[1983]

Hooking Mortality
Kamloops trout
Harper L.

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Canadian Cataloguing in Publication Data

Facchin, A. (Angelo), 1952-
Hooking mortality of fly-caught Duncan River rainbow trout (Salmo gairdneri) in Harper Lake, British Columbia

(Fisheries technical circular, ISSN 0229-1150 ; no. 58)

Bibliography: p.
ISBN 0-7719-9378-1

1. Rainbow trout - Mortality. I. British Columbia. Ministry of Environment. II. Title. III. Series.

SH167.T86F32 1984 639.3'755 C84-092035-0

HOOKING MORTALITY OF FLY-CAUGHT DUNCAN RIVER RAINBOW TROUT *(Salmo gairdneri)* IN HARPER LAKE, BRITISH COLUMBIA

by

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Fisheries Technical Circular No. 58
1983

ACKNOWLEDGEMENTS

The Harper Lake project was a cooperative venture involving Kamloops regional staff and Fisheries Research staff. I would like to thank E. Parkinson for reviewing the manuscript and I. Warner for typing it.

INTRODUCTION

The need for a varied angling experience on reasonably accessible lakes has increased with the steadily increasing number of anglers in British Columbia. One way to vary the angling experience is through special regulations, such as, reduced kill limits, seasonal closures and gear restrictions on some lakes. An example is the "trophy fishery", where generally there is a daily kill limit of 2 fish, icefishing closure and fishing is restricted to artificial flies. These regulations are intended to increase both the catch per unit effort and the size of fish. Rainbow trout may be caught and released several times before reaching trophy size, so hooking mortality may be a major factor in the success or failure of trophy fisheries.

STUDY AREA

Harper Lake (50° 44'20", 119° 42' 40") is 8 km south of Chase, British Columbia and drains into the South Thompson River. The lake has a surface area of 28.5 hectares, elevation of 671 meters, maximum depth of 22.9 meters, mean depth of 12 meters and a TDS of 150 ppm (Fish and Wildlife Branch). The inlets and outlet provide very little spawning area but some natural reproduction does occur. In 1977, Harper was stocked with yearling Duncan River (adipose clip) and Mission Creek (right maxilla clip) rainbows. There was a second stocking of yearling Duncan River rainbow (adipose and right pelvic clip) in 1978.

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METHOD

Duncan River and Mission Creek rainbow were angled by fly fishing with single barbed hooks. Fish were played out as in a normal fishery and did not receive special handling when landed. A trap net was set with the centre lead anchored to shore and the trap box set near the edge of the shoal. Separate holding pens were set up for each stock and various fin clips were used to separate each day's catch and angled and trap caught fish. Captured fish were transported in a 130 L garbage bucket to the holding pens. Fish were held for 2 days except those caught on the last sampling day which were held for 1 day only. Lengths and weights (Pesola balance) were taken on dead fish only. Temperature and oxygen profiles of the lake were taken with a YSI model 54 oxygen-temperature meter.

There were two experiments, one in June 1981 and the other in May 1982.

Holding pens were set in shallow and deep water during the first experiment. Shallow pens were set in 1.3 meters of water and deep pens were set on the lake bottom at a depth of 6 meters. Badly hooked fish were specially clipped so they could be identified. Oxygen and temperature changes in the transportation bucket were monitored with a YSI model 54 oxygen-temperature meter. Dead fish were frozen with dry ice and tissue samples from these fish were checked for disease by the Fish and Wildlife Branch fish pathologist.

The procedure for the second experiment was set by results of the first experiment and availability of equipment.

RESULTS

The trap net set caught only 2 Mission Creek spawners during the first experiment. Results of the hooking mortality of fly caught rainbow in June 1981 are given in Table 1.

Table 1. Per cent mortality during June 1981 experiment. Sample size in brackets.

Stock	Holding Period	Per Cent Mortality Pen Type Shallow	Deep	Combined
Duncan	2 days	10% (10)	70% (10)	40% (20)
Duncan	1-2 days	13% (15)	53% (17)	34% (32)
Mission	2 days	33% (3)	50% (2)	40% (5)
Mission	1-2 days	17% (6)	50% (2)	25% (8)

A G-test (Sokol and Rolf 1982) was performed on the raw data. There was no significant difference between mortality rates between stocks but the difference in the mortality rates between shallow and deep pens was significant at 0.05.

Mortality in the deep pens (12°, 6.5 ppm O_2) was much higher than in the shallow pens (17°, 8.0 ppm O_2). The reason for this is not clear, possibly it is related to a change in temperature combined with exhaustion. The fish were hooked near the surface in 17° C water and then put in 12° C water to recover. Marnell and Hunsaker (1970) found no temperature effects on lure-caught cutthroat trout (Salmo clarki) over a range of 3° C to 18° C. In a fishery, fish would be released over deep water and exhausted fish may sink to the bottom, so the deep pens are thought to be part of the normal situation.

Of the 8 Duncan fish that died amongst the group of 20 that were held for 48 hours, 7 died within 12 hours of capture and 1 died between 24 and 36 hours after capture. Other studies on salmonids have found that nearly all hooking mortalities occurred within 24 hours (Warner and Johnson 1978; Marnell and Hunsaker 1970). The combined mortality rate of 34% for Duncan River rainbows held for at least 1 day is considered a reasonable estimate.

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Two Duncans were considered seriously hooked, but neither of them died. All angled Duncan's were immature 4 and 5 year old fish. The mean length and weight of the Duncans that died was 47.1 cm and 1406 g respectively. Water temperature in the transporting bucket rose from 17° C to 19° C and the oxygen level dropped from 8 ppm to 6 ppm during the separate transporting of 2 fish. Tissue samples taken from the dead fish indicated that pathogenic organisms were not a factor in any of the deaths (pers. comm. Terry Shortt). However, the pathologist that took the tissue samples commented on the unusually large fat deposits in the body cavity.

During the second experiment only shallow holding pens were used. Results are given in Table 2.

Table 2. Per cent mortality during May 1982 experiment. Sample size in brackets.

Stock	Holding Period	Per Cent Mortality Angled	Per Cent Mortality Trap Net
Duncan	1-2 days	38% (8)	0% (12)
Mission	1-2 days	0% (1)	0% (6)

Transportation conditions for fish caught in the trap net were worse than those of fly caught fish; up to 10 fish were transported in a single garbage bucket. None of the trap caught fish died or showed signs of dying after being in a holding pen for 1 day. This indicates that transporting in itself did not cause the fish to die. All trap net fish were spawners.

Angled Duncan River rainbow showed a similar hooking mortality rate to the 1981 experiment. Of the 3 Duncans that died, 2 were immature and one was in spawning condition. Marnell and Hunsaker (1970) found no evidence that spawning cutthroat trout (<u>Salmo clarki</u>) were any less resistant to the effects of hooking and handling than non-spawning adults.

Of the 40 Duncan River rainbow caught on flies during the two experiments, 35% died (mean length 47.8 cm). Mission Creek rainbow had a lower hooking mortality (22%) but only 9 were caught.

DISCUSSION

Hooking mortality may be an important factor in the success of fisheries where a large proportion of small fish that are caught, are released in anticipation of catching larger fish.

Table 3. A comparison of hooking mortality studies on fly-caught salmonids.

Source	Species	Location	Mean Fish Length (cm)	Hooking Mortality
Cartwright '61	S. gairdneri	Bonaparte R.	17.8	2%
Stringer '67	S. gairdneri	Pennask L.	29.1	8%
Warner & Johnson '78	S. salar	Kenebec R.	31.3	4%
Hunsaker, Marnel & Sharpe '70	S. clarki lewisi	Yellowstone L.	35.6	4%
Present study	S. gairdneri Duncan R.	Harper L.	47.8	35% (22%)*

*Mortality in shallow pens only (sample size, 23 fish). This is more comparable to the procedures in other studies.

All of the studies in Table 3, except this study, support Stringer's (1967) statement that death resulting from hooking with a fly is in the order of 10% or less, as is associated with physical trauma.

Hooking mortality may also be associated with physiological stress. Delayed mortality due to physiological stress (6-24 h post-exercise) after short periods (~ 5-10 min) of exercise is a well known phenomena in rainbow trout. Older literature (eg. Black 1957) suggested that this mortality is due to lactic acid build up in the blood but Wood _et al_. (1983) believe that a more complex mechanism is involved.

The high mortality in this study was probably due to physiological stress. No pathogenic organisms were found in these fish, the two severely hooked fish did not die and death from physical trauma has been low in other studies on fly-caught rainbow. It is difficult to understand why high mortality due to physiogical stress occurs only in some hooking mortality studies. Although mortality in many studies of fly-caught fish is usually < 5%, Bouck and Ball 1966 report a mortality of 85% in lure caught fish played to exhaustion (not including bleeders) and a mortality of ~ 40% occurred in a laboratory study of fish exercised vigorously for 6 min (Graham et al. 1982). I have two suggestions which may warrant further study. High mortality may be associated with more complete exhaustion. The fish in this study were the largest of those in Table 3 and the extra time required to land these fish may have resulted in more complete exhaustion. Marnell and Hunsaker (1970) did not find evidence in cutthroat trout to support the idea that a longer fight on a fishing line increases mortality. The second suggestion is that some strains of rainbow may be more susceptible to mortality from physiological stress but it should be noted that different strains were used by Bouck and Ball (1966), Graham et al. (1983) and in this study. In a study currently underway, various blood parameters will be compared in four strains of rainbow trout (Duncan, Thompson River steelhead, Domestic, Pennask) following vigorous exercise (R. Weinz, pers. comm.).

Flies are generally accepted as the least harmful of sport fishing gear (Stringer 1967). If Duncan River rainbow in general (irrespective of size) have a 35% hooking mortality from flies, they would not be suitable for fisheries where catch and release is encouraged.

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APPENDIX

Appendix 1. Data for hooking mortality study.

a) June 1981, angled fish only.

Stock	Date	Shallow Pen Lightly Hooked Caught	Shallow Pen Lightly Hooked Died	Shallow Pen Seriously Hooked Caught	Shallow Pen Seriously Hooked Died	Deep Pen Lightly Hooked Caught	Deep Pen Lightly Hooked Died	Deep Pen Seriously Hooked Caught	Deep Pen Seriously Hooked Died	Length of Time Held
Duncan	Jun 23	5	0	-	-	6	5	-	-	48 hr
Duncan	Jun 24	4	1	1	0	3	2	1	0	48 hr
Duncan	Jun 25	5	1	-	-	7	2	-	-	24 hr
Mission	Jun 23	-	-	-	-	1	1	-	-	48 hr
Mission	Jun 24	3	1	-	-	1	0	-	-	48 hr
Mission	Jun 25	3	0	-	-	-	-	-	-	24 hr

b) May 1982, angled and trap net fish

Stock	Date	Angling Caught	Angling Died	Trap Net Caught	Trap Net Died	Length of Time Held
Duncan	May 25	3	1	-	-	48 hr
Duncan	May 26	1	0	-	-	48 hr
Duncan	May 27	4	2	12	0	24 hr
Mission	May 25	-	-	-	-	48 hr
Mission	May 26	1	0	-	-	48 hr
Mission	May 27	-	-	6	0	24 hr

Appendix 2. Lengths and weights of fish that died.

a) June 1981

Stock	Clip	Length (cm)	Weight (gr)	Age
Duncan	Adipose	44.0	1190	5
Duncan	Adipose	45.2	1290	5
Duncan	Adipose + Right Pelvic	45.3	1280	5
Duncan	Adipose + Right Pelvic	49.5	1680	4
Duncan	Adipose + Right Pelvic	48.0	1550	4
Duncan	Adipose + Right Pelvic	48.0	1650	4
Duncan	Adipose + Right Pelvic	47.8	1402	4
Duncan	Adipose + Right Pelvic	50.4	1508	4
Duncan	Adipose + Right Pelvic	47.7	1440	4
Duncan	Adipose + Right Pelvic	45.0	1350	4
Duncan	Adipose + Right Pelvic	45.0	1230	4
Duncan	Adipose + Right Pelvic	49.5	1300	4
Mission	Right Maxilla	49.5	1500	5

b) May 1982

Stock	Clip	Length (cm)	Weight (gr)	Age
Duncan	Adipose + Right Pelvic	51.6	1800	5
Duncan	Adipose + Right Pelvic	53.0	2170	5

Red Pittack

A SUMMARY OF SALMONID HOOKING MORTALITY

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Washington Department of Game

February, 1984

INTRODUCTION

Releasing fish back to the wild probably first occurred because a particular fish was too small to interest the angler. Concern for the fish's survival after release was likely minimal. As state fish and wildlife agencies were formed early in this century, many fishing regulations were implemented to control increasing demand on the resource. One of these regulations was the minimum size. Although most of the early minimum sizes had no strong biological basis, fishery managers began wondering if the fish they were requiring released were surviving to grow and be caught again. The first recorded hooking mortality investigation was done by Westermen (1932) on brook trout. Since then approximately 30 additional studies have been completed on various aspects of hooking mortality and stress.

