mean	12.4	47.9	52.9
		StDev.	7.2	10.4	5.9
5	396.8		28.8	39.0	32.2
			17.5	36.4	30.5
			24.1	31.7	34.2
			24.0	31.3	37.2
		Mean	23.6	34.6	33.5
		StDev.	4.6	3.7	2.9
6	501.4		6.4	22.4	22.6
			10.7	19.7	20.1
			10.8	26.2	30.2
			13.5	36.6	42.6
		Mean	10.4	26.2	28.9
		StDev.	2.9	7.4	10.1

Appendix B. (Continued).

Yellowstone Lake Cutthroat Trout

Test	Daily Temp. Units		Control	Percent Mortality 1.0 Meter	0.3 Meter
1	4.4		8.0	3.5	2.0
			4.0	3.0	4.0
			1.5	2.0	4.0
			5.0	8.0	7.0
		Mean	4.6	4.1	4.3
		StDev.	2.7	2.7	2.1
2	109.3		2.5	5.0	8.0
			4.5	8.0	5.0
			5.5	5.5	2.5
			3.0	8.0	2.5
		Mean	3.9	6.6	4.5
		StDev.	1.4	1.6	2.6
3	257.2		4.5	8.0	12.0
			3.5	9.5	5.0
			2.0	9.0	9.5
			2.0	10.5	9.5
		Mean	3.0	9.3	9.0
		StDev.	1.2	1.0	2.9
4	286.8		21.0	40.5	64.0
			10.0	30.5	60.5
			12.5	40.5	62.0
			6.5	37.0	57.5
		Mean	12.5	37.1	61.0
		StDev.	6.2	4.7	2.7
5	369.0		49.5	56.0	52.3
			49.0	84.3	50.5
			48.5	63.6	40.5
			38.1	46.0	58.5
		Mean	46.3	62.5	50.5
		StDev.	5.5	16.2	7.5
6	444.0		8.0	33.8	7.4
			12.6	19.1	16.0
			12.5	45.7	27.9
			8.0	46.0	21.4
		Mean	10.3	36.2	18.2
		StDev.	2.6	12.7	8.7