THESIS

SURVIVAL OF RAINBOW TROUT (*Oncorhynchus mykiss*) CAUGHT AND RELEASED ON SCENTED ARTIFICIAL BAITS

Submitted by

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George J. Schisler

Department of Fishery and Wildlife Biology

In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY GEORGE J. SCHISLER ENTITILED "SURVIVAL OF RAINBOW TROUT (*Oncorhynchus mykiss*) CAUGHT AND RELEASED ON SCENTED ARTIFICIAL BAITS" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work

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Advisor ______________________

Department Head ______________________

ABSTRACT OF THESIS

SURVIVAL OF RAINBOW TROUT (Oncorhynchus mykiss) CAUGHT AND RELEASED ON SCENTED ARTIFICIAL BAITS

The mortality of rainbow trout (Oncorhynchus mykiss) caught and released on scented artificial baits was compared with mortalities of trout caught and released on traditional artificial flies. A total of 457 fish were captured on flies, 505 on artificial baits fished actively (ABA), and 511 on artificial baits fished passively (ABP) in five replicate experiments. Water temperature, fish length, time played, time out of water, hook location, leader treatment, and bleeding intensity were all recorded for each fish captured. Mortalities were recorded daily over a three week holding period. Overall mortalities were 3.9% for fly-caught fish, 21.6% for fish caught on ABA, and 32.1% for fish caught on ABP. Differential mortality among gear types was largely due to differences in the number of fish critically hooked (gill arches or deep in the esophagus) in each group. Overall critical hookings were 3.9% for the fly-caught group, 45.7% for the ABA group, and 78.3% for the ABP group. Akaike Information Criterion (AIC), a model selection procedure, was used to develop a logistical regression model that best fit the mortality data. Parameters that reduced mortality probability include using flies rather than synthetic baits, hooking the fish in a non-critical location, and cutting the leader on critically hooked fish. In addition, as fish length increased, mortality probability decreased. Parameters that increased mortality probability were fishing with artificial baits (either actively or passively), critically hooking a fish, and failure to cut the leader on a critically hooked fish. Length of time played and length of time out of water contributed to mortality, and increasing water temperatures and bleeding intensity caused higher mortality probabilities as well.

The model developed was used along with creel survey data to estimate mortalities of released fish in Spinney Mountain Reservoir, a popular trout fishery. Estimated numbers of fish dying after being caught and released on flies and lures was 159 of 4948 (3.2%), while 220 of 887 (24.8%) died after being caught on scented artificial baits. Mortalities were from 5.8 to 12.9 times higher per angler-hour for scented artificial baits than for flies and lures.

George J. Schisler
Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins, Colorado 80523
Spring 1995

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CHAPTER 1

Rainbow Trout Catch and Release Survival in a Controlled Pond Experiment

INTRODUCTION

Special regulations such as catch and release and artificial fly and lure only regulations in trout waters are becoming more and more important as angling pressure increases, and the number of quality trout fishing waters decreases due to habitat loss (Behnke 1980). Many fish stocks can no longer support excessive fishing pressure because of the high demand for quality trout fishing. A high percentage of fish must be returned unharmed by anglers for future recapture to keep the size and numbers of fish sufficient in quality waters to maintain angler satisfaction. Special regulations are useful tools that can be implemented to provide for the increased demand on trout stocks. Colorado currently has special regulations such as catch and release on 6% of its fishable water (Powell 1994). Special regulations are only useful if they can be enforced in such a way that the original intent or purpose of the regulations are met. More specifically, special regulations on catch and release waters are used to ensure that a single fish can be caught by more than one angler. Fly and lure only fishing in certain waters was originally adopted to reduce mortality of released fish. This was based on the overwhelming evidence in studies of hooking mortality that salmonids caught on bait sustain a higher percentage (30-50%) of mortalities when released than those caught on flies and lures (5-10%) (Mongillo 1984).

Recently, artificial scented baits that fit the Colorado Division of Wildlife definition of "artificial fly or lure" have been developed that are made of a combination of cellulose ether, a polyalkylene glycol, plasticizers, and other chemicals, and are impregnated with amino acids that stimulate active feeding behavior. Fish attack these artificial scented baits ravenously because they are easily detected and are greatly preferred over other substances by the olfactory and gustatory systems of the fish (Jones 1991). Because of the strong attraction fish have to these artificial baits, they may be effectively fished passively, unlike traditional artificial flies and lures. As with natural baits fished in this manner, such as minnows, grubs, or salmon eggs, fish will actually swallow these artificial baits, exposing themselves to being critically hooked (hooked in the gill arches or deep in the esophagus). The relationship between deep-hooking and mortality in released fish is also well documented, in fact, it is the single most important factor in contributing to initial hooking mortality (Wydowski 1977). This information led us to believe that these artificial baits have the potential to cause mortalities similar to those observed for traditional bait fishing. As a result, a study was initiated to quantify mortalities of trout caught on artificial scented baits, and to isolate the exact cause of mortality of those fish. The specific objectives of this study were to determine if angling with artificial scented baits, either actively or passively, result in the same mortalities as observed for traditional artificial flies and lures. In addition, the study was designed to quantify how bleeding, fish length, time played, time out of water, water temperature, and cutting the leader influence survival of caught and released trout.

METHODS

A series of five replicate experiments were conducted to meet our objectives. The first two were preformed in the late summer and fall of 1993, and the remaining three in the spring and early summer of 1994. The study area chosen was Gates Pond, a 0.1 hectare stream-fed pond located in Rist Canyon near Fort Collins, Colorado. The site was chosen because of its limited access by the public, and suitable water temperatures and forage for rainbow trout.

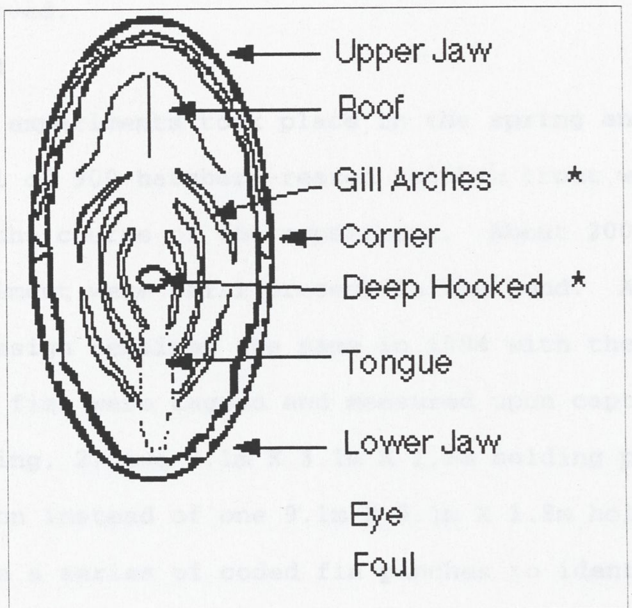
Gates Pond 1993

During the summer experiments of 1993, a total of 1200 hatchery-reared rainbow trout were stocked into Gates pond. These trout had been measured to the nearest millimeter and tagged with visible implant tags (in the adipose tissue posterior to the eye) prior to stocking. Fish were captured using flies, artificial baits fished passively (ABP), and artificial baits fished actively (ABA). The flies category consisted of traditional wet or dry flies fished with either a fly rod or a spinning rod and casting bubble. The artificial bait categories consisted of a slip-rig with a size ten hook and one or two artificial eggs attached. Fishing the artificial eggs passively is a common trout angling technique; the bait is cast out, the fishing rod is set down, and the fishermen simply wait for the fish to take the bait. Fishing the artificial eggs actively involved keeping the bait in constant motion, never setting the rod down, and setting the hook as soon as a strike was felt. The two different methods of fishing with the artificial eggs were used to test the hypothesis that active fishing would reduce mortalities to a level similar to that of traditional flies and lures, which are usually fished actively.

Fish were captured by anglers with a wide range of experience who were required to record the gear type and fishing method, tag number, time played, time out of water, hook location, and bleeding intensity for each fish. Time played was recorded to the nearest second by timing the angler with a stopwatch from the instant the hook was set until the fish was removed from the water. Time out of water was recorded similarly from the moment the fish was removed from the water until it was returned to the water. Surface water temperatures were recorded in each replicate experiment as well.

Hook location was recorded as one of the following: upper jaw, lower jaw, corner of mouth, roof of mouth, tongue, gill arches, eye, deep hooked, or foul hooked (Fig. 1.1).

Figure 1.1.--Recorded hook locations. Locations with astricks are considered critical hookings. Adapted from Mongillo 1984.



Fish were considered critically hooked if the fish was hooked in the gill arches, or the fish was deeply hooked. Fishermen were asked to alternate between cutting the leader and removing the hook from fish that were critically hooked to get a relatively equal number of both treatments. This procedure was used to test the hypothesis that cutting the leader on critically hooked fish improved their chances of survival. Bleeding intensity was described as either none, light, medium, or heavy.

Anglers were asked to switch fishing method frequently to reduce bias caused by differential handling. If the fish had lost its tag, the tag was replaced and the fish was remeasured. After each fish was captured and the data recorded, they were temporarily placed into 1.2m X 1.2m livecages, and then moved to a large 9.1m X 9.1m X 1.8m holding pen for the duration of the experiment. The fish were fed once daily with pelleted fish food, and pens were checked every 24 hours for mortalities. Date of death and tag number was recorded for each mortality observed.

Gates Pond 1994

The 1994 experiments took place in the spring and early summer of 1994. A total of 900 hatchery-reared rainbow trout were stocked into the pond over the course of the experiment. About 200 fish stocked for the 1993 experiment were still present in the pond. All aspects of the experimental design remained the same in 1994 with the following exceptions; 1) fish were tagged and measured upon capture instead of prior to stocking, 2) two 3.1m X 3.1m X 1.8m holding pens were used for each replication instead of one 9.1m X 9.1m X 1.8m holding pen, and 3) fish were given a series of coded fin punches to identify method of capture and treatment of fish in case the tag was lost.

Analysis

Mortality rates and proportions of critically-hooked fish were calculated for each gear type as follows:

$$\hat{p} = \frac{y}{n}, \tag{1}$$

$\hat{p}$ = proportion dead or proportion critically hooked,

y= number of fish dead at the end of the holding period or number of fish critically hooked,

n= total number of fish caught in a particular category.

The standard error of this binomial parameter was calculated by (Ott 1993):

$$\hat{\sigma}_{\hat{p}} = \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \tag{2}$$

Binomial confidence limits were calculated using SAS system software. An alpha level of .10 was chosen to reveal 90% confidence intervals.

Logistic Regression Analysis

Logistic regression analysis was used to identify a model that would best describe the relationship between the variables recorded and mortality observed in this experiment. To avoid problems associated with model selection in multiple regression analysis caused by traditional goodness-of-fit tests and likelihood ratio tests, Akaike Information Criterion (AIC) was used for model selection (Lebreton et al. 1992). AIC is a method that selects a model that most closely fits the theoretical distribution of the data without over-parametrization. This model selection procedure can also choose from many different alternate models at once. AIC values were calculated as follows:

$$\text{AIC} = -2 \ln L + (2\ k), \tag{3}$$

where:

L=likelihood value calculated for the model, and

k=number of parameters used in the model

An AIC value was calculated for each candidate model. Models with AIC values within one or two of the minimum AIC value were considered to be valid candidate models. In this analysis, the GENMOD procedure in SAS system software was used to obtain log-likelihoods for the AIC formula. All data were truncated at 2 weeks, and incomplete records were eliminated from the data set to maintain homogeneity of the data set and arrive at comparable AIC values.

RESULTS

Hook Location and Mortality

Mortality rates and 90% confidence intervals were calculated for all five experiments (Figure 1.2). Mortality rates for fish caught with artificial baits fished passively ranged from 19 to 45% with an average of 32.1% (n=511). Mortalities for artificial baits fished actively ranged from 9 to 29% with an average of 21.6% (n=505). Mortalities for fly caught fish ranged from 1 to 14% with an average of 3.9% (n=457) The average values reflect overall results of the study. There were differences in mortality in each of the five replicate experiments, so the averages reported reflect the wide variety of environmental and handling conditions throughout the entire study.

Figure 1.2.--Mortalities and 90% confidence intervals for each of the five replicate experiments at Gates Pond. FLIES represents fly caught fish, ABA represents fish caught on artificial baits fished actively, and ABP represents fish caught on artificial baits fished passively.