Here in Washington we are proposing broad ranging changes in the management of our salmonid streams. The main thrust of these changes is to protect young steelhead during stream rearing and outmigraiton and to ensure that most wild salmonids, anadromous and resident, spawn at least once before death. To meet these measures, various minimum size limits are required. Generally speaking, in order for minimum sizes to produce the desired effect, most of released sub-legal fish must survive. This report summarizes the literature and some unpublished records on hooking mortality as it relates to salmonids under the jurisdiction of the Washington Department of Game. The objective of this review is to determine what gear restrictions, if any, cause the least amount of hooking mortality.

METHODS

Data were obtained through 2 computerized literature searches: one by the Washington State Library and the other by the U.S. Fish and Wildlife Service in Denver. Additional literature was obtained by word of mouth. Unpublished records and personal communications were collected by calling knowledgeable professionals, not only from Washington, but from other states and provinces. Over the past 50 years, approximately 16,000 individual salmonids, composed of 9 different species, taken in 11 states and provinces were caught and held to determine hooking mortality. All are summarized in this report. No ocean caught salmon or steelhead are included.

The studies cited all utilized similar study methods to determine hooking mortality. Generally, fish ranging in size from 150mm to 300mm were caught by angling with flies, lures or bait and with either barbed or barbless hooks. Bait was primarily worms with salmon eggs occasionally used. The fish were then separated by gear taken on and occasionally anatomical site of hooking. Fish were held anywhere from 1 day to several months to record mortality. Most studies also held a control group of fish captured by electrofishing, trap or seine. This allowed separation of handling and holding mortality from hooking mortality.

Wydoski (1977) utilized most of the same literature in the

However, because different species of fish are grouped, it was difficult to get an overall picture of any single species. Also no attempt was made to separate hatchery from wild fish. It was determined that for the purpose of developing gear regulations directly aimed at wild salmonids of certain species that those items should be examined separately where possible. Data from different studies are pooled by single species in this report. Because rainbow and cutthroat trout (anadromous and resident) are of primary concern in Washington streams, they will be emphasized. However, some conclusions will be drawn based on other salmonid species.

In the remainder of this report, hatchery and wild fish will be separated when possible. The purist would define a wild fish only as a species that evolved where it is now located and genetically remains uncontaminated by introduced species. A more realistic definition would be any fish living in the wild that came from eggs spawned in the wild. However, for the purposes of this study, the definition of wild fish will be stretched a bit further to mean fish acclimated to the wild environment. This definition would include the 2 above, but would also include fish planted as fry or fingerlings that have grown in the wild to a size that includes them in a fishery. For all practical purposes these fish are wild fish, because they are succussfully living in the wild. These fish tend to act much more like a fish spawned in the wild than one recently planted. Hatchery fish are defined as those raised to a catchable size and caught either in the hatchery or immediately after planting in a stream or lake environment.

Contingency tables utilizing the chi-square statistic were used exclusively in this investigation for hypothesis testing. A hypothesis was only rejected at the 95 percent confidence level.

RESULTS AND DISCUSSION

Hatchery vs. Wild

Initially, it was thought that hatchery and wild fish would not differ greatly with regard to hooking morality. However, this hypothesis had not previously been tested and it needed examination. Figure 1 summarizes information on 3 species for all artificials and another 3 for bait. Adequate information was not available to compare the same species in both instances.

The artificials portion of the graph clearly shows a difference between hatchery and wild fish for all 3 species. These differences are all statistically significant. Wild rainbow trout and atlantic salmon suffer about double the hooking mortality than hatchery fish do. Wild cutthroat experience over 4 times the mortality as do hatchery cutthroat. What causes this?

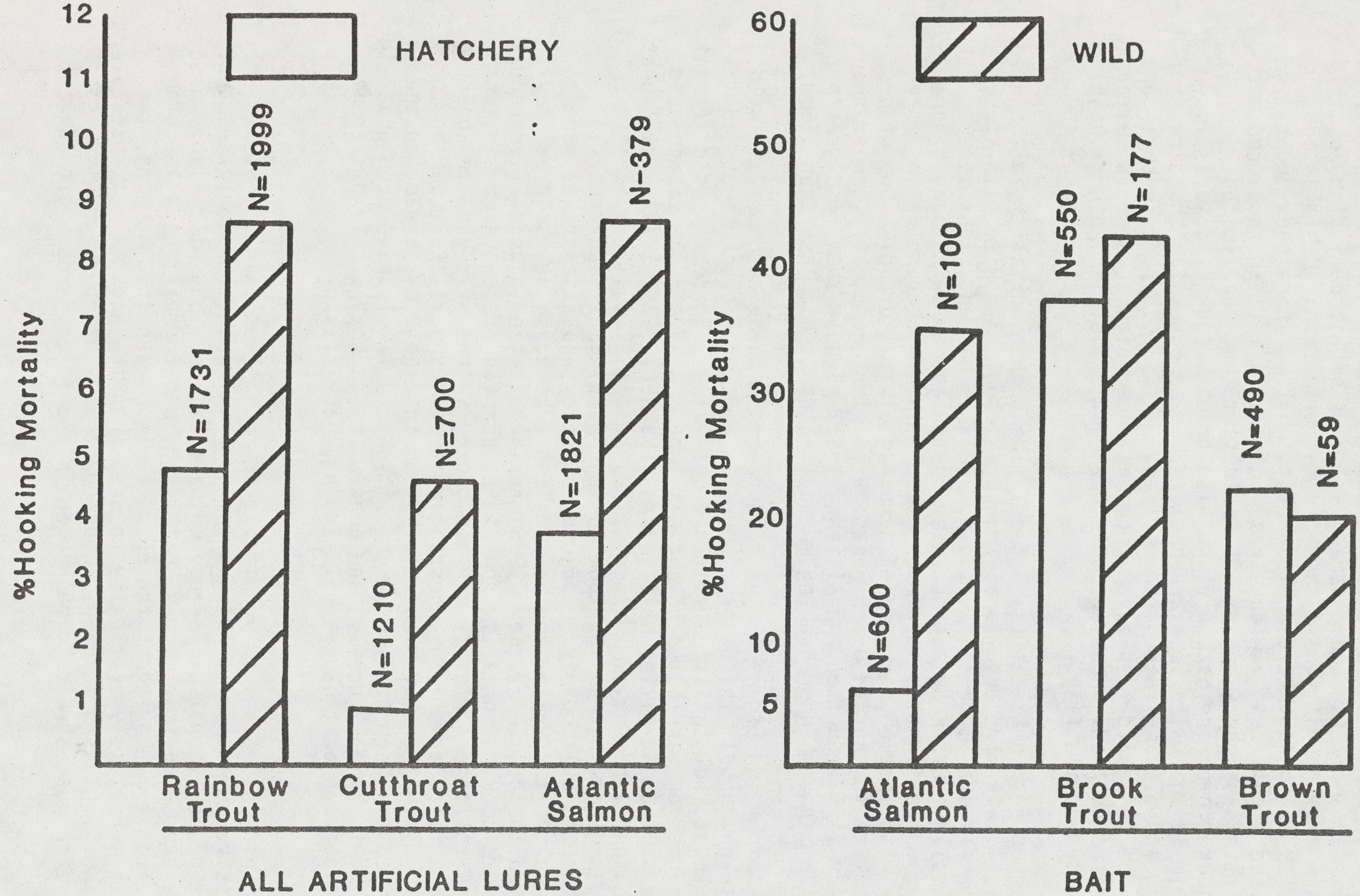

Figure 1. Comparison of hooking mortality between fish adapted to hatchery and wild environments. Only species with similar experiments done on hatchery and wild fish were included. Atlantic salmon are landlocked.

Cartographer Susan Peterson

Wydosky, et al (1976) compared various blood chemistry changes from hooked and played rainbow trout. Hatchery and wild fish were compared for plasma osmolality and plasma glucose. The hatchery fish actually showed more signs of stress than did the wild fish. Casillas and Smith (1977) found that the blood clotting time in rainbow trout decreased significantly with stress and that wild fish recovered more quickly than hatchery trout. It would seem that the limited literature comparing hatchery and wild trout blood characteristics would imply that wild fish are better able to cope with the stress of hooking and playing than hatchery fish. This would make sense if one concludes that wild fish have a more balanced diet and are in better physical condition. However, this does not explain the higher hooking mortality in wild fish.

One can only theorize at this stage. The higher mortality in the wild fish is likely more behavioral than physiological. Wild fish strike a lure or fly much more aggressively, and when hooked, fight more frantically. Striking aggressivley could lead to being hooked more deeply, while fighting hard might result in a hook penetrating more deeply with more of a chance of damaging a vital organ. One other possibility is that in experiments, wild fish are usually larger than hatchery fish. Shetter and Allison (1955) suggest that fish greater than 175mm have higher hooking mortality than those less than 175mm.

Upon reexamining Figure 1, the differences between hatchery and wild fish taken on bait is not as clear. In fact, for brook trout and brown trout, no statistical differences exist. There is a significant difference for landlocked atlantic salmon. However, the salmon used in the studies involving bait (worms) (Warner, 1976, 1979) were caught from hatchery raceways. Warner (1979) states, "It was noticeable during angling that salmon took worms very gingerly and rarely ingested the bait deeply. Too, in our study, no attempt was made to allow salmon to swallow the bait. Fish were hooked as soon as they accepted the bait." Warner (1976) further stated in an earlier report that worm hooking mortality done in hatcheries (raceways) would tend to underestimate mortality of fish hooked in the wild because anglers are able to observe fish ingesting bait with superficial hooking more likely. If Warner had planted his fish in a pond or stream and then conducted his worm hookings, mortality would likely have been equal to the wild fish in Figure 1. The conclusion is that little difference occurs between bait caught wild and hatchery fish.

Again, one can only speculate why. What probably occurs is that the act of picking up a slowly drifting or motionless bait is not as aggressive an act as striking a lure. This would tend to lessen that aspect of behavioral difference between hatchery and wild fish. Also, and perhaps more importantly, bait fishermen normally give the fish sufficient time to ingest the hook deeply. When that happens, the fish is more likely critically injured when the hook is set, not later when the fight is occurring. Consequently, a hatchery or wild fish would each just as likely be hooked in a critical area. The concept of critical areas will be discussed more fully in a later section.

Mortality by Gear and Species

Because wild fish will be the issue in most instances requiring minimum size limits and because wild fish likely experience higher hooking mortality from artificials than do hatchery fish, the discussions in this section will center primarily on wild fish.

Figures 2 through 6 depict comparisons between hooking mortality caused by flies with barbed and barbless hooks, lures with barbed and barbless hooks and bait. Single hook and treble hook data were grouped together with the appropriate gear. Various hook sizes and treble vs. single hooks will be discussed later.

For rainbow trout, no significant difference was found between barbed flies, barbless flies or barbed lures. No studies were done that included barbless lures. A significant difference did occur between all artificials and bait. One would expect between 5 and 10 percent mortality associated with any artificial fly or lure and roughly 30 percent associated with bait. The situation is similar for cutthroat trout even with barbless lures included. There is still no significant difference between any artificials and there is a significant difference between bait and all artificials. Expected mortality from artificial lures and flies would be in the area 5 percent for cutthroat. Mortality from bait would be close to 50 percent. Even though all gear types were not tested for the other species included, the results are the same. The only statistically significant differences that occurred are between artificials and bait.

Because treble and single hooks were grouped in Figure 1-6 there may be some questions related to hooking mortality associated with each. Figure 7 represents data from various studies summarizing both hooks attached to either artificial flies or lures. For both species, there is a difference visually. However, only data on the rainbow trout are statistically different. Please note that even though there is a statistical difference that mortality is still very low.

The likelihood that treble hooks cause lower mortality than single hooks is very possible. It would make sense that a treble hook is more difficult to engulf deeply than a single hook. Klein (1965) found no differences between single and treble hooks for rainbow trout when water temperatures were cool (6.5 C). However, at higher temperatures (14.5 C) hooking mortality from single hooks was about double that of treble hooks. At higher temperatures, the fish probably struck more aggressively, engulfing the hook deeper.

Hook size as it relates to hooking mortality also needs some discussion. Shetter and Allison (1955) examined various hook sizes. They found that #4 and #8 single hooks fished with worms killed significantly more brook trout than did #2 hooks. The #4 and #8 hooks

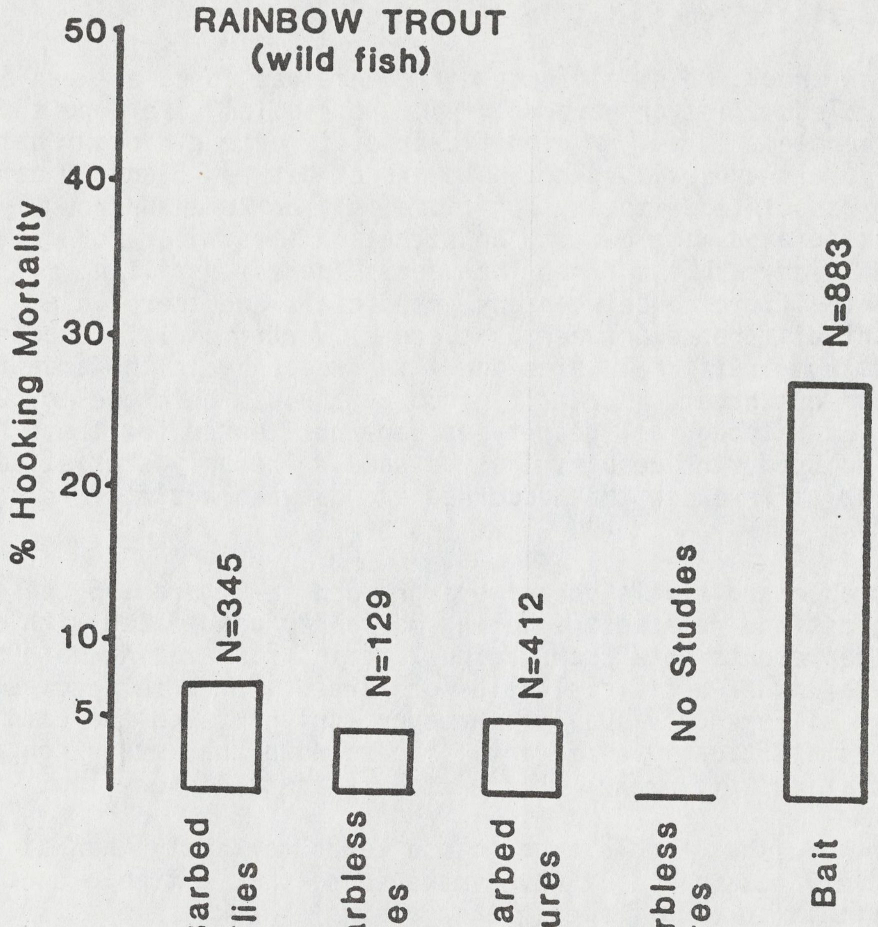

Figure 2. Hooking mortality associated with various gear and bait.

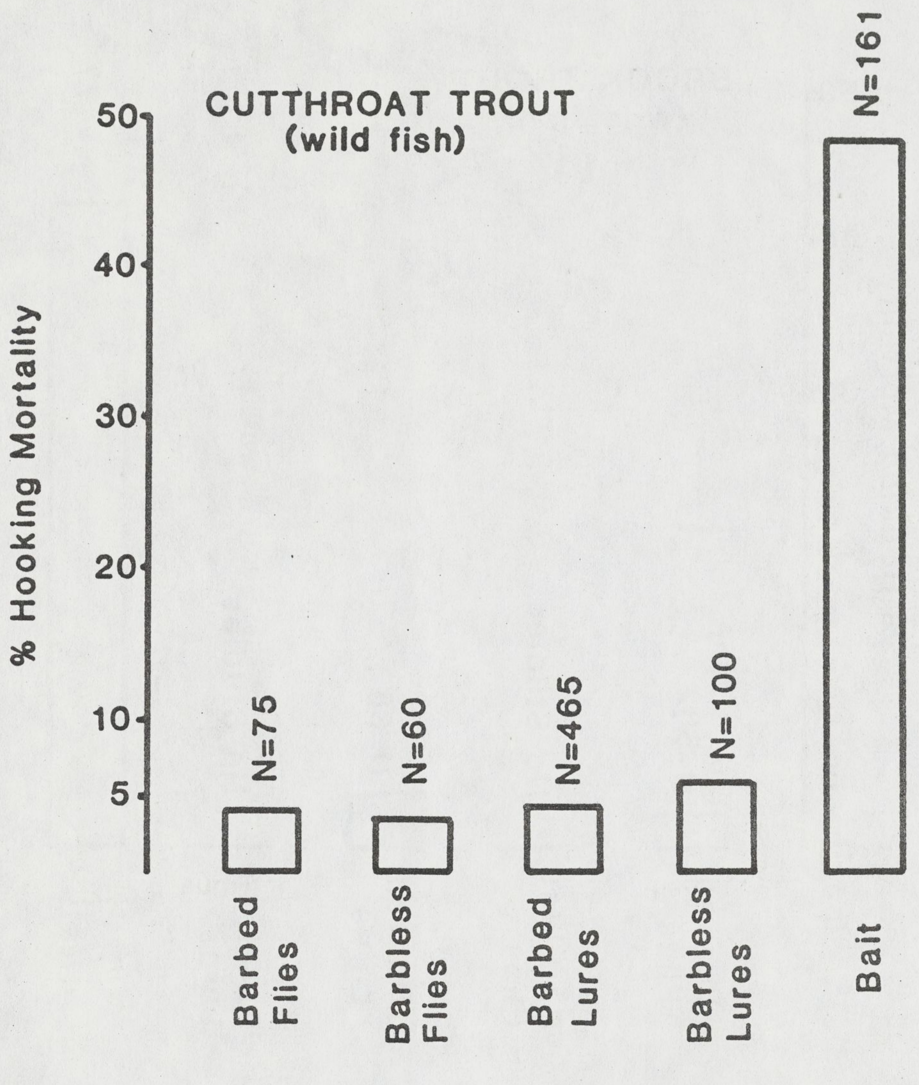

Figure 3. Hooking mortality associated with various gear and bait.