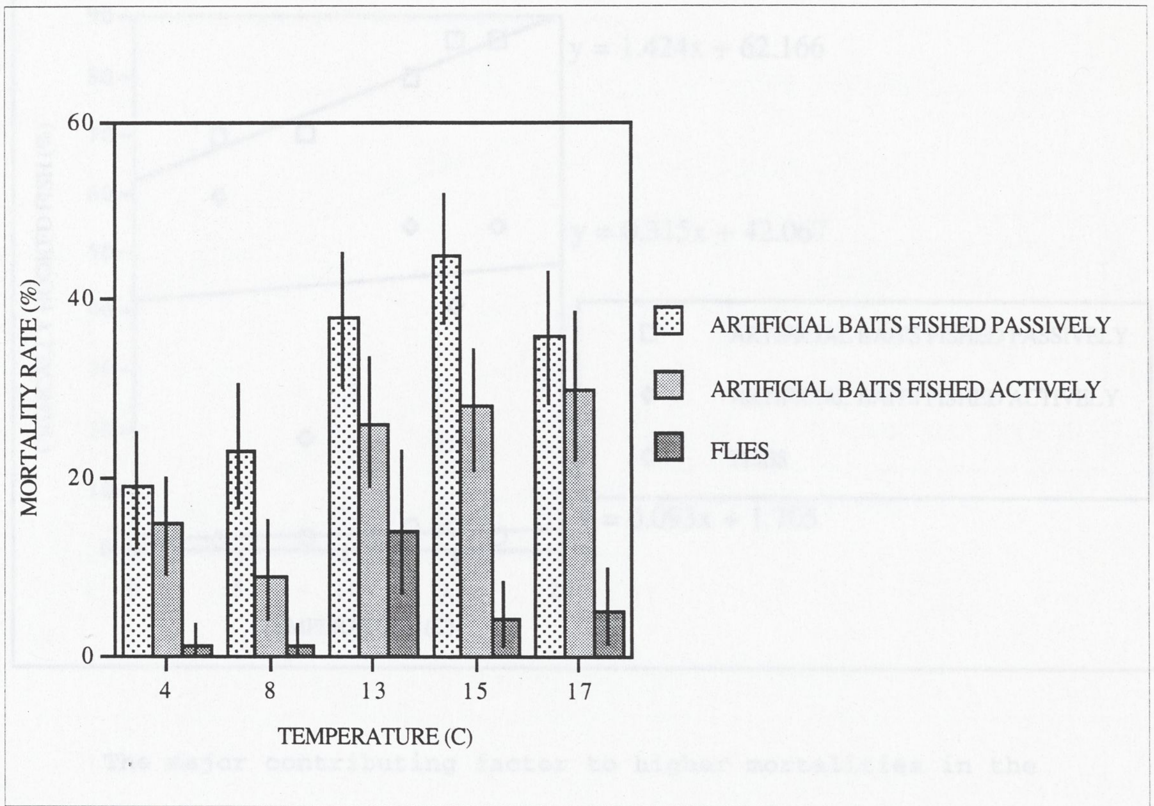
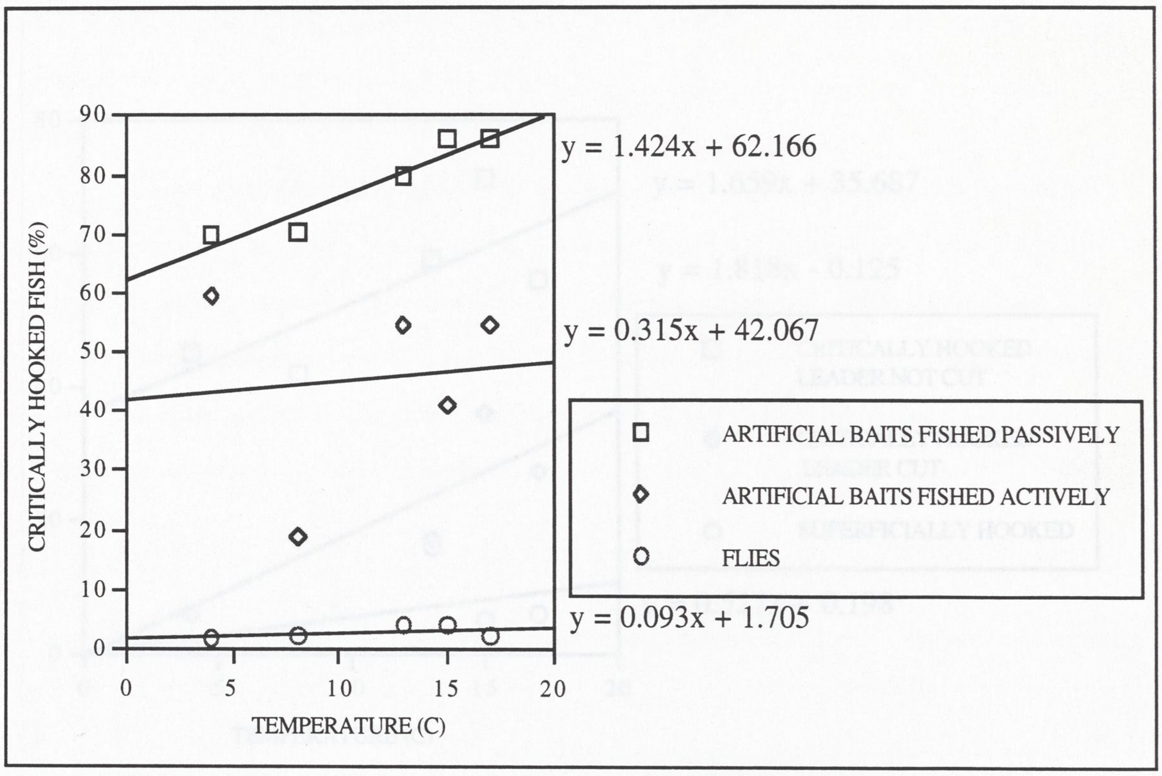
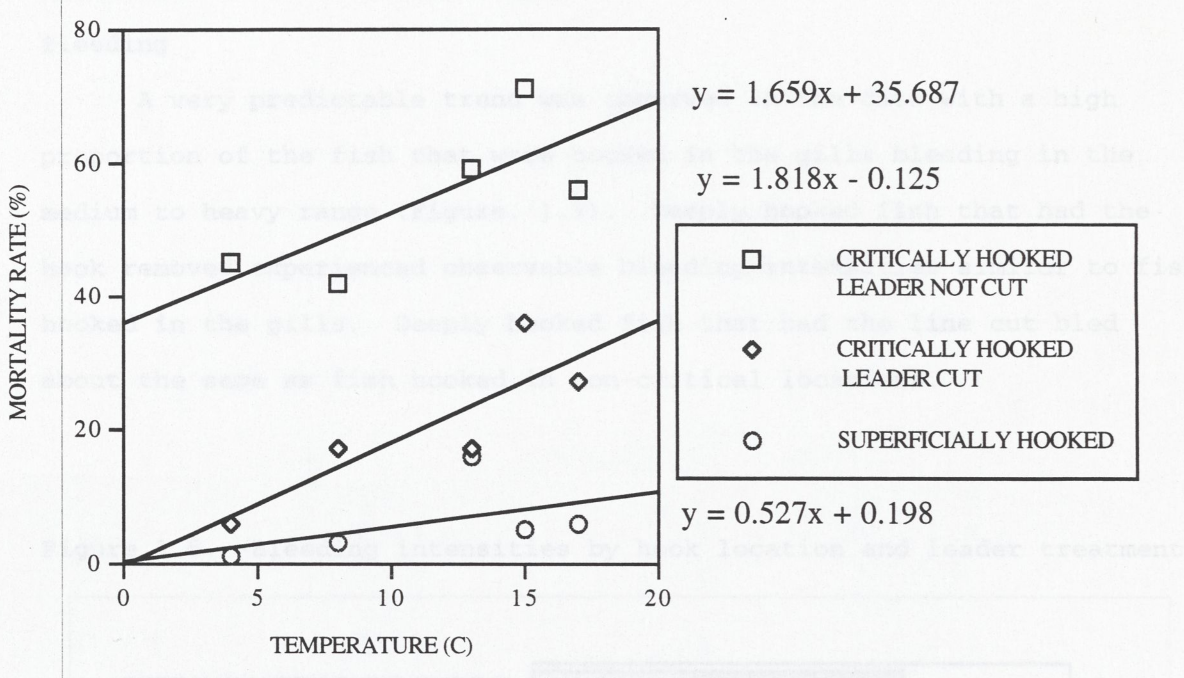


Figure 1.3. Percentages of critically hooked fish by gear type for each replicate experiment. Simple linear regression lines are drawn through the data points to emphasize trends.



The major contributing factor to higher mortalities in the artificial bait categories was the high proportion of fish that were critically hooked (Figure 1.3). Less than 5% of the fly caught fish were critically hooked in every replicate experiment (average of 2.6%), while from 19 to 59% (average of 45.7%) of the fish caught on artificial bait fished actively were critically hooked, and from 70 to 86% (average of 78.3%) of the fish caught on artificial bait fished passively were critically hooked.

Figure 1.4.--Percent mortalities by hook location and leader treatment for each replicate experiment. Simple linear regression lines are drawn through the data points to emphasize trends.



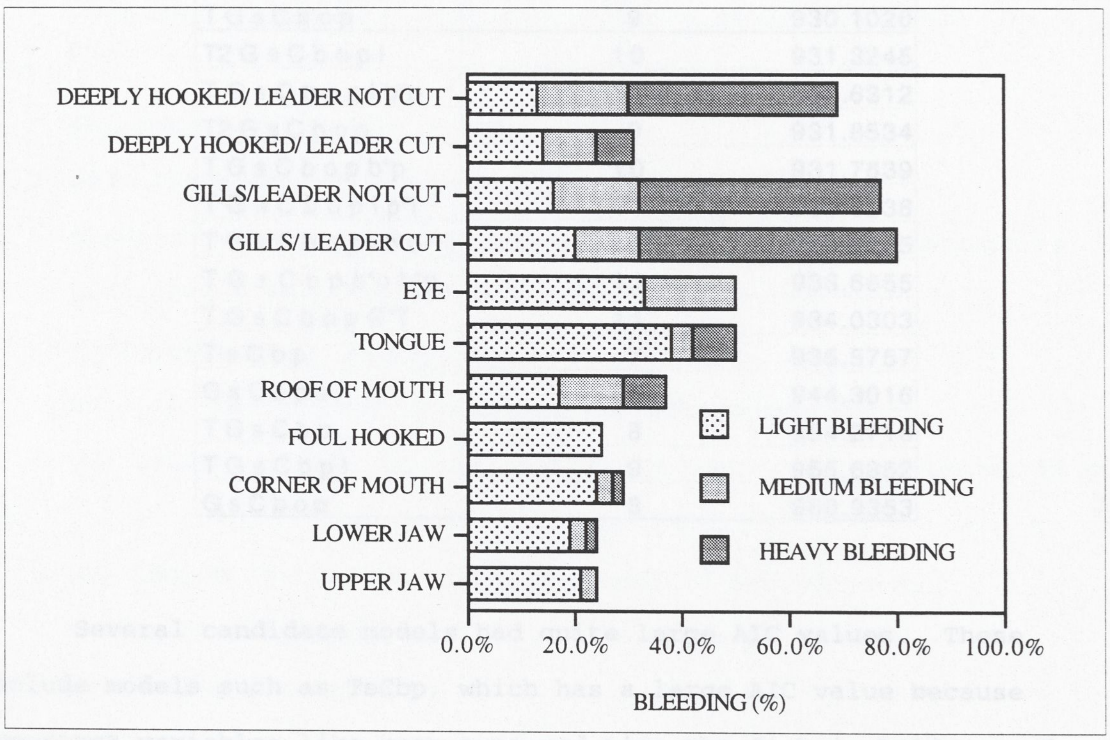
Mortalities of fish superficially hooked are much lower than those of fish critically hooked, and critically hooked fish that had the leader cut had lower mortalities than those without the leader cut (Figure 1.4). Critically hooked fish experienced mortalities of 44.9 to 70.9% (average of 55.3%) when the hook was removed (n=333), and from 5.7 to 36.2% (average of 20.6%) when the leader was cut (n=310). Superficially hooked fish (n=829) experienced mortalities of 1.1 to 15.5% (average of 5.2%).

About one-half of the critically hooked fish in each replicate experiment had the leader cut, while the hook was removed from the other half. In typical fishing situations, fishermen rarely cut the leader when a sublegal fish is captured, so overall mortalities in these experiments for both active and passive fishing with scented premolded artificial baits are probably lower than would be expected under field conditions with the average angler.

Bleeding

A very predictable trend was observed in the data with a high proportion of the fish that were hooked in the gills bleeding in the medium to heavy range (Figure. 1.5). Deeply hooked fish that had the hook removed experienced observable bleeding intensities similar to fish hooked in the gills. Deeply hooked fish that had the line cut bled about the same as fish hooked in non-critical locations.

Figure 1.5.--Bleeding intensities by hook location and leader treatment.



Model Selection

The AIC values were calculated using potential interactions between variables and different combinations of potentially important parameters (Table 1.1).

Table 1.1.--Examples of potential models, their parameters, and AIC values. T represents temperature, T2 temperature squared, G gear types, s superficial versus critical hooking, C cutting or not cutting the leader on a critically hooked fish, b bleeding intensity, o time out of water, p time played, l length of the fish, and * represents any interactions between variables.