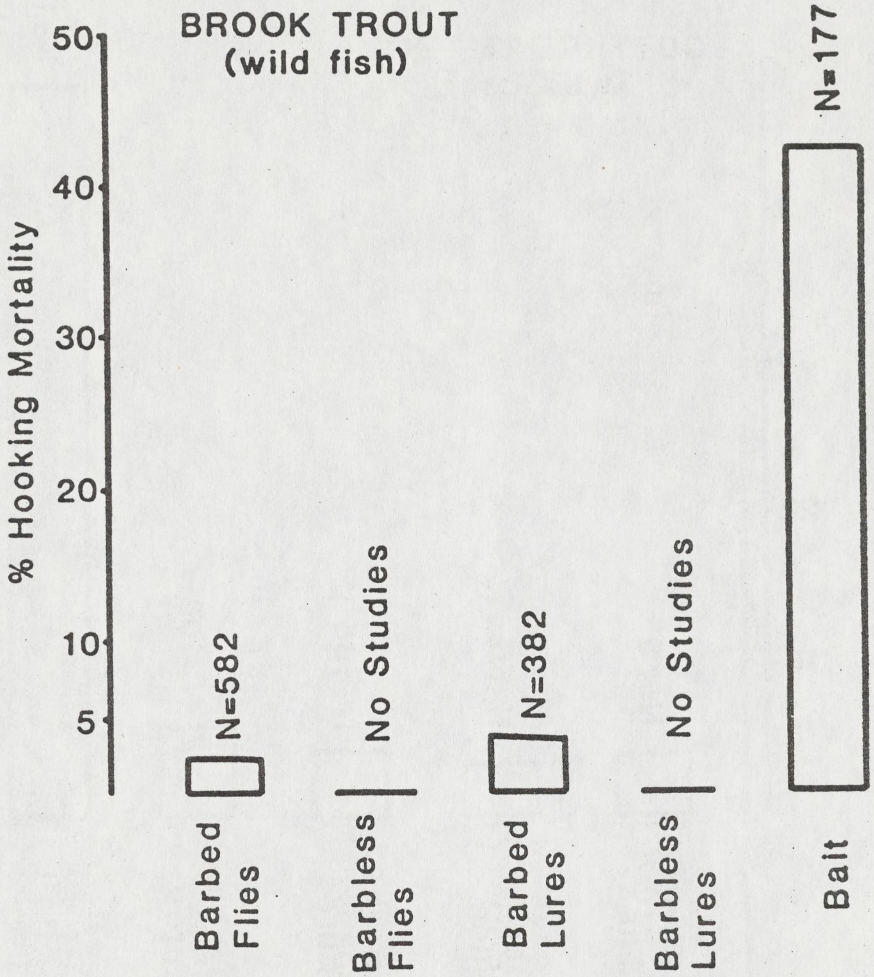

Figure 4. Hooking mortality associated with various gear and bait

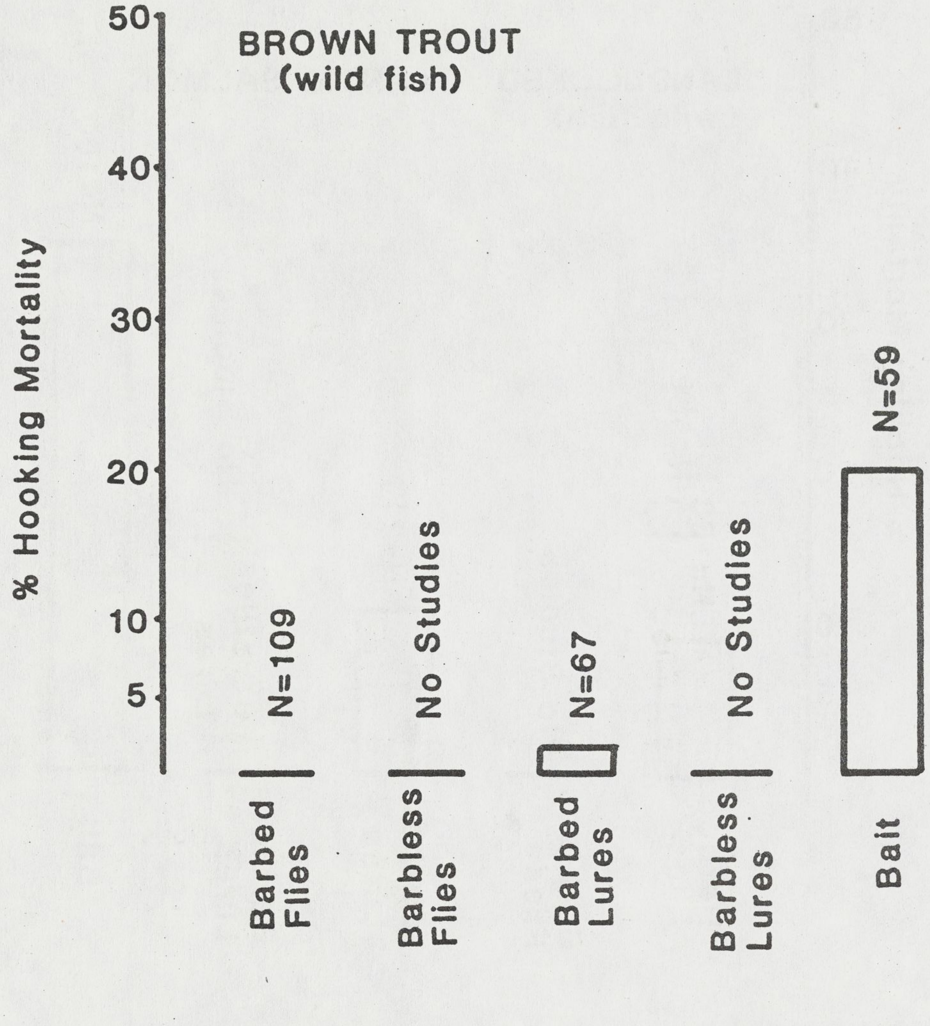

Figure 5. Hooking mortality associated with various gear and bait

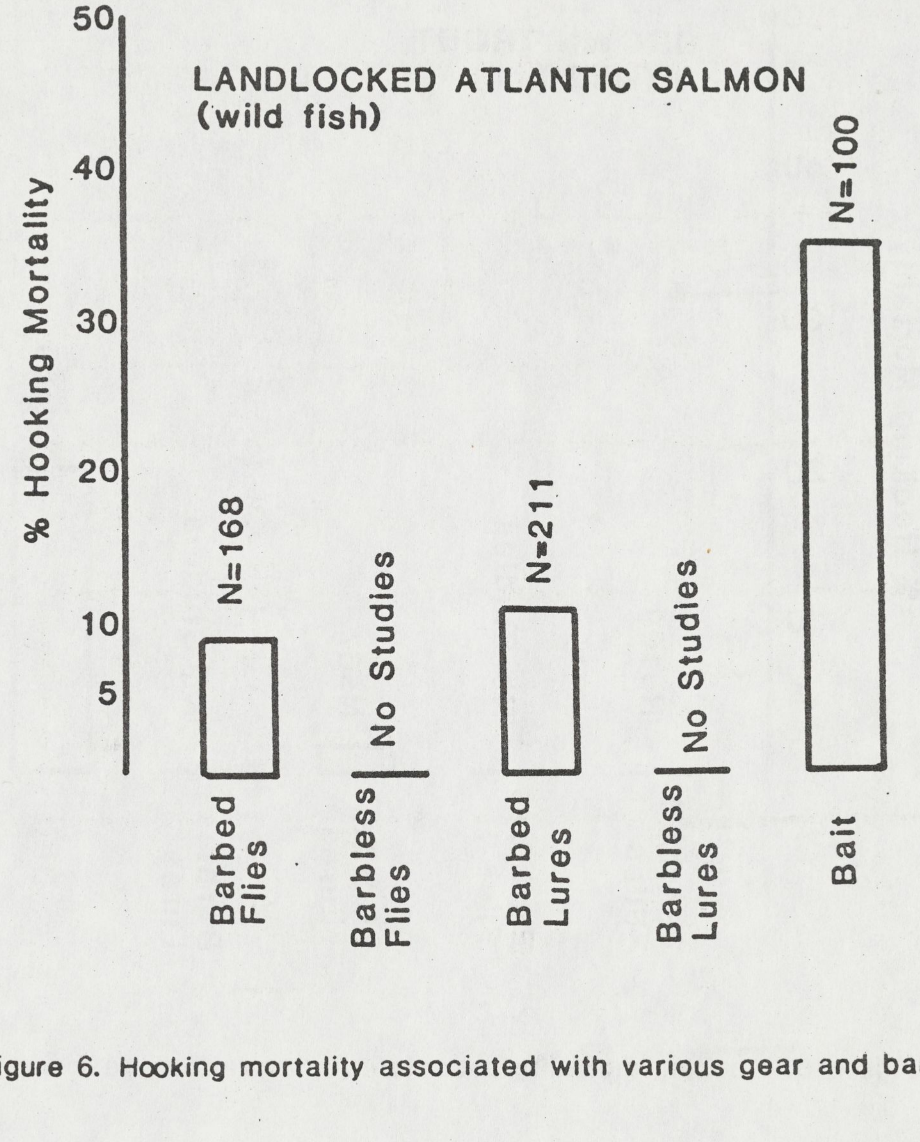

Figure 6. Hooking mortality associated with various gear and bait.

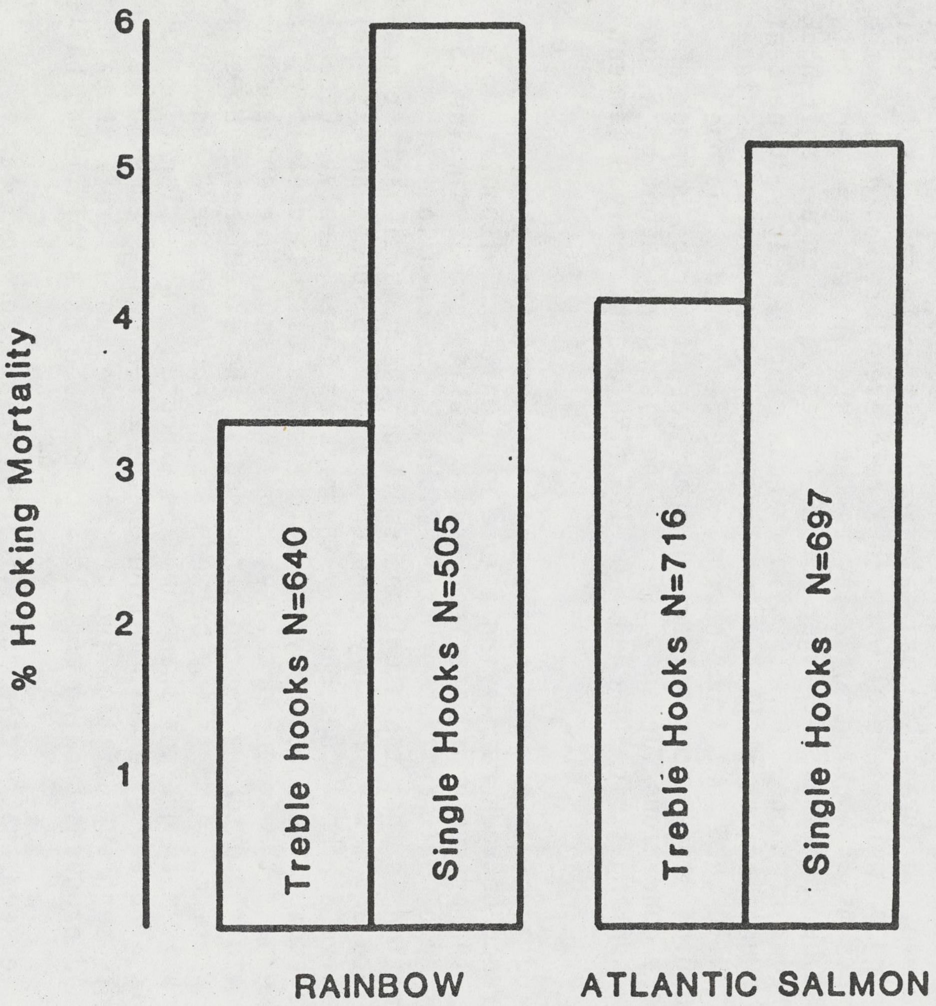

Figure 7. Comparison of hooking mortality betyween lures with treble hooks and single hooks.

were not different from each other. It was only apparent in fish greater than 175mm. This was likely related to smaller hooks being engulfed more deeply than larger hooks. Although differences occur, we must not lose perspective. Mortality on #2 hooks was 20.4 percent, 44 percent #4 hooks and approximately 41 percent for #8 hooks. All are still quite high. Hulbert and Engstrom-Heg (1980) found #4 hooks caused more mortality than #2 or #6. This does not support the highly accepted theory that smaller hooks produce higher mortality. With the limited information on hook size vs. mortality, it would be unwise to encourage regulations involving hook size. However, the available data indicate further investigations are warranted.

Finally, some comments should be made related to trolling with bait, and retrieving lures with bait attached. It would seem likely that attaching a small piece of worm to a retrieved lure would cause the same or similar hooking mortality as the lure alone. However, this may not be the case. Stringer (1967) fished worms on a single hook attached to a spoon. Of 239 wild rainbow caught, nearly 36 percent died. Hunsaker, et al (1970) trolled worms behind a set of spinners. Of 161 wild cutthroat trout caught, 48 percent died. The one confounding study was completed on sport caught spring chinook under hatchery conditions (Jensen, 1958). The fish were caught on a lure with a herring strip attached. Of 125 fish caught, only 8 percent died.

It is quite clear on wild rainbow and cutthroat that there is a difference between retrieving a lure with bait and without bait. The presence of bait increases mortality and is similar to mortality of bait drifted or still fished. The only logical explanation is that the sight and smell of the natural bait attached to a lure and moving rapidly through the water produces an extremely aggressive strike. Consequently the hook is taken deeply. Because of differences between hatchery and wild fish as discussed earlier, one would expect the lower mortality on hatchery fish. The chinook were raised in the hatchery to the size used in the experiment. However, the difference in mortality between the chinook and the 2 resident species is much greater than would be expected. No explanation for this is offered. The information on the 2 resident species does strongly suggest that trolling bait or retrieving a lure with bait attached produces hooking mortality comparable to still fished bait.

It would seem that little justification exists for any gear restrictions for artificials. All induce mortality of less than 10 percent. Data also indicates that the practice of using single hooks on lures may actually be causing higher mortality than treble hooks. However, in either case, the mortality would still be less than 10 percent. The most significant finding is that bait produces from 5 to 10 times more hooking mortality than artificials. There is some indication that larger hook sizes reduce mortality of both bait and lure hooked fish, but evidence is sparse. The subject does warrant further research.

Although no research has specifically been completed on juvenile steelhead and searun cutthroat trout, some comment is in order. It is extremely likely that data pertaining to resident rainbow and cutthroat trout is applicable to juvenile steelhead and searun cutthroat trout because of similar angling techniques and sizes of fish.

Steelhead

No studies have been done that directly assessed the hooking mortality of various gears on adult steelhead. Reingold (1975) removed steelhead from a trap, transported them back downstream, hooked and played them and tagged and released them. The hooked fish returned to the spawning streams in similar numbers as the unhooked. All fish were hooked in the mouth by hand before playing them. Pettitt (1977) caught hatchery adult steelhead on hook and line (flies and lures), tagged them and released them. Egg survival was compared at the hatchery between hooked and unhooked fish. No difference was found. Although both investigations provide valuable information, they lend little insight into the subject of hooking mortality on adult steelhead produced by different gear.

Table 1 presents the information available from broodstock collection records that proved of some use. The records were not retained to determine hooking mortality, however. Probably the most important question related to steelhead fishing is: does bait fishing cause as high a mortality rate as occurs on resident species? The information gathered from Canada clearly indicates that fishing for winter steelhead with eggs produces only 7 percent hooking mortality. Egg fishing is the most common bait used for steelhead. Similar data have been collected in Washington, however data on gear has not been as clear. One must realize that this is a worst case situation, because fish are held for up to 5 months in hatcheries before spawned. It was not possible to isolate hooking mortality from holding mortality. However, the evidence suggests that hooking mortality associated with eggs on winter run adult steelhead is less than 10 percent. In the 2 sets of data with higher mortality, the fish were tethered through the gills for several hours before transport to a hatchery. This possibly injured some fish critically.

In conversations with knowledgeable steelhead fishermen, one thing stands clear. That is that all claim the overwhelming majority of egg caught winter run fish are hooked in the mouth and therefore not severely injured. Fish are likely hooked in the mouth because eggs are picked up very delicately and dropped quickly if the hook is not set immediately. As mentioned earlier, anatomical hooking site as it related to mortality will be discussed later.

At this time no information on hooking mortality associated with summer run adults is available. The only general opinion picked up in discussions with knowledgeable anglers and biologists is that summer run fish are more aggressive. This coupled with higher water temperatures and a more actively feeding fish may cause higher

Table 1. Data summary of winter steelhead hooking mortality.

Gear	% Mortality	N[b]	°C	Length (mm)	Origin[a]	Time Held	Location	Author
95% eggs	7	1100-1200	4.4	---	80% wild	1 wk-5 mo	B.C.	Hooten, 1983[c]
Lures & eggs	9	34	12.8	---	---	weeks	Wash.	Paulsen, 1983[c]
80% lures	11	235	---	---	---	weeks	Wash.	Kraemer, 1983[d]
---	12	121	12.8	---	---	weeks	Wash.	Paulsen, 1983[d]

[a] Definition in text.

[b] Fish taken over several years.

[c] Fish held in tubes while on river.

[d] Fish tethered through gills while on river.

mortalities than on winter run fish. At this time, however, conclusions on summer run steelhead with regard to gear should be consistent with winter runs until the subject is researched further in the field.

Factors Affecting Hooking Mortality

Initial vs. Delayed Mortality

The vast majority of fish injured seriously while hooked die within the first 48 hours (Falk, et al, 1974; Marnell and Hunsaker, 1970; Hunsaker et al, 1970; Stringer, 1967; Warner and Johnson, 1978). The fish included in those studies were held for at least 10 days (Warner and Johnson, 1978, only 2 to 5 days). Stringer, 1967, kept track of mortality every 12 hours and the results are shown in Figure 8. There seems to be little difference in gear type.

Some variations do occur. Klein (1965) showed that fish caught on treble hooks may die over a slightly longer period than those caught on single hooks (Figure 9). Because Klein emphasized that single hooks caused more severe injuries than treble hooks, perhaps fish injured less seriously took slightly longer to die. However, Klein only held his fish for 3 days. Bouch and Ball (1966) investigated hatchery rainbows caught on lures. The mortality of those fish took place gradually over 10 days. However, the authors chose to exclude bleeding fish from their research and the sample size and methods were difficult to determine from the text.

The situation appears to be different for swallowed hooks left in. Mason and Hunt (1967) allowed rainbow trout to swallow baited hooks. Some were left in (leader clipped) and others were removed. For trout with the hook removed, 96 percent died the first day of the 4 month period. For the group with the hook left in, almost 50 percent died the first day with the remainder dying slowly over the next 2 months of the 4 month period. Hulbert and Engstrom-Heg (1980) found similar delayed mortality for deeply hooked brown trout with hooks left in. The results of these 2 investigations will be discussed further in the next section.

Data indicate that virtually all mortality associated catching a fish, removing the hook and releasing it takes place during the first 24 to 48 hours. Some less seriously injured fish may die up to a week or 10 days later, however, in most circumstances this appears insignificant.

Handling Mortality

Wydoski (1977) reviewed the literature on physiological responses to hooking and handling. Blood chemistry definitely changes, with several days sometimes required to reach normal levels. However, there is little supporting evidence of the theory that hooking a fish, playing it to exhaustion and releasing it will cause its death. Marnell and Hunsaker (1970) investigated that theory on wild cutthroat

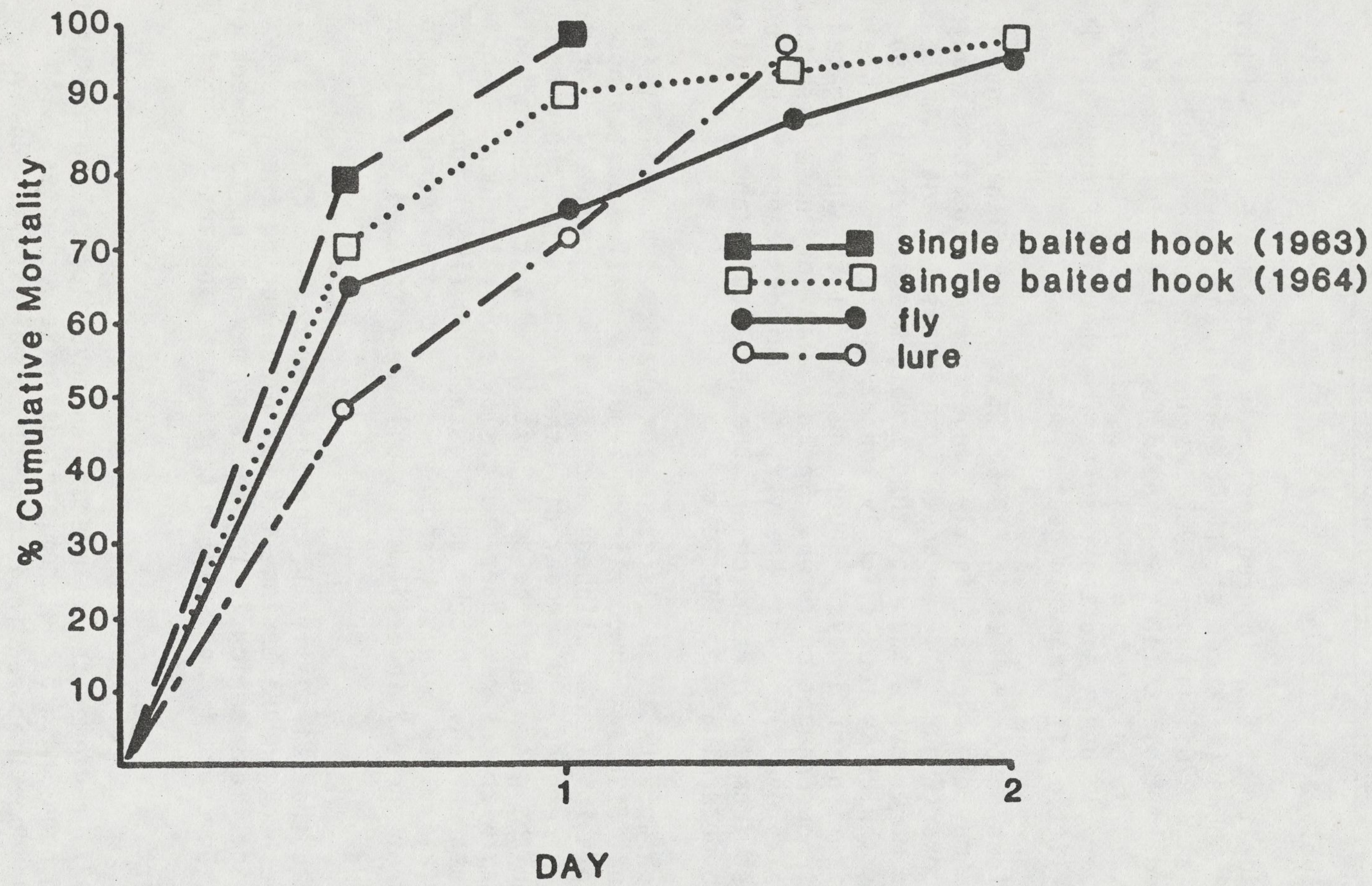

Figure 8. Cumulative mortality of wild rainbow trout caught on three types of gear (Stringer, 1967). Fish held for 10 days at 15-17°C.

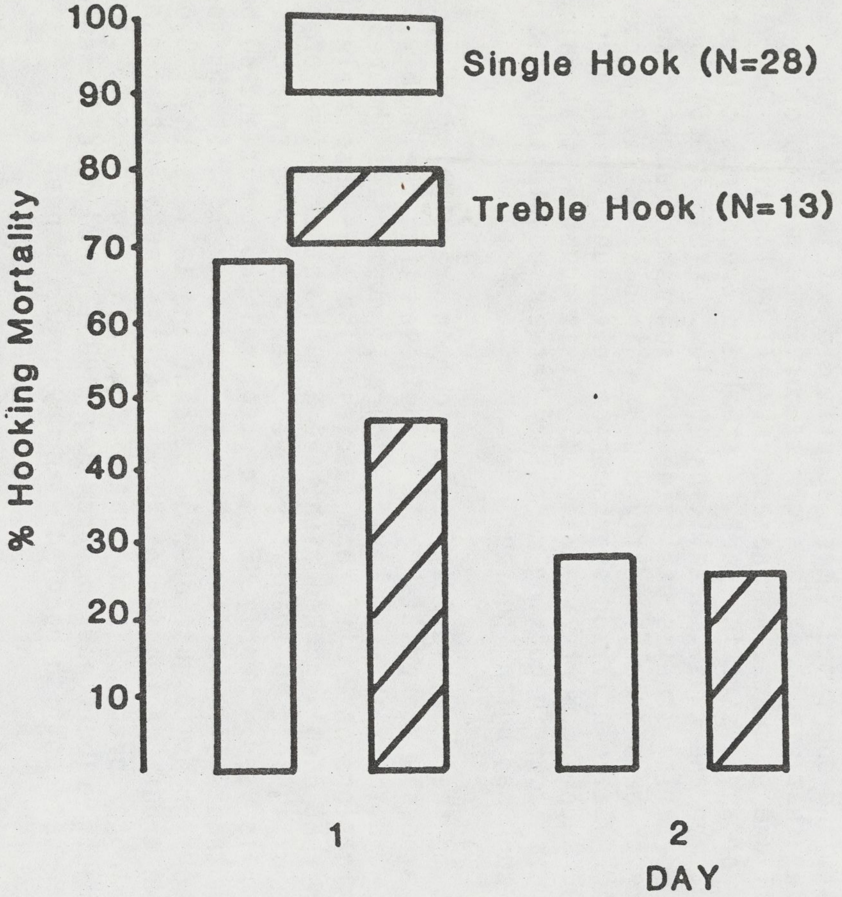

Figure 9. Effect of delayed hooking mortality in hatchery rainbow trout from two types of hooks on lures (Klein, 1965). Fish held for 3 days at 14.5° C.

(Figure 10). There was no significant difference between controls (fish hooked and retrieved immediately), fish played for 5 minutes and fish played for 10 minutes. Horak and Klein (1967) reported that only 7.9 percent of 101 fish hooked on flies and lures and played to exhaustion died.

No investigations addressed the subject of hook removal time as it relates to mortality of various gear types. Falk, et al (1974) generally observed that barbless hooks require less time to remove than barbed hooks. However, no significant difference in mortality was found between the 2 hook types. Most biologists and sportsmen questioned agree that hook removal time is decreased with barbless hooks. The data do not, however, indicate that mortality is altered. It is likely that hook removal times do vary between gear types, but not significantly enough to overshadow mortality caused by the hook injury itself.

Some criticism of hooking mortality studies has arisen implying that results are not valid because of differences in handing between biologists and sportsmen. Most studies did not identify who fished. In studies that did identify anglers, most were made up of agency personnel and students, not necessarily all biologists. The vast majority of anglers taking part in steelhead broodstock collections are sportsmen and those mortalities are low. Klein (1966) conducted hooking mortality studies utilizing 1109 sportsmen caught fish. Total mortality on barbed lure and fly caught rainbows was 11.2 percent. Klein (1974) also utilized sportsmen on bait caught rainbows (ice fishing). Hooking mortality was 23%. It is doubtful that major differences occur in hooking mortality between people involved in studies and the angling public.

Finally, is there any validity to the common practice of leaving the hook in a deeply hooked fish? It is believed that the hook will dissolve--and the fish will live. Figure 11 summarizes the results of 2 investigations on 2 different species. There is absolutely no question that deeply hooked fish have a much better chance of survival if the hook is left in than if removed even when some type of extractor is used. Nearly 95 percent of rainbow trout and 60 percent of brown trout will die if the hook is removed. If left in, mortality of rainbows drops to just over 30 percent and to less than 20 percent for brown trout. Autopsies of surviving fish revealed that many hooks were no longer present in the gut of the fish. In the same study of brown trout, Hulbert and Engstrom-Heg (1980) found no difference in mortality between fish handled with dry or wet hands.

The evidence suggests that some slight differences in mortality associated with hooking and releasing a fish may occur, though none are likely significant enough to overshadow the mortality actually caused by the hook injury itself. The one outstanding exception to this is the important advantage of leaving the hook in a fish that

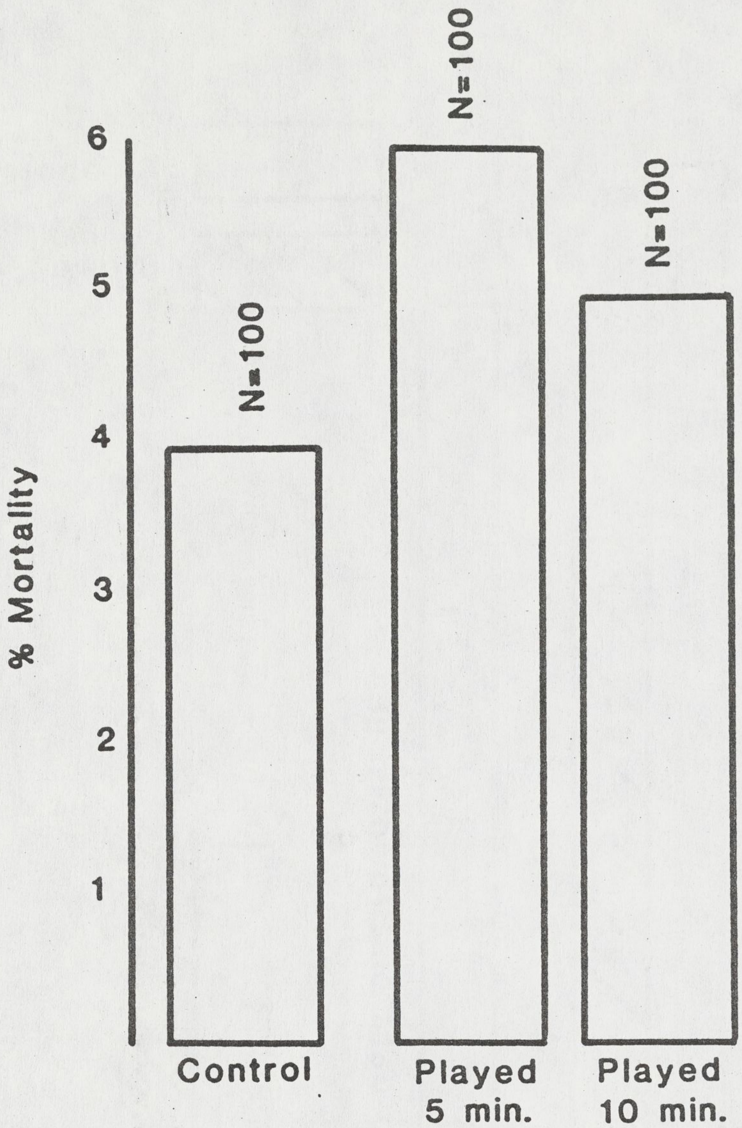

Figure 10. Mortality of wild cutthroat trout caught on lures and played for 5 and 10 minutes. (Marnell and Hunsaker, 1970)