MODEL	PARAMETERS	AIC VALUES
T G s C b o	8	928.9036
T G s C b o p l	**1 0**	**929.9429**
T2 G s C b o	8	930.6386
T G s C b o p	9	930.1020
T2 G s C b o p l	10	931.3245
T G s C b o p l b*p	11	931.6312
T2 G s C b o p	9	931.8534
T G s C b o p b*p	10	931.7639
T G s C b o p l p*l	11	931.8238
T G s C b o p l b*o	11	931.8385
T G s C b p b*o b*p	11	933.6655
T G s C b o p G*T	11	934.0303
T s C b p	7	935.5757
G s C b p o	8	944.3016
T G s C b p	8	954.2716
T G s C b p l	9	955.6352
G s C b o p	8	960.9353

Several candidate models had quite large AIC values. These include models such as TsCbp, which has a large AIC value because important variables like gear type and time the fish is held out of water are not included in the model. This results in underfitting the model, which produces a disproportionally large negative log-likelihood value, and a large AIC value. The other extreme is overfitting the model, which results in a large AIC value because an excessive number of parameters are used. An example of overfitting is model TGsCbopG*T, which attempts to use an interaction term between gear type and temperature. The highlighted model in the table (TGsCbopl) was the model chosen for the mortality data set. It was within one or two points of the minimum AIC, and includes all parameters deemed important to mortality. The selected logistical regression model (equation 4) included gear type, fishing method (active or passive), critical hooking, cutting or not cutting the leader, bleeding intensity, time the fish is played, time the fish is out of water, and fish length.

$$LOG(M/1-M)=-3.1459-.9141(G1)+.0960(G2)+.1057(T)$$
$$-.9418(S)+.9834(NC)+.0053(PL)+.0092(O)+.4262(B)-.0031(L)\ , \qquad (4)$$

where:

M=probability of fish dying,

G1=value used if fish are caught on flies,

G2=value used if fish are caught on ABA (only the intercept is used if the fish are caught on ABP),

T=temperature in degrees C,

S=value used if fish are hooked superficially,

NC= value used if fish are critically hooked and the leader is not cut,

PL= length of time the fish is played in seconds,

O=length of time the fish is out of water in seconds,

B=bleeding intensity,

L=length of fish in millimeters.

The model not only quantifies how important each parameter is to mortality, but allows the prediction of mortality probability of a fish in a given scenario. Parameters that reduced mortality probability included using flies rather than synthetic baits, hooking the fish in a non-critical location, and cutting the leader on critically hooked fish. As fish length increased, mortality probability decreased. Mortality probability increased with the use of artificial baits (fished either actively or passively), critically hooking a fish, and failing to cut the leader on a critically hooked fish. Length of time played and length of time out of water also increased mortality, with length of time out of water increasing mortality probability at about twice the rate as length of time played. Increasing water temperatures and bleeding intensity contributed to higher mortality probabilities as well.

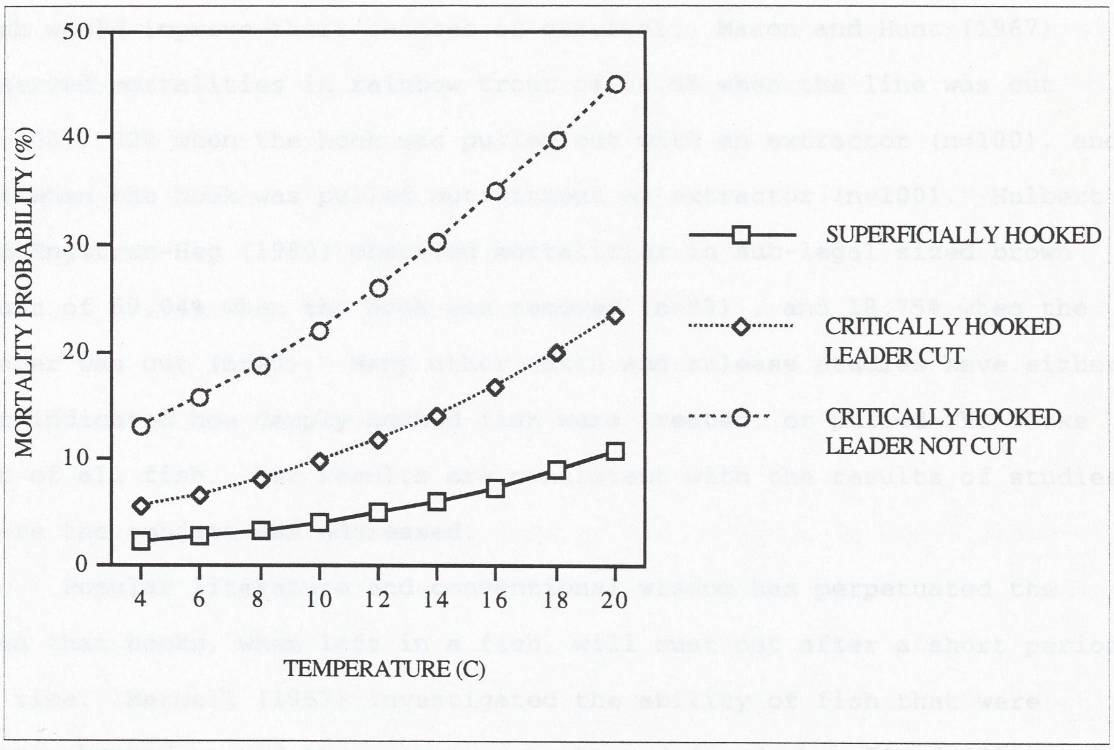
DISCUSSION

The raw results of the experiments in this study give us a good general overview of the effects of using synthetic baits versus traditional artificial flies (Figure 1.2). We observed much higher mortalities when fish were caught on synthetic baits, especially when fished passively, than for fish caught on flies. Fishing actively reduced mortalities of fish caught on synthetic baits, but not to the level observed with flies. Numbers of critically hooked fish varied widely, especially in the ABA group. This variation could be due to a number of factors, including individual angler experience and attentiveness, or fish behavior. Variation in mortality for each replicate experiment was a result of many factors contributing to mortality. For example, mortalities for fly caught fish were unusually high at 13 °C. High mortalities in this case were not necessarily a function of temperature, but could be contributed to long playing times, holding the fish out of water for long periods of time, or simply poor handling of the fish by a few individual anglers. To isolate the effects of handling and environmental conditions, a logistical regression model was chosen to describe the data.

The model chosen identified variables such as gear type, fishing method, water temperature, bleeding intensity, hook location, leader treatment, and length of time out of water as major contributors to hooking mortality probability. Fish size and length of time the fish was played were minor contributors, and would have been eliminated from the model with traditional goodness of fit or likelihood ratio tests of significance.

Critical hooking is the single most important factor in catch and release morality because of the potential for serious tissue and organ damage (Wydowski 1977). The proportion of fish that are critically hooked when organic baits are used is roughly 50%, while critical hooking with traditional artificials is typically less than 10% (Mongillo 1984). Our results show much higher incidence of critical hookings on the artificial baits when passively fished. This could be because of the highly effective scents used in the baits. The trout swallowed the baits at much higher rates than they swallowed traditional flies. Fishing the baits actively reduced critical hookings, but not to a level observed with traditional flies and lures. The serious effect of critical hooking, especially when the leader is not cut, can be illustrated by the logistical regression model (Figure 1.6).

Figure 1.6.--Effect of temperature, critical hooking and leader treatment on mortality probability.



In this example mortality is shown for a 380 mm trout caught on synthetic baits fished passively, played for sixty seconds, held out of water for thirty seconds, and with light bleeding. If the fish was superficially hooked, mortalities would remain below 11%, while a critically hooked fish with the leader not cut could have a mortality probability nearing 45% at 20°C. Cutting the leader on a critically hooked fish in this case would reduce mortality probability by 5.3% at 4°C to 21.6% at 20°C. It should be noted that this difference reflects <u>only</u> the effect of hook location and leader treatment. Bleeding intensity increases when a fish is critically hooked, especially if the leader is not cut, and contributes to mortality above and beyond the effect seen here. Relative differences in mortality by hook location and leader treatment are much larger when individual parameter effects are not isolated (Figure 1.4).

It has long been suspected that cutting the line on deeply hooked fish would improve their chances of survival. Mason and Hunt (1967) observed mortalities in rainbow trout of 34.5% when the line was cut (n=200), 82% when the hook was pulled out with an extractor (n=100), and 95% when the hook was pulled out without an extractor (n=100). Hulbert and Engstron-Heg (1980) observed mortalities in sub-legal sized brown trout of 59.04% when the hook was removed (n=83) , and 18.75% when the leader was cut (n=80). Many other catch and release studies have either not indicated how deeply hooked fish were treated, or pulled the hooks out of all fish. Our results are consistent with the results of studies where the subject was addressed.

Popular literature and conventional wisdom has perpetuated the idea that hooks, when left in a fish, will rust out after a short period of time. Marnell (1967) investigated the ability of fish that were deeply hooked to rid themselves of hooks and found that 76 of 131 (58.1%) fish had eliminated their hooks after four weeks. Marnell (1969) also found that hook corrosion rates in the esophagus were only .14 mg/day (n=129). He found higher corrosion rates for hooks in the stomach (n=20), but concluded that they were too variable to be meaningful. After 90 days, mean weight loss of hooks in the esophagus was 5.65% of their original mean weight. Obviously the notion that the hooks rust out is dispelled by these data. A sample of deeply hooked fish that had the hook left in and died during our experiment were x-rayed and autopsied. This was done to identify where the hook had penetrated and find out if the fish had shed the hook before death. Of the 22 fish sampled that were deeply hooked and had the line cut, 4

(18.1%) had shed the hook, 14 had the hook embedded in the esophagus, 3 had the hook lodged in the gill arches, and 1 had the hook in the stomach. A sample of 79 deeply hooked fish that had the hook left in and lived to the end of the three week holding period were also x-rayed and autopsied. Of these fish, 20 had shed the hook (25.3%), 45 had the hook embedded in the esophagus, 2 had the hook lodged in the gill arches, and 12 had the hook all the way down in the stomach. These data suggest that when a fish is critically hooked and the hook is left in, it has a good chance of shedding the hook on its own. Even if the hook is not shed, fish surviving three weeks appear to be able to move the hook farther down the digestive tract, away from vital organs such as the heart and liver.

Temperature has been identified as a key factor in mortalities of trout in many previous studies (Klein 1965, Hunsaker et al. 1970, Dotson 1982, Titus and Vanicek 1988, Nuhfer and Alexander 1989). Taylor and White (1992) in a meta-analysis of trout mortality found no relationship between temperature and mortality. However, they were limited to five studies that used temperature as a variable, three of which did produce correlations between mortality and water temperature. Our results clearly indicate a positive correlation between water temperature and mortality (Figures 1.6 and 1.8). This is especially true among fish that had been critically hooked. Fish captured passively have extremely high mortalities because at the high water temperatures they tended to be critically hooked more often. At colder water temperatures the fish may feed less voraciously, which would explain fewer critical hookings.

Other factors contribute to higher mortalities at warmer water temperatures besides increasing numbers of critically hooked fish. Cardiac output increases linearly with water temperature in rainbow trout (Barron et al. 1986), which could potentially cause more blood loss at higher temperatures. Blood chemistry disturbances such as hyperglycemia and hyperchloremia are also more severe at higher water temperatures (Wydowski et al. 1976). Fungal infections caused by handling in our experiment were more evident at higher water temperatures. At colder water temperature, an abrupt dieoff of injured fish was observed, while at warmer temperatures, mortalities continued until later in the holding period as fish eventually succumbed to the secondary infections (fungal and bacterial infections) caused by their initial injuries. When fungal lesions appeared on the fish, they were often located exactly where the fish had been held. Fungal infection after stress and handling is a common occurrence with salmonid fishes. Pickering and Pottinger (1985) found that cortisol (which is released after exhaustive exercise or as a response to stress) can increase susceptibility of brown trout to diseases such as furunculosis, Saprolegnia infection, and bacterial fin rot.

Fish are exposed to fungal spores at all times in their natural environment. There are three components of defense against fungal infections in fish. The first is physical removal of the spores by sloughing off of mucus. The second is a morphogen, present in the external mucus, that inhibits fungal growth. The third is a cellular response of lymphocytes or neurophils that become attached to the mycelium and lyse it internally (Willoughby 1989). All three of these defenses are negated if the outer layer of mucus is removed from the fish, as is often the case when fish are captured and released. Excessive stress also results in lower lysosyme activity (Mock and Peters 1990). This would obviously result in the fish becoming more susceptible to secondary infections after the fungus has been established.

Previous hooking mortality studies have come to different conclusions about the role of fish size as a contributor to mortality. Nuhfer and Alexander (1992) found that large brook trout tended to swallow artificial lures more often than smaller fish, leading to higher mortalities for larger fish. Smaller fish in the study cited were unable to engulf the lures because of the relatively small size of their mouths. Dotson (1982) found no significant correlation between length and mortality in rainbow and cutthroat trout, although fish sizes only ranged from about 170 to 250 mm, which could explain the lack of size related differences. Loftus et al. (1988) found that smaller lake trout caught on lures had higher mortalities than larger fish. A decrease in mortality was also observed in our study with increasing length of fish caught when other variables such as hook location were held constant (Figure 1.7). Figure 1.7 depicts mortality of a trout caught on flies in 10°C water, superficially hooked, bleeding lightly, and held out of water for thirty seconds. A 450 mm fish played for 1 minute would have a 1.3% mortality probability, while a 200 mm fish played for the same length of time would have a 2.8% mortality probability, a difference of only 1.5%. However, when playing time is increased to 5 minutes, the 200 mm fish would have a 9.3% mortality probability, and the 450 mm fish would have a 4.5% mortality probability, a difference of 4.8%. We suspect a higher incidence of severe tissue damage may occur to small fish when the hook is removed. A smaller fish may also be subjected to more internal organ damage if the fisherman squeezes the fish while trying to remove the hook.

Several previous studies have linked bleeding intensity with mortality (Clark 1991; Nuhfer and Alexander 1992; Pauley and Thomas 1993). In our experiments, increasing bleeding intensity contributed substantially to mortality (Figure 1.8).

Figure 1.7.--Mortality probability as a function of fish length and time played.

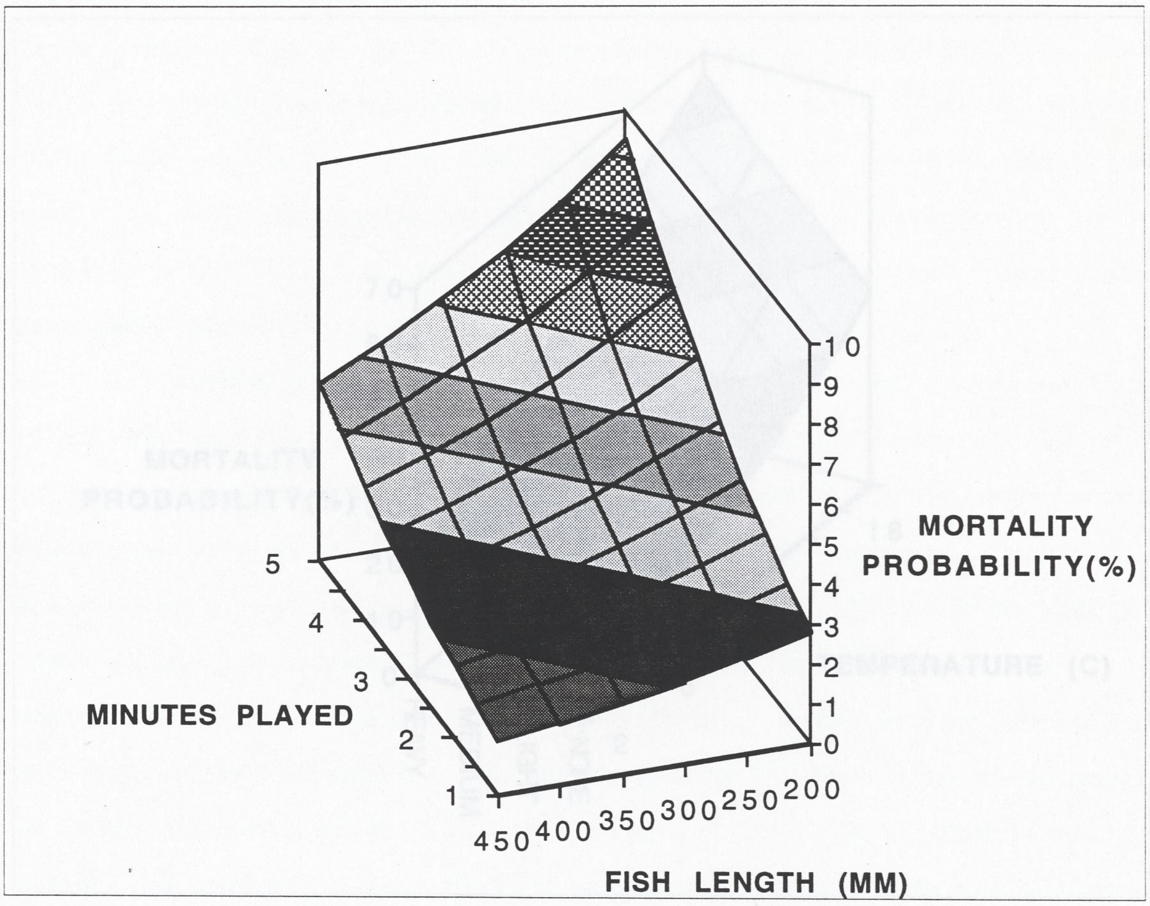
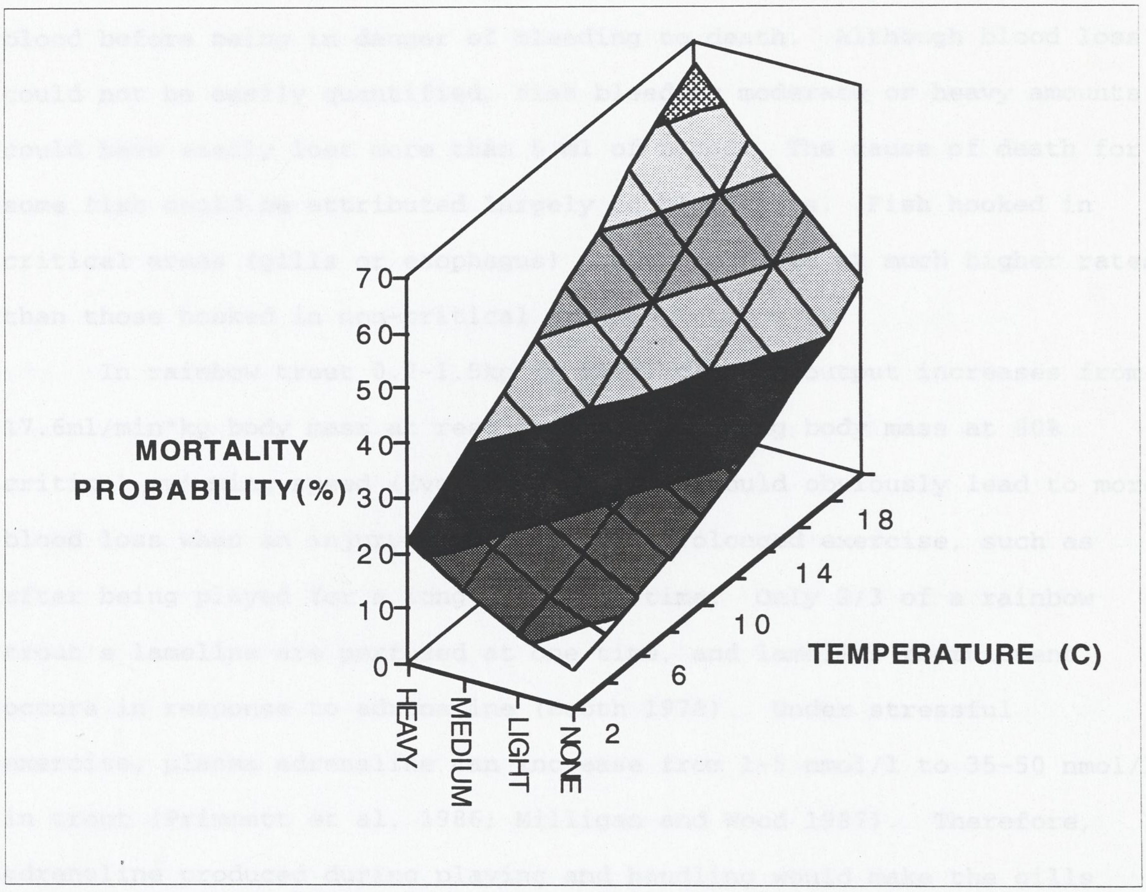


Figure 1.8.-- Effect of increasing water temperature and bleeding intensity on mortality probability.



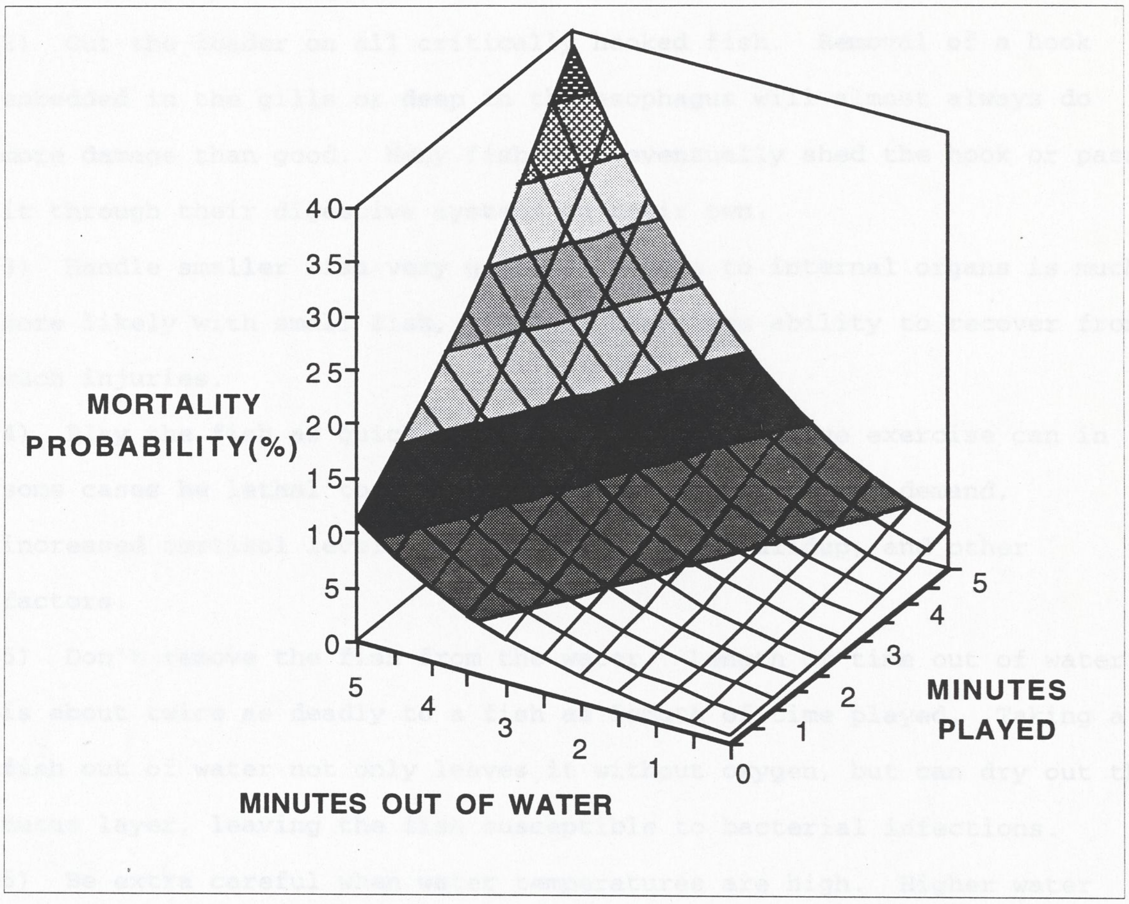
The example shown in Figure 1.8 depicts a 380 mm trout, caught on synthetic baits fished passively, played for 60 seconds, held out of water for 30 seconds, and critically hooked with the leader not cut. As in Figure 1.6, mortality probability increases with temperature, but even more dramatically with increasing bleeding intensity. In this case, a fish caught in 10 degree C water would have mortality probability increasing from 16% with no bleeding to 40% with heavy bleeding. Combined volume of blood, plasma, and erythrocytes in a fish is generally only 5.5-12.5% of total body volume (Stoskopf 1993). The fish used in our study had total body volumes of 150ml to 600 ml. Vertebrates can typically tolerate up to a 10% blood loss, therefore, a trout with a body volume of 400ml could lose between 2.2 and 5 ml of blood before being in danger of bleeding to death. Although blood loss could not be easily quantified, fish bleeding moderate or heavy amounts could have easily lost more than 5 ml of blood. The cause of death for some fish could be attributed largely to blood loss. Fish hooked in critical areas (gills or esophagus) tended to bleed at much higher rates than those hooked in non-critical areas.

In rainbow trout 0.7-1.5kg in size, cardiac output increases from 17.6ml/min*kg body mass at rest to 42.9 ml/min*kg body mass at 80% critical swimming speed (Evans 1993). This would obviously lead to more blood loss when an injury occurred after prolonged exercise, such as after being played for a long period of time. Only 2/3 of a rainbow trout's lamellae are perfused at one time, and lamellar recruitment occurs in response to adrenaline (Booth 1978). Under stressful exercise, plasma adrenaline can increase from 1-5 nmol/l to 35-50 nmol/l in trout (Primmett et al. 1986; Milligan and Wood 1987). Therefore, adrenaline produced during playing and handling would make the gills even more susceptible to damage and blood loss.

Blood chemistry disturbances caused by prolonged exercise are well documented. These include elevated plasma cortisol and plasma glucose, hypochloremia, a depletion of glycogen reserves, increased haematocrit, haemoglobin, plasma protein, and a buildup of blood lactate. Excessive lactic acid buildup in the blood has often been implicated as a possible cause of mortality in intensely exercised fish (Black 1958, Bennett 1978). Wood et al. (1983) concluded that this is not the case, and suggested that intracellular acidosis may be the actual cause of death. They also suggested that a keto acid produced from excessive fat metabolism, or a product of anaerobic metabolism such as succinate may be the cause of the acidosis. Marnell and Hunsaker (1970) found no significant difference in mortality of lure-caught cutthroat trout played 0, 5, and 10 minutes. Reported mortalities were 4% (n=100), 6% (n=100), and 5% (n=100). Our modeling results indicate that length of time played does indeed contribute to mortality, although it is only about half as important as how long the fish is held out of water.