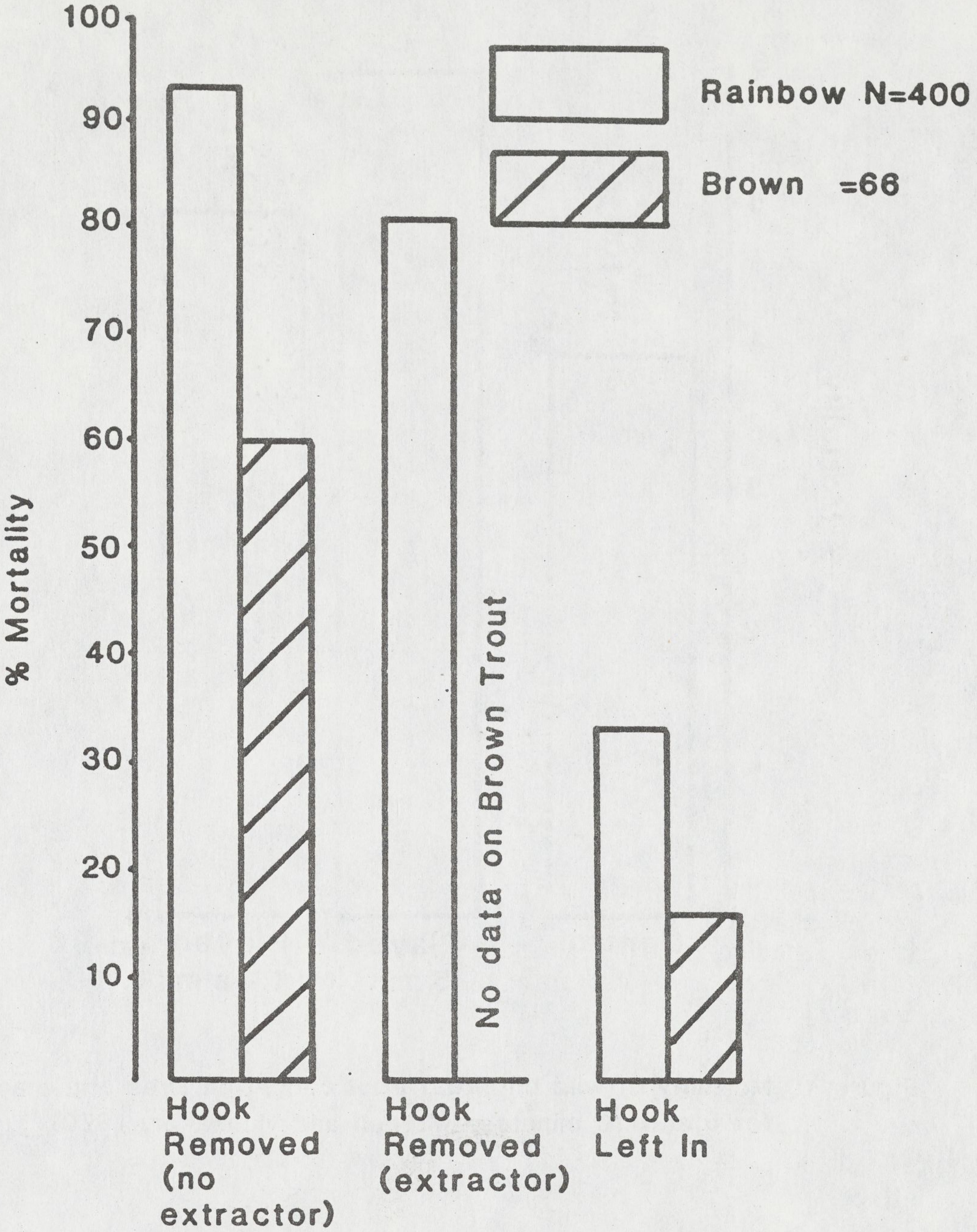

Figure 11. Differential mortality of deeply hooked rainbow trout (Mason and Hunt, 1967) and brown trout (Hulbert and Engstrom-Heg, 1980) related to handling procedures. All fish were caught on worms.

has swallowed it.

Temperature

Many authors suggested that higher temperatures produce higher hooking mortality. However, few thoroughly examined the subject. Klein (1965) observed a general increase in mortality of lure caught rainbow trout as water temperature rose. Benson and Bulkley (1963) observed an increase in mortality of lure caught cutthroat trout with increasing temperature. However, Marnell and Hunsaker (1970) could find no difference in hooking mortality of lure caught cutthroat trout over a water temperature range of 2.7 C to 16.7 C. Dotson (1982) did find a very clear relationship between water temperature and hooking mortality for lure caught hatchery rainbow trout (Figure 12).

Although results are unclear, it is likely that a relationship does occur. As temperatures increase metabolism, feeding and activity levels all increase (Mongillo, 1976). The increased levels may cause more aggressive feeding and fighting, leading to more serious injuries. However, based on the best information available (Dotson, 1982), even at the high end of the temperature spectrum, rainbow trout mortality from artificial lures is still less than 9%.

Anatomical Site of Hooking

Throughout this report, it has been suggested that deeply hooked or critically hooked fish have higher mortality. This section will describe mortality as it relates to site of hooking and how different gear types affect frequency of hooking in critical areas. Figure 13 is presented to aid in the discussion of the anatomy of the fishes' feeding parts.

Figure 14 presents the mortality of 3 salmonid species that results when hooked in each location. The rainbow trout seems to be the most sensitive species with mortality greater than 40 percent from eye, tongue, esophagus or gill hooking. The brook trout and atlantic salmon only had high mortalities associated with gills and the esophagus. The esophagus and gills are clearly the most deadly area to hook a fish with evidence suggesting that the tongue and eyes are also very critical. Mortality associated with the mouth and jaws remains low. It is apparent that fish hooked in non-critical areas have a much higher chance of survival.

The next step is to determine if various gear types produce higher incidences of hooking in a critical area. Figure 15 depicts those results quite clearly. Critical areas were defined as gills, esophagus, eyes and tongue. Please note that sufficient data were not available in the literature to present the same species under all three circumstances. Rainbow trout was the one exception.

It is quite obvious why bait fishing produces a significantly higher mortality than use of artificials. The use of worms causes hooking in

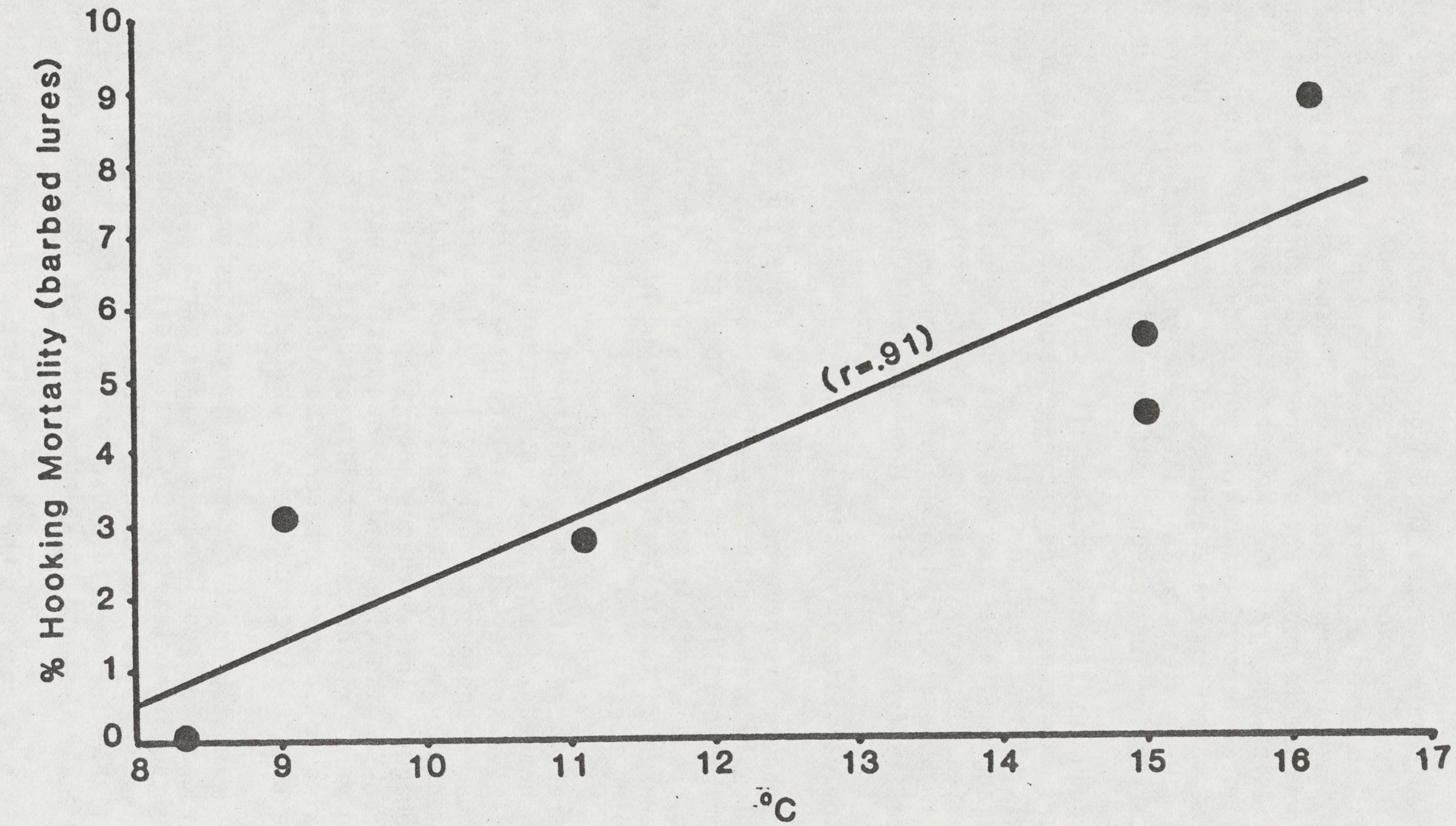

Figure 12. Regression of hatchery rainbow trout hooking mortality on rising water temperatures(Dotson, 1982).