A recent study (Ferguson and Tufts 1992) demonstrated that very high mortalities (up to 80%) can occur when trout are played to exhaustion and held out of water. The fish used in the experiment were exhaustively exercised for 10 minutes before being held out of water, and subjected to blood drawing for blood chemistry analysis. The combined effects of exercise, blood drawing, and being held out of water all contributed to the high mortalities observed in their study. The modeling procedure we used to analyze the data from the Gates Pond experiments allowed us to isolate the effect of holding a fish out of water. We did find that holding the fish out of water increased mortalities, but only caused very high mortalities when other factors such as long playing times or other factors contributed as well. Figure 1.9 depicts a 380 mm trout caught on a fly, in 10 degree C water, superficially hooked and not bleeding. The effect of time out of water alone can be observed by following the increasing mortality function where time played is equal to 0 minutes. In this situation, you would see mortality rising to 11.5% after 5 minutes out of water if no bleeding occurred and the fish was not exercised at all. If playing time is increased from 0 to 5 minutes, mortalities rise to 38.8%. Increasing bleeding intensity or water temperature would similarly raise the mortality probability.

Figure 1.9.--Effect of time played and time out of water on mortality probability.



Hooking mortality is caused by a variety of factors, which when acting alone may not seriously affect the probability of mortality for a fish that is released. High mortalities in caught and released fish are caused by a combination of many factors rather than single parameters acting alone. When faced with the challenge of recycling as many fish as possible in special regulation waters, every effort should be taken to inform and educate anglers on how to reduce mortalities of released fish. Our research has led us to several suggestions fishery managers may make to anglers to reduce mortalities in released fish:

1) If you intend to release fish and you are fishing with any type of bait, fish actively and set the hook immediately when a fish strikes the bait. This will reduce the numbers of critically hooked fish.

2) Cut the leader on all critically hooked fish. Removal of a hook embedded in the gills or deep in the esophagus will almost always do more damage than good. Many fish will eventually shed the hook or pass it through their digestive systems on their own.

3) Handle smaller fish very gently. Damage to internal organs is much more likely with small fish, and they have less ability to recover from such injuries.

4) Play the fish as quickly as possible. Exhaustive exercise can in some cases be lethal to a fish because of higher oxygen demand, increased cortisol levels, intracellular acid buildup, and other factors.

5) Don't remove the fish from the water. Length of time out of water is about twice as deadly to a fish as length of time played. Taking a fish out of water not only leaves it without oxygen, but can dry out the mucus layer, leaving the fish susceptible to bacterial infections.

6) Be extra careful when water temperatures are high. Higher water temperatures increase mortality. Warmer water increases the metabolism of trout making them more likely to swallow a bait, more likely to experience muscle fatigue, and more likely to become stressed.

7) Try to avoid touching the gill arches, and avoid tissue damage when removing a hook, even if the fish is only hooked in the lip or jaw. Bleeding intensity increases mortality. Fish have a relatively low blood capacity, and a seemingly small amount of blood loss can be lethal to a fish.

CHAPTER 2

Estimating Annual Catch and Release Mortality of Rainbow Trout in Spinney Mountain Reservoir, Colorado

INTRODUCTION

Size and slot limits are important tools used by fisheries managers to maximize recreational potential for certain bodies of water, especially where heavy angling pressure would otherwise result in over-exploitation of the fishery. Slot and size limits are often accompanied by an artificial fly and lure only regulation to reduce mortalities of released fish. Special regulations that require catch and release have proven to be very effective in producing high catch rates and large fish (Bjornn et al. 1977; Hunt 1981; Anderson and Nehring 1984). Artificial baits that currently fit the Colorado definition of "artificial fly or lure" have become increasingly popular in Colorado's special regulation waters. Artificial baits cause much higher mortalities than traditional artificial flies and lures, especially when fished passively (Schisler 1995). Concern over use of these artificial baits in special regulation waters has increased in recent years because of the potential effects of these baits on trout fisheries with catch and release regulations. Effects of catch and release mortalities on fish populations have been investigated by several authors (Waters and Huntsman 1986; Clark et al. 1980). Former investigations involving catch and release mortalities have not taken into account variables attributable to angler behavior or environmental conditions. Recent studies of hooking mortality have indicated that many factors contribute to mortality of released fish. Specific parameters that affect mortality such as water temperature, fish size, and treatment of released fish may be specific to individual bodies of water. The objective of this study was to quantify annual fishing mortality rates at a popular special regulation water given different levels of artificial bait use, taking into account angler behavior and environmental factors that may contribute to mortality.

STUDY SITE

Spinney Mountain Reservoir is a popular special regulation trout fishery in Colorado. This highly productive reservoir has 1020 surface hectares and a maximum depth of 17 meters, although the majority of the lake is less than 6 meters deep. Regulations include artificial flies and lures only, a 50.8 cm minimum size limit, and a one fish daily bag limit. The reservoir is closed to fishing when ice cover is present (early November through late April). The reservoir is stocked annually with rainbow (Oncorhynchus mykiss) and cutthroat trout (Oncorhynchus clarki). Northern pike (Esox lucius), white suckers (Catostomus commersoni), and brown trout (Salmo trutta) also inhabit the reservoir. The reservoir has been regarded as one of the best trophy trout fisheries in Colorado since its opening in 1984.

METHODS

Hooking mortality of rainbow trout at Spinney Mountain Reservoir was estimated for traditional artificial flies and lures, and artificial bait using a model for rainbow trout hooking mortality (Schisler 1995) that incorporates the effects of gear type, water temperature, fish length, hook location, leader treatment, bleeding intensity, time played, and time held out of water.

Proportions of critically hooked fish caught on each gear type were estimated by averaging proportions of critically hooked fish from three sampling events at Spinney Mountain Reservoir in May, June, and November of 1993. A total of 192 fish were caught by anglers of diverse ages and skill levels during these sampling events, so critical hookings observed during the sampling should be representative of typical angling activity.

Bleeding intensity depends largely upon hook location, so critically hooked fish and superficially hooked fish were assigned separate bleeding intensities. Bleeding intensities for the two groups were obtained by calculating an average bleeding intensity (on a scale of 0 to 3) for superficially hooked and critically hooked fish from previously conducted pond experiments (Schisler 1995).

Observations during the 1993 fishing season revealed that very few, if any fishermen cut the leader on critically hooked fish. As a result, mortalities for critically hooked fish were calculated assuming that the leader was not cut.

Values used in the mortality model for length of time fish were played and held out of water were obtained by calculating an average of angler observations at Spinney Mountain Reservoir. Forty-six out-of-water times and thirty-four playing times were recorded from anglers in the spring of 1993. The anglers did not know they were being observed, so times are probably representative of typical fishing situations.

Fish length at age was determined from scales of twenty-five large (23 over 400 mm) rainbow trout caught in trap nets at Spinney Mountain Reservoir. Back-calculation of length at age was conducted by using a modification of the Fraser-Lee equation (Table 2.1):

$$L_i = a+(L_c-a)(S_i/S_c);$$

where;

L_c =length of fish at capture,

L_i =calculated length at age i,

S_c=distance from focus to edge of scale,

S_i=distance from focus to annulus, and

a=intercept of the body-scale regression.

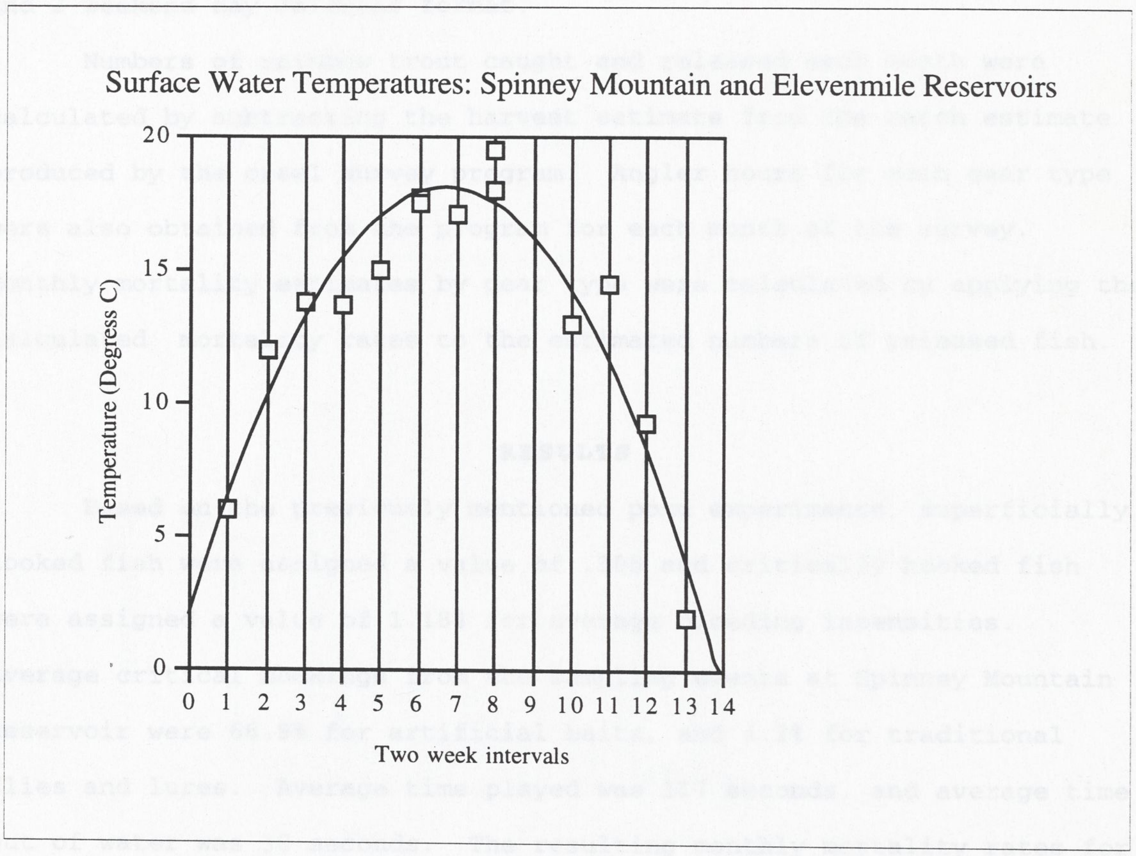
Table 2.1--Average length at annulus* and age of rainbow trout in Spinney Mountain Reservoir. *as defined in Summerfelt and Hall (1987)

ANNULUS	AGE (YEARS)	LENGTH (MM)
1(FALSE)	0.5	102
2	1	185
3 (FALSE)	1.5	283
4	2	376
5	3	446
6	4	511
7	5	585
8	6	609

Identification of each annulus as a yearly winter mark would be incorrect because the rainbow trout in Spinney Mountain Reservoir are primarily stocked. The first annulus was a nonannualar mark or "false annulus", which appeared when the fish were around 102 mm. This mark was caused by a slowing of growth when the fish were removed from the hatch-house in March or April of their first year of life, and placed in outdoor raceways with colder water. The second annulus (a true annulus) was caused by a period of slow growth during their first winter in the raceways (Kelly 1995). The fish were then stocked in April or May of their second year at around 254 mm, corresponding fairly well with the false annulus we observed at 283 mm. The rest of the annuli were considered true annuli, and represent periods of slow growth during the winter months. Monthly lengths were calculated by dividing the yearly growth increment by the seven months of the growing season (May through November), and adding the resulting monthly growth increment to the total length.

Water temperatures used in the model were calculated for each month Spinney Mountain Reservoir was free of ice. The temperatures used are based on surface water temperature measurements at Spinney Mountain and Elevenmile Reservoirs from 1990-1993 (Figure 2.1).

Figure 2.1.-- Data points shown are a combination of measurements made by the author, Colorado Cooperative Fish and Wildlife Research Unit employees, and the Colorado Division of Wildlife. The data were divided into two week intervals throughout the open water season starting with May 1-14 (increment 1), and ending in November 1-14 (increment 13).



Monthly mortality estimates were calculated for fish caught on both artificial flies and lures, and artificial baits. Based on the length-at-age estimates, rainbow trout were vulnerable to angling for an average of 3 fishing seasons before reaching harvestable size (508 mm). Monthly mortality rates for each year of vulnerability were averaged to generate an overall mortality rate for each gear type for each month of the fishing season.

To obtain monthly catch and release estimates, a creel survey was conducted at Spinney Mountain Reservoir during the months of May through September 1993. The standard Colorado Division of Wildlife creel survey was modified to estimate catch, harvest and angler-hours separately for fly and lure users, and artificial bait users. The creel survey was otherwise the same as the standard creel survey, and used a 2 weekday and 2 weekend day calendar format.

Numbers of rainbow trout caught and released each month were calculated by subtracting the harvest estimate from the catch estimate produced by the creel survey program. Angler hours for each gear type were also obtained from the program for each month of the survey. Monthly mortality estimates by gear type were calculated by applying the calculated mortality rates to the estimated numbers of released fish.

RESULTS

Based on the previously mentioned pond experiments, superficially hooked fish were assigned a value of .305 and critically hooked fish were assigned a value of 1.184 for average bleeding intensities. Average critical hookings from the sampling events at Spinney Mountain Reservoir were 66.9% for artificial baits, and 4.2% for traditional flies and lures. Average time played was 117 seconds, and average time out of water was 30 seconds. The resulting monthly mortality rates for fish caught on artificial baits ranged from 9.3% to 34.7%, while mortality rates for artificial flies and lures ranged from 0.82% to 4.53% (Figure 2.2). The highest mortalities occurred in the months of July and August when water temperatures were the warmest.

Catch rates varied from month to month for both flies and lures, and artificial baits, although artificial baits had higher catch rates than flies and lures in three of the five survey months (Figure 2.3).

Catch rates declined for both groups in late summer. Higher numbers of fish were captured by fly and lure users in each month of the survey (Figure 2.4 and 2.5) because many more angler-hours were spent fishing by fly and lure users (Figure 2.6).

Figure 2.2--Estimated mortality rates for each month during the 1993 fishing season.

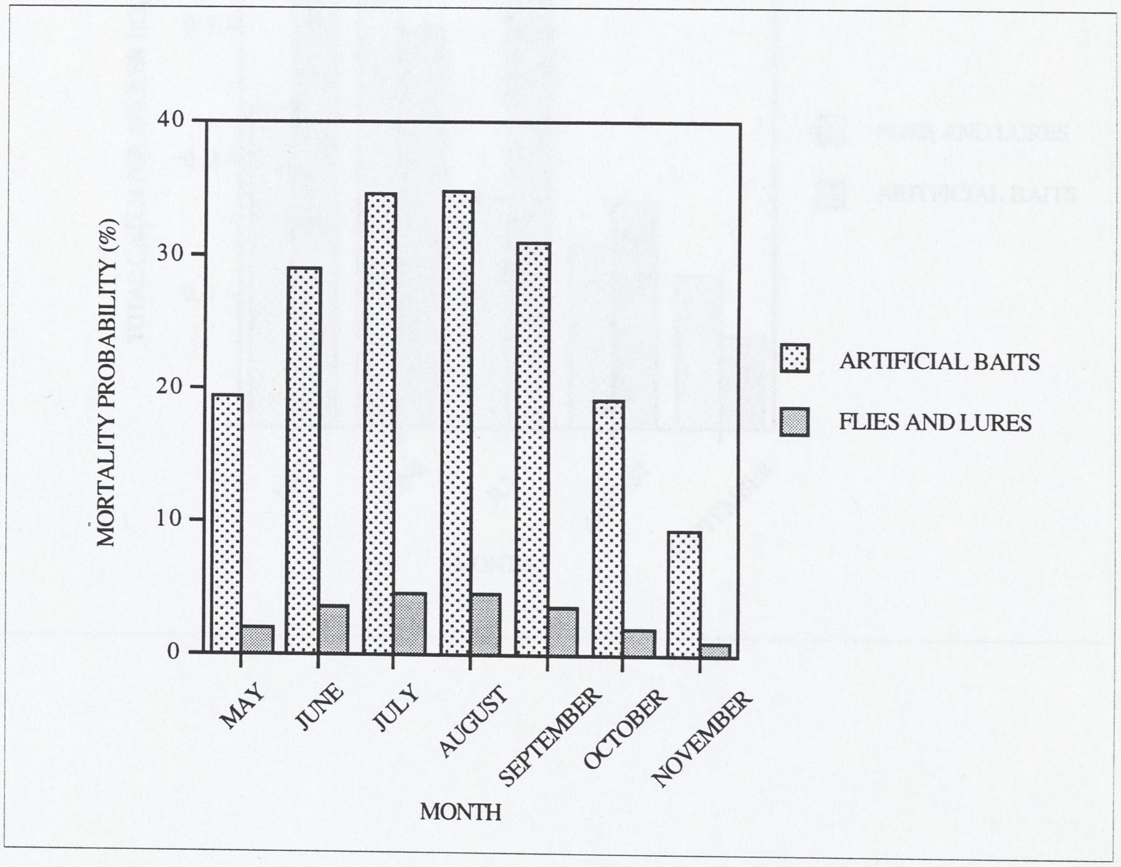


Figure 2.3--Catch rates by gear type during the 1993 fishing season at Spinney Mountain Reservoir.

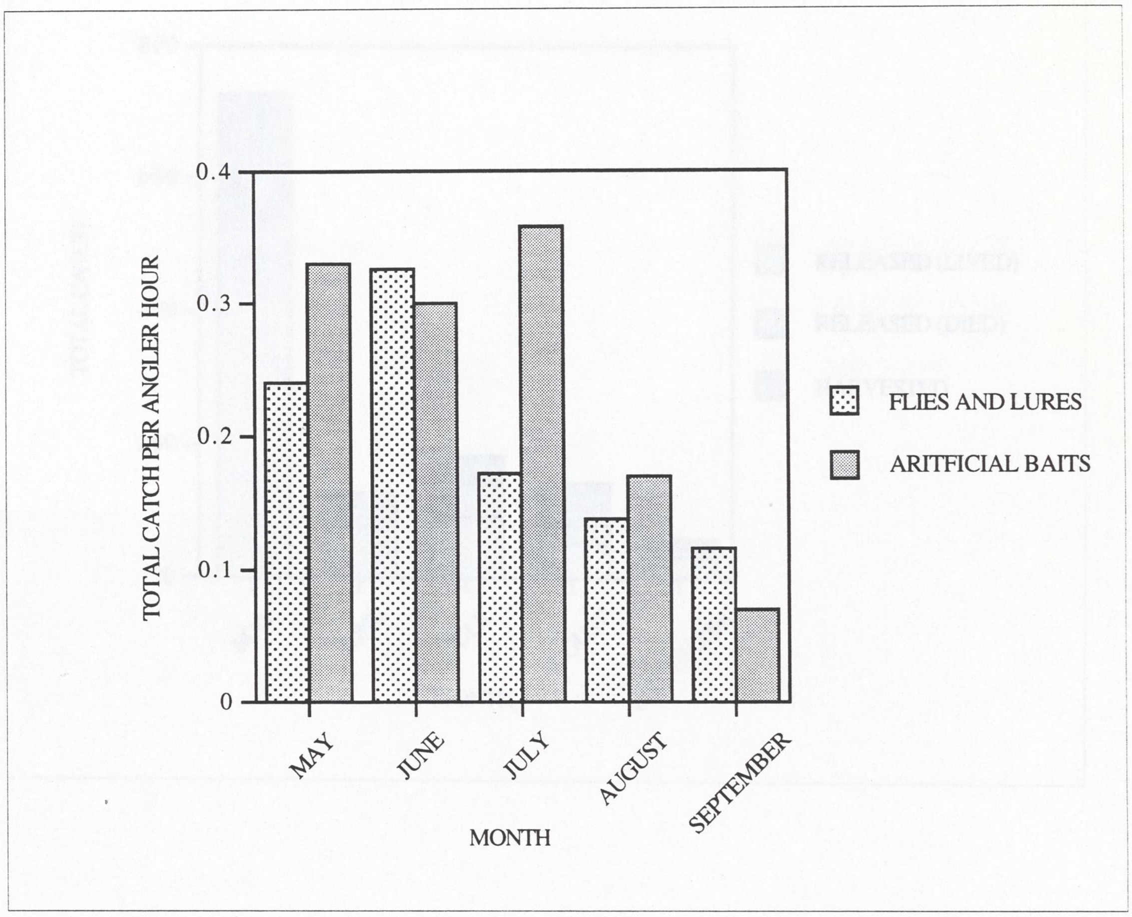


Figure 2.4.--Catch and harvest of rainbow trout by artificial bait users at Spinney Mountain Reservoir in 1993.

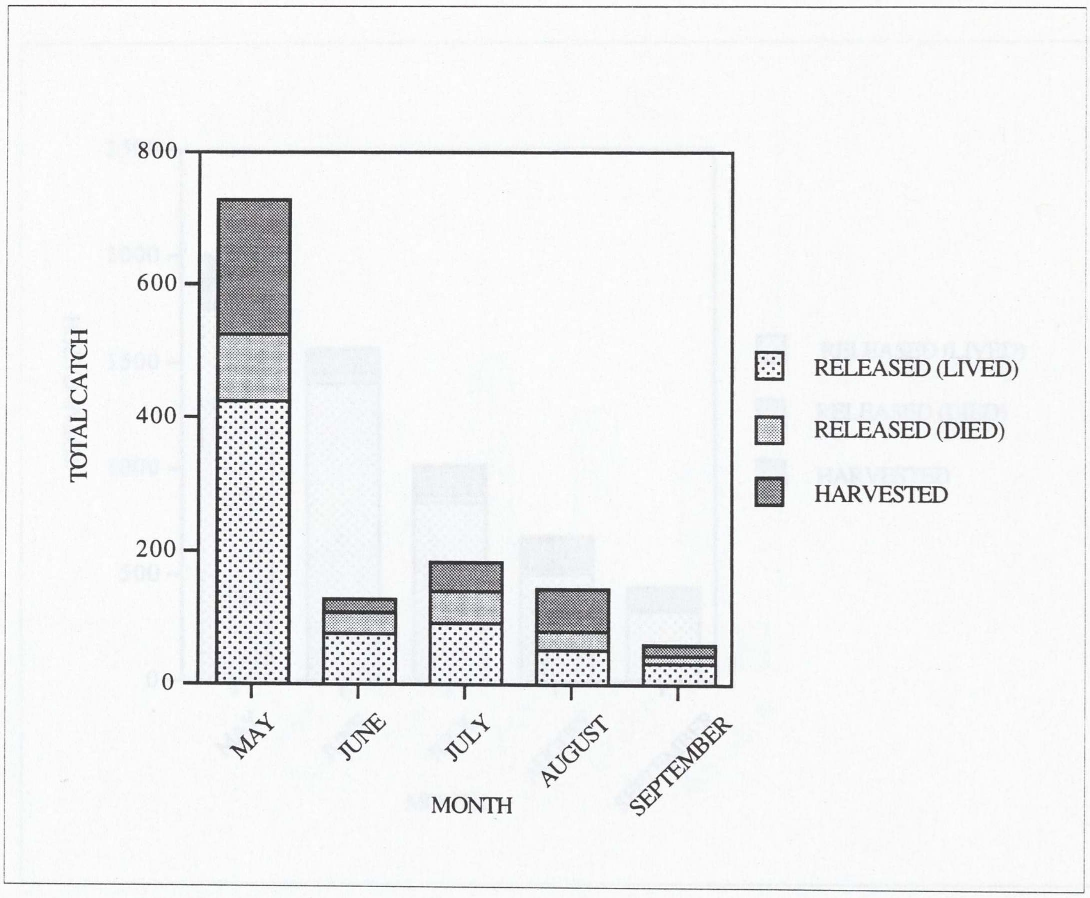


Figure 2.5.--Catch and harvest of rainbow trout by fly and lure users at Spinney Mountain Reservoir in 1993.

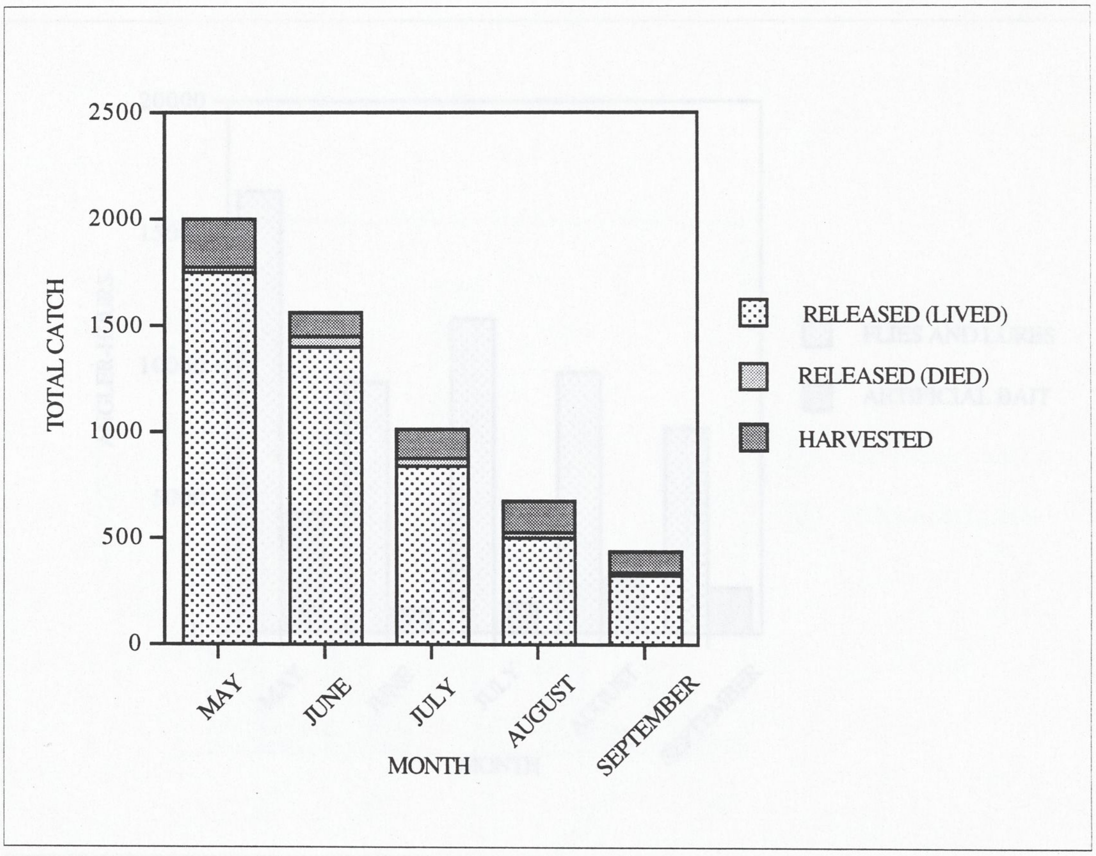


Figure 2.6.--Angler-hours by gear type in Spinney Mountain Reservoir in 1993.