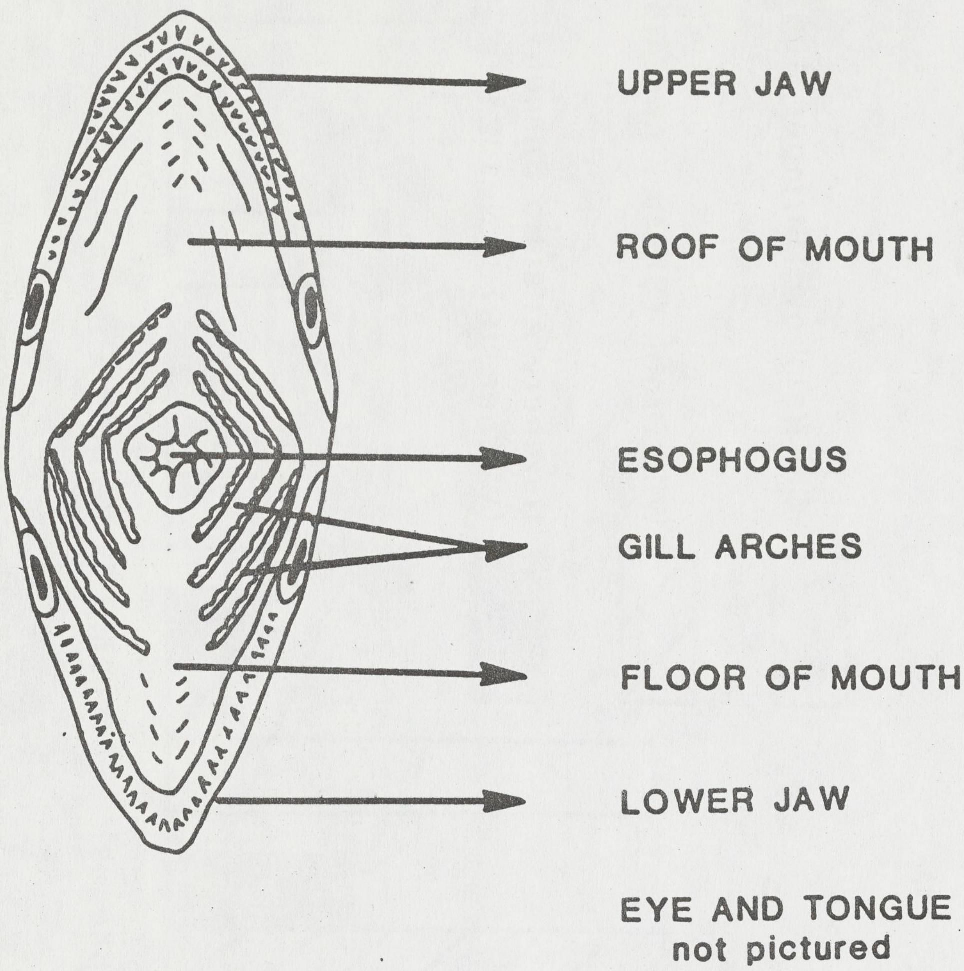

Figure 13. Diagrammatic view of a salmonid mouth illustrating hook placement areas.

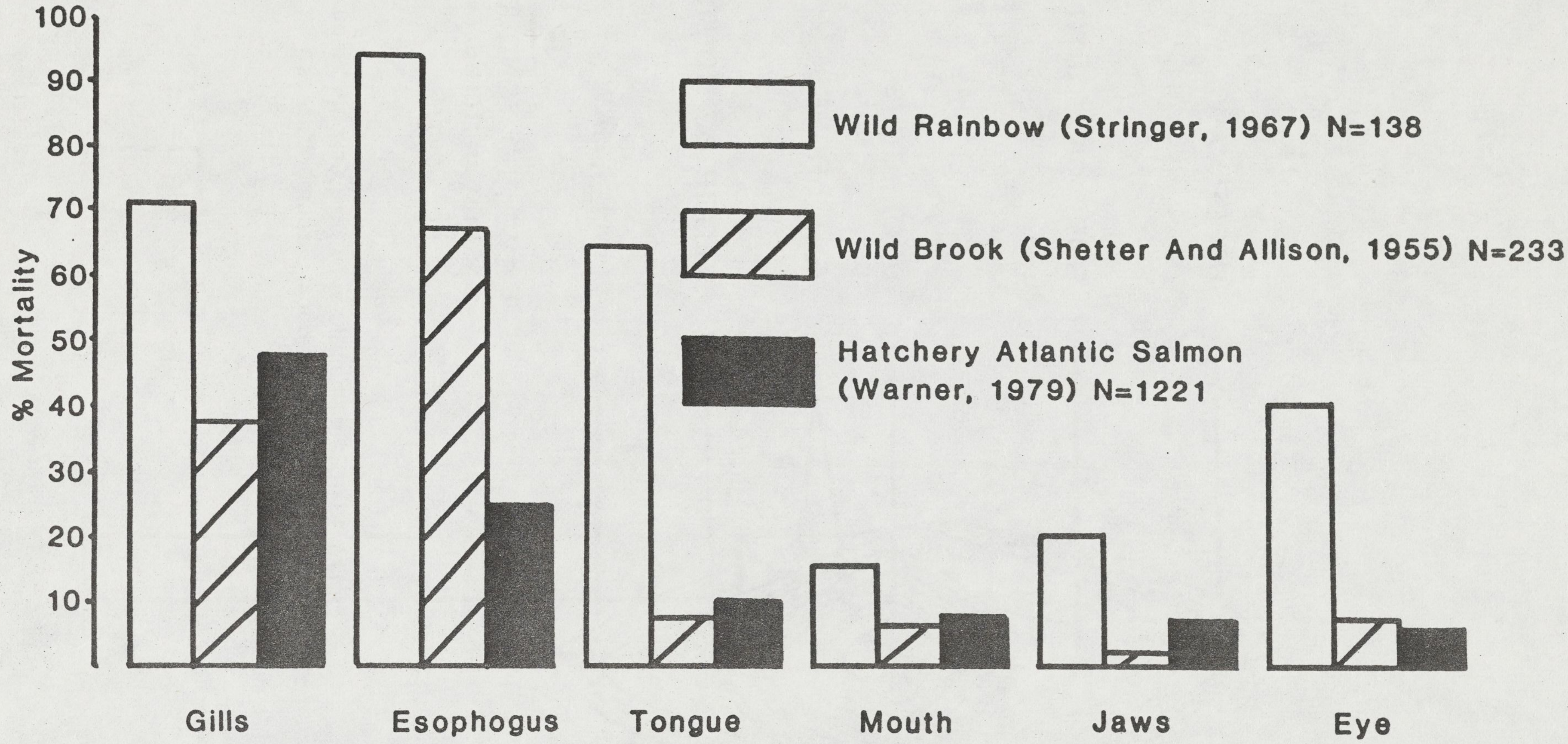

Figure 14. Mortality of three species of salmonids caught on various gear types related to anatomical hooking site.

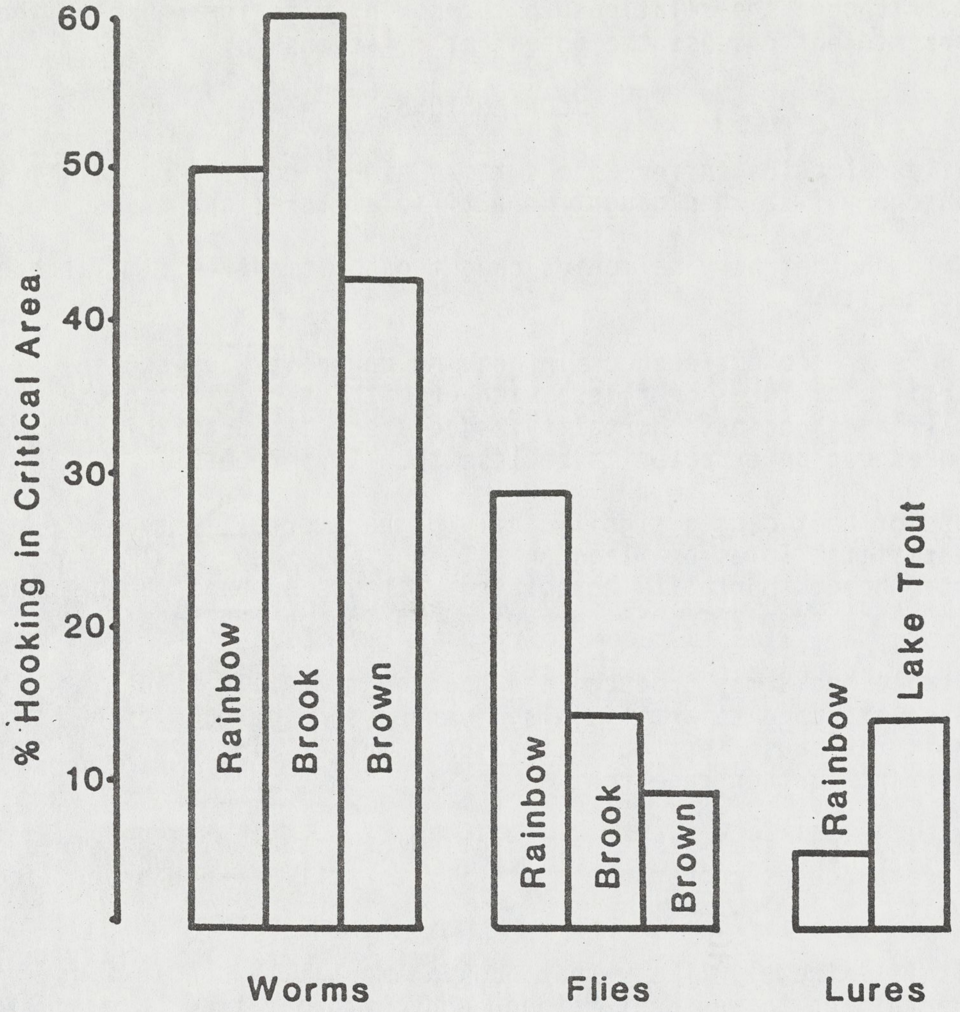

Figure 15. Percent hooking occurance in critical areas (Esophogus, gills, tongue, eye) for various species and gear types. Data from Shetter and Allison, 1955, Falk et al, 1974 and Stringer, 1967.

Cartographer Susan Peterson

critical areas roughly 50 percent of the time while artificials generally penetrate a critical area less than 10 percent of the time. These percentages are comparable with the actual hooking mortalities produced by use of these gear types. For some unexplained reason, the fly caught rainbow were hooked in the eye frequently, causing the high occurrence of hooking a critical area for that species.

A comment should be made regarding hook penetration and bleeding. Warner and Johnson (1978) observed that 86 percent of bleeding fish died. Although the relationship to hooking site is probable, the authors did not discuss the potential relationship.

CONCLUSIONS

1. Wild salmonids suffer 2 to 4 times higher hooking mortality than hatchery fish when caught on artificial lures and flies.

2. Wild and hatchery salmonids caught on bait suffer similar hooking mortality.

3. There are no differences in hooking mortality between any artificial lures or flies, with or without barbless hooks on any salmonid species. Mortality associated with artificial flies and lures can be expected to be less than 10 percent.

4. Use of bait causes significantly higher mortality than use of artificial lures or flies on all species except adult winter run steelhead. Mortality associated with use of bait can be expected to range from 20 to 50 percent depending on the species.

5. Treble hooks may produce less hooking mortality than single hooks when attached to artificials. Larger single hooks fished with bait may cause less mortality than smaller single hooks. Both warrant further research.

6. It is very likely that bait trolled or attached to a retrieved lure produces comparable mortality to still fished or drifted bait.

7. It is extremely likely that hooking mortality conclusions pertaining to resident rainbow and cutthroat trout are applicable to juvenile steelhead and searun cutthroat because of similar angling techniques and sizes of fish.

8. Use of eggs for winter run steelhead fishing produces less than 10 percent hooking mortality.

9. From 90 to 95 percent of hooking mortality occurs within 48 hours after capture.

10. Although some differences in mortality occur because of various handling techniques of anglers, it is unlikely that it is

significant enough to overshadow the mortality actually caused by the hook injury itself. The one exception to this would be leaving the hook in a deeply hooked fish.

11. There likely is a positive relationship between temperature and hooking mortality. However, for lure caught rainbow trout, even at the high end of the temperature tested, mortality was still less than 10 percent.

12. Fish hooked in the gills, esophagus, tongue or eye are approximately 4 times more likely to die than those hooked in the mouth or jaw.

13. Bait fishing for salmonids, with the exception of adult winter steelhead, causes hook penetration in critical areas approximately 50 percent of the time. Artificials penetrate critical areas less than 10 percent of the time.

RECOMMENDATIONS

1. There is no valid technical basis for requiring the use of single barbless hooks, as opposed to all other artificial lure types, in order to minimize gear-induced mortalities on trout. All current regulations requiring single barbless hooks should be changed to artificials only.

2. There is a firm technical basis for prohibiting the use of bait for trout fishing, except in the case of adult steelhead angling. At a very minimum, the use of bait must be banned when hooking mortality losses threaten the capability of a natural population to offset total mortality with recruitment (i.e. gear-induced overfishing).

3. The use of bait is basically incompatible with management of natural self-sustaining trout populations. If no minimum size limits or minimal standards are applied, then signficant mortalities can still be applied to those small fish which are released voluntarily. If higher minimum sizes are needed to meet basic conservation needs of the trout resources, then the situation is exacerbated by the addition of mortalities from mandatory release.

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APPENDIX

Table 2 . Data summary of Rainbow trout hooking mortality studies. Grouped by gear type.