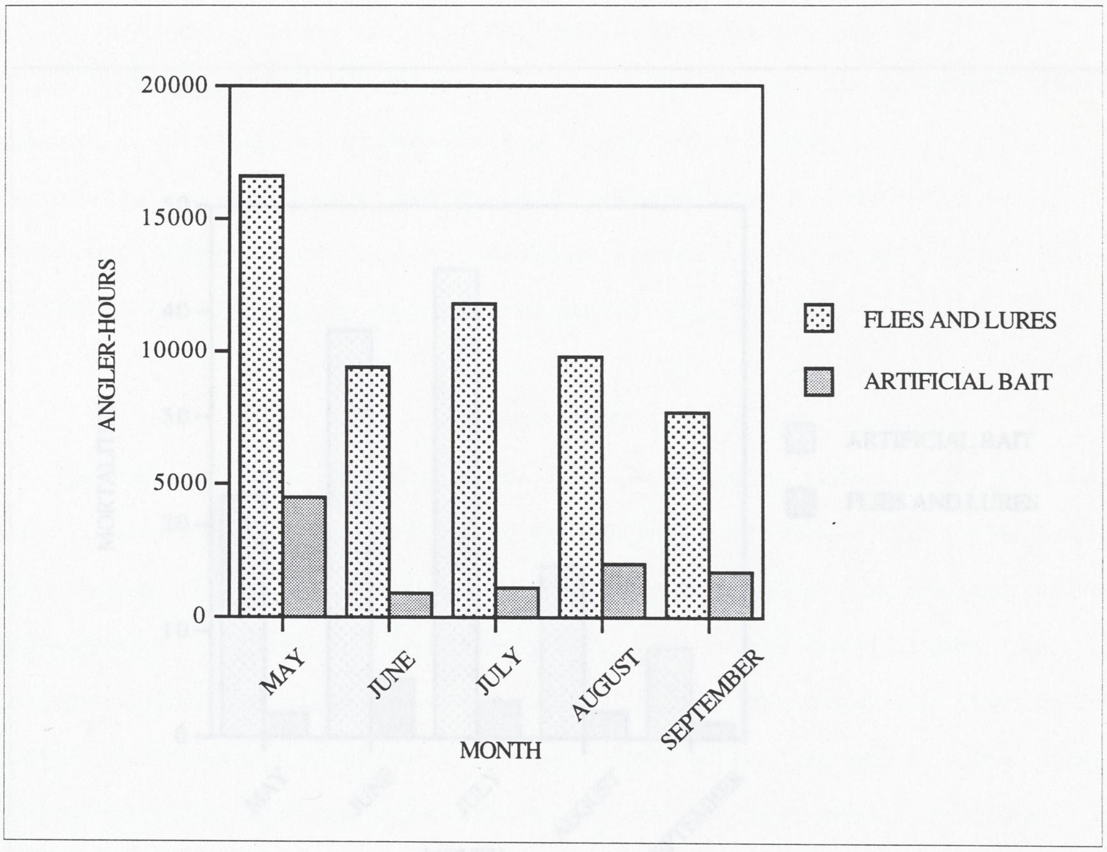
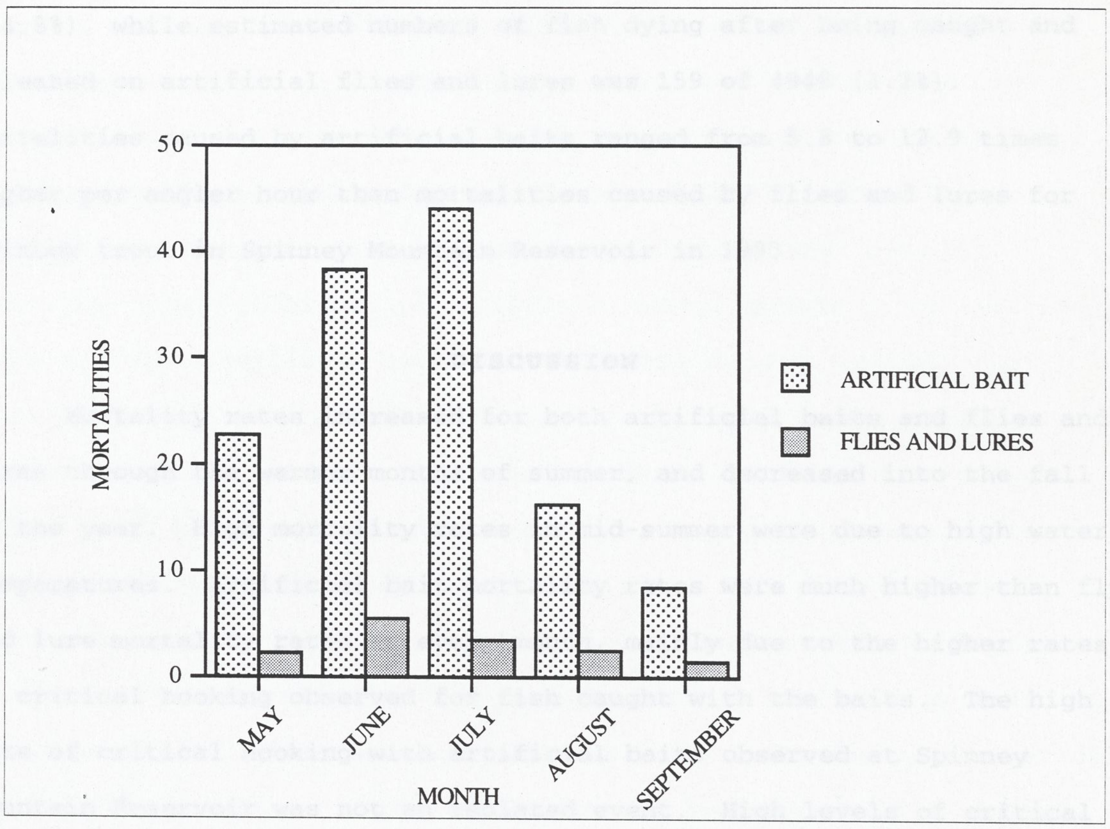


Figure 2.7.--Catch and release mortalities per 1000 angler-hours by gear type at Spinney Mountain Reservoir in 1993.



A much higher proportion of fish died after release when caught with artificial bait than with flies and lures (Figures 2.4 and 2.5). The estimated number of fish caught on artificial baits that died after being released from May through September of 1993 was 220 of 887 (24.8%), while estimated numbers of fish dying after being caught and released on artificial flies and lures was 159 of 4948 (3.2%). Mortalities caused by artificial baits ranged from 5.8 to 12.9 times higher per angler hour than mortalities caused by flies and lures for rainbow trout in Spinney Mountain Reservoir in 1993.

DISCUSSION

Mortality rates increased for both artificial baits and flies and lures through the warmer months of summer, and decreased into the fall of the year. High mortality rates in mid-summer were due to high water temperatures. Artificial bait mortality rates were much higher than fly and lure mortality rates in every month, mainly due to the higher rates of critical hooking observed for fish caught with the baits. The high rate of critical hooking with artificial baits observed at Spinney Mountain Reservoir was not an isolated event. High levels of critical hooking were observed with the use of these baits during several other sampling events in other waters, including ice fishing, a wild cutthroat trout population, and a river. Fish attacked the artificial baits ravenously in all of these trials, and were critically hooked from 37.5 to 85% of the time, depending on fishing method and environmental conditions. Scents used in the artificial baits appear to stimulate feeding behavior of the fish to a level that the bait is eagerly engulfed. The only scenario where the baits did not cause high rates of critical hookings (4.4%) involved attaching the bait to a 1/16 oz. jig-head and fishing actively through the ice. The direct contact of the anglers with the terminal tackle, and their ability to set the hook as soon as the fish grasped the bait prevented most fish from ingesting the bait.

Catch per unit effort at Spinney Mountain Reservoir was highest early in the year, with a decline later in the summer for both artificial baits and flies and lures. High water temperatures late in the summer may have had some effect on this result by causing the fish to forgo feeding or seek refuge in the colder depths of the lake.

Estimated mortalities of rainbow trout in Spinney Mountain Reservoir, although higher for artificial baits, appear to be relatively small for both artificial baits and flies and lures. However, the significance of the mortalities caused by the baits becomes apparent when the number of angler-hours are considered. The results indicate that a small proportion of anglers are causing a high proportion of the total mortalities from catch and release. In 1993, artificial bait users made up only 14.9% of the total angler-hours at Spinney Mountain Reservoir, but accounted for 59.5% of the catch and release mortalities in rainbow trout. Because these baits are relatively new on the market, and are very effective, their use in fly and lure waters will probably increase substantially in the future.

Exploitation rates, population size, and natural mortality rates for rainbow trout in Spinney Mountain Reservoir are currently unknown. As a result, the true effect of fishing mortality on the rainbow trout population is also unknown. Identifying if current levels of fishing mortality at Spinney Mountain Reservoir are additive or compensatory is neccesary to determine what effects the artificial baits are having on the population. Compensatory mortality refers to mortality caused by fishing that reduces the amount of natural mortality, but does not effect total mortality. Additive mortality is fishing mortality that occurs in addition to natural mortality, and increases total mortality. If fishing mortality is compensatory at current levels in Spinney Mountain Reservoir, catch and release mortality from artificial bait will not affect the numbers of trophy-sized trout present. However, if fishing mortality is additive, the increased total annual mortality rate caused by bait use could greatly reduce the numbers of fish reaching trophy size. Because recruitment into the fishery is largely due to stocking of fairly large fish (9-11"), high levels of compensatory mortality usually associated with small trout (age 0 or 1) doesn't exist in the reservoir. Mortality should be mostly additive for large fish with adequate habitat and forage, so mortality of sublegal fish in the reservoir can be assumed to be additive.

Behnke (1989) noted that "susceptibility of a fish species to being caught and caught again - in combination with the age structure of a population in relation to percent survival to an older terminal age - is a major determinant of success or failure of special regulations." While rainbow trout are not the most susceptible species of trout, they can be caught quite readily by anglers, especially soon after being stocked. Heavy angling pressure in areas such as Spinney Mountain reservoir also increases the odds of a fish being caught repeatedly. The age analysis of rainbow trout in Spinney Mountain Reservoir indicated that they may reach 6 years of age. Because the fish are relatively long-lived and have the potential to grow to a large size, reduction of fishing mortality becomes an important consideration when maintaining a trophy trout fishery is the management goal.

Clark (1983) found that voluntary catch and release can improve numbers of trophy fish caught per recruit, given low mortality rates for released fish. Fly and lure users at Spinney Mountain Reservoir released a much higher proportion of their total catch. If fishing mortality at Spinney Mountain Reservoir is presently additive, or becomes additive at some future level of fishing pressure, voluntary release may become very important to maintain a trophy trout population.

Clawson (1965) identified three types of anglers: (1) purists, (2) active fishermen, and (3) incidental anglers. Purists were identified as highly informed anglers who would spend considerable amounts of time and money on fishing. Active fishermen were described as skilled anglers, interested in the sport, but they would spend less time and money because of alternate interests. Incidental anglers were described as fishermen who are generally less successful because of lack of knowledge and proper tackle, and generally fished while involved in some other outdoor activity such as picnicking or hiking. While these three major classes of anglers still exist, these classes can be split further into three subsets of anglers: (1) non-harvesters, (2) provisional harvesters, and (3) harvesters. Non-harvesters are interested in fishing only for the recreational benefits. They prefer fishing for wild fish to those they suspect are stocked, and release all the fish they catch. These fishermen tend to use tackle that increases fish survival, and are usually well informed about fish handling techniques. Provisional harvesters are interested in angling for both the recreational aspect and the potential for bringing home an occasional meal or trophy fish. Creeling fish is not always necessary to these anglers, but often an added benefit. Their fish handling behaviors and fishing techniques may vary from location to location. Harvesters are interested in fishing mainly to creel fish. They usually avoid catch and release waters, and typically do not discriminate between hatchery and wild trout. Because harvesters generally intend to keep the fish they capture, they are less likely to fish with methods conducive to the fish's survival, and are more likely to use baits.

Because artificial baits are legal in Colorado's special regulation waters, more harvest-oriented anglers have taken advantage of the opportunity to fish in trophy trout waters such as Spinney Mountain Reservoir. Based on our observations, harvesters using artificial baits in special regulation waters tend to maintain handling techniques (such as holding fish out of water for long periods of time and pulling the hook out of critically hooked fish) that may be acceptable in put and take fisheries where release of fish is not required. Aside from the fact that many fish are critically hooked when caught on artificial baits, mortalities from catch and release are in part due to poor handling techniques by many anglers. This mishandling is probably not intentional, but stems from the fact that these anglers are not well informed about proper handling techniques for releasing fish alive, and have not had much experience doing so. Schisler (1995) outlined techniques that reduce mortalities of released fish that should be conveyed to a larger proportion of the angling public, especially harvest-oriented anglers.

If artificial bait use in special regulation waters such as Spinney Mountain Reservoir increases to levels observed with flies and lures, catch and release mortalities can be expected to rise dramatically. This could lead to substantial additive fishing mortality if it doesn't already exist, and failure of special regulations to produce desired populations of trophy trout in these special regulation waters. To prevent high mortalities and potential loss of quality fisheries, baits (artificial and organic) should be excluded from special regulation waters.

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APPENDIX

Appendix 1.1.--Sample sizes, mortality rates, and 95% confidence intervals for each gear type and replicate experiment.

TEMPERATURE	GEAR	N	LOWER 95% CI	UPPER 95% CI	MORTALITY RATE (%)
4 DEGREES C	FLIES	103	0.05	4.52	0.97
	ABA	101	9.38	21.94	14.85
	ABP	110	13.16	26.32	19.09
8 DEGREES C	FLIES	101	0.05	4.61	0.99
	ABA	100	4.78	15.18	9.00
	ABP	98	16.60	31.58	23.47
13 DEGREES C	FLIES	50	6.76	24.69	14.00
	ABA	103	19.19	34.29	26.21
	ABP	103	29.86	46.40	37.86
15 DEGREES C	FLIES	103	1.34	8.67	3.88
	ABA	100	20.69	36.32	28.00
	ABP	100	36.52	53.71	45.00
17 DEGREES C	FLIES	100	1.99	10.23	5.00
	ABA	101	22.26	38.07	29.70
	ABP	100	28.00	44.63	36.00
OVERALL	FLIES	457	2.56	5.78	3.94
	ABA	505	18.60	24.82	21.58
	ABP	511	28.68	35.66	32.09

			SUPERFICIAL HOOKINGS							CRITICAL HOOKINGS	
TEMPERATURE	GEAR	Sample	UPPER JAW	LOWER JAW	CORNER	ROOF	TONGUE	FOUL	EYE	GILL ARCHES	DEEP HOOKED
4 DEGREES C	FLY	103	58.25%	15.53%	15.53%	2.91%	0.97%	2.91%	1.94%	1.94%	0.00%
	PEA	101	20.79%	9.90%	5.94%	2.97%	0.99%	0.00%	0.00%	0.99%	58.42%
	PEP	110	15.45%	10.91%	1.82%	0.91%	0.91%	0.00%	0.00%	3.64%	65.36%
8 DEGREES C	FLY	101	48.51%	20.79%	14.85%	0.99%	8.91%	1.98%	1.98%	0.99%	0.99%
	PEA	100	48.00%	14.00%	16.00%	1.00%	2.00%	0.00%	0.00%	6.00%	13.00%
	PEP	98	12.24%	10.20%	5.10%	1.02%	0.00%	1.02%	0.00%	5.12%	64.29%
13 DEGREES C	FLY	50	46.00%	28.00%	14.00%	2.00%	4.00%	0.00%	2.00%	2.00%	2.00%
	PEA	103	13.59%	13.59%	15.53%	1.94%	0.97%	0.00%	0.00%	11.65%	42.72%
	PEP	103	6.80%	4.85%	7.77%	0.97%	0.00%	0.00%	0.00%	6.80%	72.82%
15 DEGREES C	FLY	103	78.64%	17.48%	0.00%	0.00%	0.00%	0.00%	0.00%	2.91%	0.97%
	PEA	100	30.00%	21.00%	7.00%	1.00%	0.00%	0.00%	0.00%	3.00%	38.00%
	PEP	100	8.00%	1.00%	3.00%	2.00%	0.00%	0.00%	0.00%	8.00%	78.00%
17 DEGREES C	FLY	100	70.00%	18.00%	0.00%	1.00%	6.00%	2.00%	1.00%	2.00%	0.00%
	PEA	101	21.78%	15.84%	1.98%	4.95%	0.99%	0.00%	0.00%	8.91%	45.54%
	PEP	100	9.00%	4.00%	0.00%	1.00%	0.00%	0.00%	0.00%	4.00%	82.00%
OVERALL	FLY	457	61.93%	19.04%	8.32%	1.31%	3.94%	1.53%	1.31%	1.97%	0.66%
	PEA	505	28.73%	14.85%	9.31%	2.38%	0.99%	0.00%	0.00%	6.14%	39.60%
	PEP	511	10.37%	6.26%	3.52%	1.17%	0.20%	0.20%	0.00%	5.68%	72.60%

Appendix 1.2.--Hook locations by gear type and replicate experiment.

Appendix 1.3.--Bleeding intensity was rated on a scale of none to heavy for each hook location and leader treatment. This table represents combined bleeding intensities for all five replicate experiments.

HOOK LOCATION AND	BLEEDING INTENSITY			
LEADER TREATMENT	NONE	LIGHT	MEDIUM	HEAVY
UPPER JAW	76.43%	20.81%	2.55%	0.21%
LOWER JAW	76.80%	18.56%	2.58%	2.06%
CORNER OF MOUTH	70.87%	24.27%	2.91%	1.94%
FOUL HOOKED	75.00%	25.00%	0.00%	0.00%
ROOF OF MOUTH	62.50%	16.67%	12.50%	8.33%
TONGUE	50.00%	37.50%	4.17%	8.33%
EYE	50.00%	33.33%	16.67%	0.00%
GILLS/ LEADER CUT	20.00%	20.00%	12.00%	48.00%
GILLS/LEADER NOT CUT	22.73%	15.91%	15.91%	45.45%
DEEPLY HOOKED/ LEADER CUT	68.55%	14.49%	9.54%	7.42%
DEEPLY HOOKED/ LEADER NOT CUT	30.56%	13.19%	17.36%	38.89%

Appendix 2.1.--Percent critical hookings by gear type for three sampling events at Spinney Mountain Reservoir. During the third event no fish were captured with flies and lures.

	n	ARTIFICIAL BAITS	n	FLIES AND LURES
SPINNEY 1	24	37.5	46	2.2
SPINNEY 2	19	63.2	25	8.0
SPINNEY 3	78	76.9	-	-
AVERAGE	121	66.9	71	4.2

Appendix 2.2.--Mortalities of sublegal rainbow trout in Spinney Mountain Reservoir caught on artificial baits, calculated with month-by-month average lengths and water temperatures. Rainbow trout are sublegal for an average of three fishing seasons after stocking. Combined mortalities are weighted averages of the mortalities for superficially and critically hooked fish. Total catch was composed of 33.1% superficially hooked fish and 66.9% critically hooked fish.

1ST YEAR	LENGTH (MM)	TEMP (C)	SUPERFICIAL (%)	CRITICAL (%)	COMBINED (%)
MAY	283	8.3	4.59	32.41	23.20
JUNE	299	14.3	7.95	46.29	33.60
JULY	314	17.5	10.36	53.53	39.24
AUGUST	330	17.8	10.21	53.13	38.92
SEPTEMBER	345	15.4	7.75	45.60	33.07
OCTOBER	361	10.1	4.38	31.33	22.41
NOVEMBER	376	2.0	1.82	15.59	11.04
2ND YEAR	LENGTH (MM)	TEMP (C)	SUPERFICIAL (%)	CRITICAL (%)	COMBINED (%)
MAY	376	8.3	3.48	26.45	18.85
JUNE	388	14.3	6.15	39.53	28.49
JULY	400	17.5	8.15	46.93	34.09
AUGUST	411	17.8	8.11	46.82	34.01
SEPTEMBER	423	15.4	6.20	39.71	28.62
OCTOBER	435	10.1	3.51	26.62	18.97
NOVEMBER	446	2.0	1.47	12.94	9.14
3RD YEAR	LENGTH (MM)	TEMP (C)	SUPERFICIAL (%)	CRITICAL (%)	COMBINED (%)
MAY	446	8.3	2.82	22.43	15.94
JUNE	457	14.3	5.02	34.53	24.77
JULY	468	17.5	6.70	41.72	30.12
AUGUST	478	17.8	6.69	41.68	30.10
SEPTEMBER	489	15.4	5.11	34.92	25.05
OCTOBER	500	10.1	2.89	22.86	16.25
NOVEMBER	511	2.0	1.21	10.86	7.66

Appendix 2.3.--Mortalities of sublegal rainbow trout in Spinney Mountain Reservoir caught on artificial flies and lures calculated with month-by-month average lengths and water temperatures. Rainbow trout are sublegal for an average of three fishing seasons after stocking. Combined mortalities are weighted averages of the mortalities for superficially and critically hooked fish. Total catch was composed of 95.8% superficially hooked fish and 4.2% critically hooked fish .

1ST YEAR	LENGTH (MM)	TEMP (C)	SUPERFICIAL (%)	CRITICAL (%)	COMBINED (%)
MAY	283	8.3	1.89	16.12	2.49
JUNE	299	14.3	3.35	25.68	4.29
JULY	314	17.5	4.43	31.59	5.57
AUGUST	330	17.8	4.36	31.24	5.49
SEPTEMBER	345	15.4	3.26	25.15	4.18
OCTOBER	361	10.1	1.80	15.46	2.38
NOVEMBER	376	2.0	0.74	6.90	1.00
2ND YEAR	LENGTH (MM)	TEMP (C)	SUPERFICIAL (%)	CRITICAL (%)	COMBINED (%)
MAY	376	8.3	1.42	12.60	1.89
JUNE	388	14.3	2.56	20.77	3.33
JULY	400	17.5	3.43	26.17	4.39
AUGUST	411	17.8	3.42	26.08	4.37
SEPTEMBER	423	15.4	2.58	20.89	3.35
OCTOBER	435	10.1	1.44	12.70	1.91
NOVEMBER	446	2.0	0.59	5.62	0.80
3RD YEAR	LENGTH (MM)	TEMP (C)	SUPERFICIAL (%)	CRITICAL (%)	COMBINED (%)
MAY	446	8.3	1.15	10.39	1.54
JUNE	457	14.3	2.08	17.46	2.72
JULY	468	17.5	2.80	22.30	3.62
AUGUST	478	17.8	2.79	22.27	3.61
SEPTEMBER	489	15.4	2.11	17.70	2.77
OCTOBER	500	10.1	1.18	10.62	1.57
NOVEMBER	511	2.0	0.49	4.66	0.66

Appendix 2.4.--Average month by month mortalities of released fish by gear type at Spinney Mountain Reservoir. Values were calculated by averaging monthly mortality rates shown in Appendix 2.2 and 2.3 for each year fish were sublegal.

	FLIES AND LURES (%)	ARTIFICIAL BAIT (%)
MAY	2.0	19.3
JUNE	3.5	29.0
JULY	4.5	34.5
AUGUST	4.5	34.7
SEPTEMBER	3.4	30.9
OCTOBER	1.9	19.2
NOVEMBER	0.8	9.3

Appendix 2.5.--Angler-hours and catch per angler-hour of rainbow trout at Spinney Mountain Reservoir from May through September, 1993. Values were obtained from the modified CDOW creel survey.

	ANGLER-HOURS		CATCH PER ANGLER-HOUR	
	FLIES AND LURES	ARTIFICIAL BAITS	FLIES AND LURES	ARITIFCIAL BAITS
MAY	16,576.2	4,400.2	0.24	0.33
JUNE	9,325.7	810.5	0.33	0.30
JULY	11,728.7	1,094.4	0.17	0.36
AUGUST	9,738.6	1,673.0	0.14	0.17
SEPTEMBER	7,636.9	1,663.1	0.12	0.07

Appendix 2.6.--Total catch and harvest of rainbow trout at Spinney Mountain Reservoir from May through September, 1993. Numbers of released and harvested fish were obtained from the modified CDOW creel survey, and estimates of fish living and dying after release were based on model predictions.

	FLIES AND LURES			
	RELEASED (LIVED)	RELEASED (DIED)	HARVESTED	TOTAL CATCH
MAY	1,740	35	225	2,000
JUNE	1,397	50	106	1,553
JULY	835	40	131	1,006
AUGUST	496	23	152	671
SEPTEMBER	321	11	100	432
OVERALL	4,789	159	714	5,662
	ARTIFICIAL BAITS			
	RELEASED (LIVED)	RELEASED (DIED)	HARVESTED	TOTAL CATCH
MAY	420	100	204	724
JUNE	75	31	20	126
JULY	91	48	41	180
AUGUST	51	27	64	142
SEPTEMBER	30	14	14	58
OVERALL	667	220	343	1,230

Appendix 2.7.--Percent critically hooked fish by gear type and fishing method in four different locations including: (1) Spinney Mountain Reservoir, (2) CSU Foothills Campus Ponds (ice fishing trial), (3) Skyscraper Reservoir (wild cutthroat trout trial), and (4) Big Thompson River (flowing water trial).