Gear	% Mortality	N	°C	Length (mm)[a]	Origin[b]	Time Held	Location	Author
Barbed Fies	11.2	80	---	153	Wild	---	Michigan	Shetter & Allison, 1955
	1.3	75	---	170	Wild	1 day	Michigan	Shetter & Allison, 1958
	7.9	101	---	185-195	Hatchery	5 weeks	Colorado	Horak & Klein, 1967
	7.9	190	15-17	199-344	Wild	2 days	B.C.	Stringer, 1967
	4.1	630	8.9-16.1	228	Hatchery	30 days	Montana	Dotson, 1982
Barbless Flies	3.9	129	15.5	---	Wild	---	Washington	Wydoski, 1970
Barbed Flies & Lures	11.2	1109	---	249	Wild	3 days	Colorado	Klein, 1966
Barbed Lures	6.3	271	---	172	Wild	1 day	Michigan	Shetter & Allison, 1958
Barbed Treble Lures	1.8	224	6.7	208-302	Hatchery	3 days	Colorado	Klein, 1965
	4.8	271	14.4	173-292	Hatchery	3 days	Colorado	Klein, 1965
	2.8	145	15-17	199-344	Wild	2 days	B.C.	Stringer, 1967
Barbed Single Lures	1.3	233	6.7	208-302	Hatchery	3 days	Colorado	Klein, 1965
	10.3	272	14.4	173-292	Hatchery	3 days	Colorado	Klein, 1965
Bait, Barbed	35.4	79	---	153	Wild	---	Michigan	Shetter & Allison, 1955
	35.9	239	15-17	199-344	Wild	2 days	B.C.	Stringer, 1967
	23.0	565	4	150-175	Wild	3 days	Colorado	Klein, 1974

[a] approximate

[b] definition in text

Table 3 . Data summary of cutthroat trout hooking mortality studies. Grouped by gear type.

Gear	% Mortality	N	°C	Length (mm)[a]	Origin[b]	Time Held	Location	Author
Barbed Flies	4.0	75	4.4-16.7	250-425	Wild	10 days	Wyoming	Hunsaker, et al, 1970
	.4	256	7	150	Hatchery	30 days	Idaho	Bjornn, 1983
Barbed Single Flies	0	105	11.1	208	Hatchery	30 days	Montana	Dotson, 1982
Barbed Treble Flies	0	105	11.1	208	Hatchery	30 days	Montana	Dotson, 1982
Barbless Flies	3.3	60	4.4-16.7	250-425	Wild	10 days	Wyoming	Hunsaker, et al, 1970
	.7	264	7	150	Hatchery	30 days	Idaho	Bjornn, 1983
	.9	105	11.1	208	Hatchery	30 days	Montana	Dotson, 1982
Barbed Treble Lure	2.7	113	4.4-16.7	250-425	Wild	10 days	Wyoming	Hunsaker, et al, 1970
	5.1	352	2.3-16.7	274-442	Wild	10-30 days	Wyoming	Marnell & Hunsaker, 1970
	2.4	209	7	150	Hatchery	30 days	Idaho	Bjornn, 1983
Barbless Treble Lure	6.0	100	4.4-16.7	250-425	Wild	10 days	Wyoming	Hunsaker, et al, 1970
	1.2	166	7	150	Hatchery	30 days	Idaho	Bjornn, 1983
Bait, Barbed	48.4	161	4.4-16.7	250-425	Wild	10 days	Wyoming	Hunsaker, et al, 1970

[a] approximate

[b] definition in text

Table 4. Data summary of brook trout hooking mortality studies. Grouped by gear type.

Gear	% Mortality	N	°C	Length (mm)[a]	Origin[b]	Time Held	Location	Author
Barbed Flies	2.7	400	---	90-178	---	15-30 days	Michigan	Westerman, 1932
	2.9	135	---	150	Wild	---	Michigan	Shetter & Allison, 1955
	1.7	484	---	159-203	Hatchery	7-10 days	Michigan	Shetter & Allison, 1955
	4.3	23	---	114-176	Wild	1 day	Michigan	Shetter & Allison, 1955
	0	36	---	114-176	Hatchery & Wild	1 day	Michigan	Shetter & Allison, 1955
	1.4	424	---	169	Wild	1 day	Michigan	Shetter & Allison, 1958
Barbed Lure	3.9	382	---	190	Wild	1 day	Michigan	Shetter & Allison, 1958
Bait, Barbed	8.7	400	---	90-178	---	15-30 days	Michigan	Westerman, 1932
	37.5	550	---	159-203	Hatchery	7-10 days	Michigan	Shetter & Allison, 1955
	32.3	34	---	114-176	Hatchery & Wild	1 day	Michigan	Shetter & Allison, 1955
	48.8	45	---	114-176	Wild	1 day	Michigan	Shetter & Allison, 1955
	40.1	132	---	170	Wild	---	Michigan	Shetter & Allison, 1955
Bait, Barbless	5.6	500	---	90-178	---	15-30 days	Michigan	Westerman, 1932

[a] approximate

[b] definition in text

Table 5 . Data summary of brown trout hooking mortality studies. Grouped by gear type.

Gear	% Mortality	N	°C	Length (mm)[a]	Origin[b]	Time Held	Location	Author
Barbed Flies	0	69	---	190	Wild	---	Michigan	Shetter & Allison, 1955
	0	40	---	192	Wild	1 day	Michigan	Shetter & Allison, 1958
Barbed Lures	1.5	67	---	211	Wild	1 day	Michigan	Shetter & Allison, 1958
Bait, Barbed	20.3	59	---	190	Wild	---	Michigan	Shetter & Allison, 1955
	22.0	490	---	134-226	Hatchery	14 days	New York	Hulbert & Engstrom, 1980

[a] approximate

[b] definition in text

Table 6. Data summary of landlocked atlantic salmon hooking mortality studies. Grouped by gear type.

Gear	% Mortality	N	°C	Length (mm)[a]	Origin[b]	Time Held	Location	Author
Barbed Flies	3.9	77	14-19	293-356	Wild	2-5 days	Maine	Warner & Johnson, 1978
Barbed Single Flies	12.0	52	---	---	Wild	5 days	Maine	Warner, 1978
	4.1	319	13.3-18.9	233-328	Hatchery	3-5 days	Maine	Warner, 1979
Barbed Treble Flies	4.6	300	9-16	190	Hatchery	10-14 days	Maine	Warner, 1976
	26.0	39	---	---	Wild	5 days	Maine	Warner, 1978
Barbled Treble Lures	.3	300	9-16	190	Hatchery	10-14 days	Maine	Warner, 1976
	8.0	116	---	---	Wild	5 days	Maine	Warner, 1978
	6.0	300	13.3-18.9	233-328	Hatchery	3-5 days	Maine	Warner, 1979
Barbed Single Lures	2.7	300	9-16	190	Hatchery	10-14 days	Maine	Warner, 1976
	15.0	95	---	---	Wild	5 days	Maine	Warner, 1978
	4.6	302	13.3-18.9	233-328	Hatchery	3-5 days	Maine	Warner, 1979
Bait, Barbed	5.7	300	9-16	190	Hatchery	10-14 days	Maine	Warner, 1976
	5.7	300	13.3-18.9	233-328	Hatchery	3-5 days	Maine	Warner, 1979
	35.0	100	14-19	293-356	Wild	2-5 days	Maine	Warner & Johnson, 1978

[a] approximate

[b] definition in text

Table 7. Data summary of lake trout hooking mortality studies. Grouped by gear type.

Gear	% Mortality	N	°C	Length (mm)[a]	Origin	Time Held[b]	Location	Author
Barbed Lures	6.9	72	---	320-960	Wild	4-10 days	NWT	Falk, et al, 1974
Barbless Lures	7.0	57	---	320-960	Wild	4-10 days	NWT	Falk, et al, 1974

[a] approximate

[b] definition in text

Table 8 . Data summary of arctic grayling hooking mortality studies. Grouped by gear type.

Gear	% Mortality	N	°C	Length (mm)[a]	Origin[b]	Time Held	Location	Author
Barbed Flies	8.6	80	11-12.5	260-460	Wild	4-10 days	NWT	Falk & Gillman, 1975
Barbed Lures	17.9	39	11-12.5	260-460	Wild	4-10 days	NWT	Falk & Gillman, 1975
Barbless Lures	5.2	38	11-12.5	260-460	Wild	4-10 days	NWT	Falk & Gillman, 1975

[a] approximate

[b] definition in text

Table 9 . Data summary of chinook salmon (sport caught) hooking mortality studies. Grouped by gear type.

Gear	% Mortality	N	°C	Length (mm)[a]	Origin[b]	Time Held	Location	Author
Barbed Lures	4.3	75	---	250-500	Hatchery	30 days	Washington	Jenson, 1958
Barbed Lures with Herring Strip	8.0	125	---	250-500	Hatchery	30 days	Washington	Jenson, 1958

[a] approximate

[b] definition in text

Table 10 . Data summary of miscellaneous salmonid hooking mortality studies. Grouped by gear type.

Species	Gear	% Mortality	N	°C	Length (mm)[a]	Origin[b]	Time Held	Location	Author
Trout	Barbed Flies	5.9	51	---	---	---	---	New Mexico	Thompson, 1946
	Barbless Flies	5.0	60	---	---	---	---	New Mexico	Thompson, 1946
	Bait, Barbed	3.3	61	---	---	---	---	New Mexico	Thompson, 1946
Splake	Barbed Single Lures	5.7	157	---	274	Wild	3 days	Colorado	Klein, 1966

[a] approximate

[b] definition in text

Table 11. All rainbow trout hooking mortality studies combined by origin and gear type.

Gear	Origin[a]	% Mortality	# of Studies	N
Barbed Flies	Combined	5.4	5	1076
	Hatchery	4.6	2	731
	Wild	7.2	3	345
Barbless Flies	Combined	3.9	1	129
	Hatchery	No studies		
	Wild	3.9	1	129
Barbed Lures	Combined	4.8	3	1416
	Hatchery	4.8	1	1000
	Wild	5.0	2	412
Barbless Lures	No studies			
All artificials	Combined[b]	6.8	8	3730
	Hatchery	4.7	3	1731
	Wild[b]	8.7	6	1999
Bait	Combined	27.6	3	883
	Hatchery	No Studies		
	Wild	27.6	3	883

[a] defined in text

[b] Includes a study where barbed flies and lures were not separated.

Table 12. All cutthroat trout hooking mortality studies combined by origin and gear type.

Gear	Origin[a]	% Mortality	# of Studies	N
Barbed Flies	Combined	.7	3	541
	Hatchery	.2	2	466
	Wild	4.0	1	75
Barbless Flies	Combined	1.1	3	429
	Hatchery	.7	2	369
	Wild	3.3	1	60
Barbed Lures	Combined	3.8	3	674
	Hatchery	2.4	1	209
	Wild	4.5	2	465
Barbless Lures	Combined	3.0	2	266
	Hatchery	1.2	1	166
	Wild	6.0	1	100
All artificials	Combined	2.2	4	1910
	Hatchery	.8	2	1210
	Wild	4.5	2	700
Bait	Combined	48.4	1	161
	Hatchery	No Studies		
	Wild	48.4	1	161

[a] defined in text

Table 13. All brook trout hooking mortality studies combined by origin and gear type.

Gear	Origin[a]	% Mortality	# of Studies	N
Barbed Flies	Combined[b]	1.9	3	1502
	Hatchery	1.7	1	484
	Wild	1.8	2	582
Barbless Flies	No studies			
Barbed Lures	Combined	3.9	1	382
	Hatchery	No Studies		
	Wild	3.9	1	382
Barbless Lures	No studies			
All artificials	Combined	2.3	3	1884
	Hatchery	1.7	1	484
	Wild	2.6	2	964
Bait	Combined[b]	21.3	3	1661
	Hatchery	37.5	1	550
	Wild	42.3	1	177

[a] definition in text

[b] studies included where origin could not be determined

Table 14. All brown trout hooking mortality studies combined by origin and gear type.

Gear	Origin[a]	% Mortality	# of Studies	N
Barbed Flies	Combined	0	2	109
	Hatchery	No studies		
	Wild	0	2	109
Barbless Flies	No studies			
Barbed Lures	Combined	1.5	1	67
	Hatchery	No studies		
	Wild	1.5	1	67
Barbless Lures	No studies			
All artificials	Combined	.6	2	176
	Hatchery	No studies		
	Wild	.6	2	176
Bait	Combined	21.8	2	549
	Hatchery	22.0	1	490
	Wild	20.3	1	59

[a] definition in text

Table 15 . All landlocked atlantic salmon hooking mortality studies combined by origin and gear type.

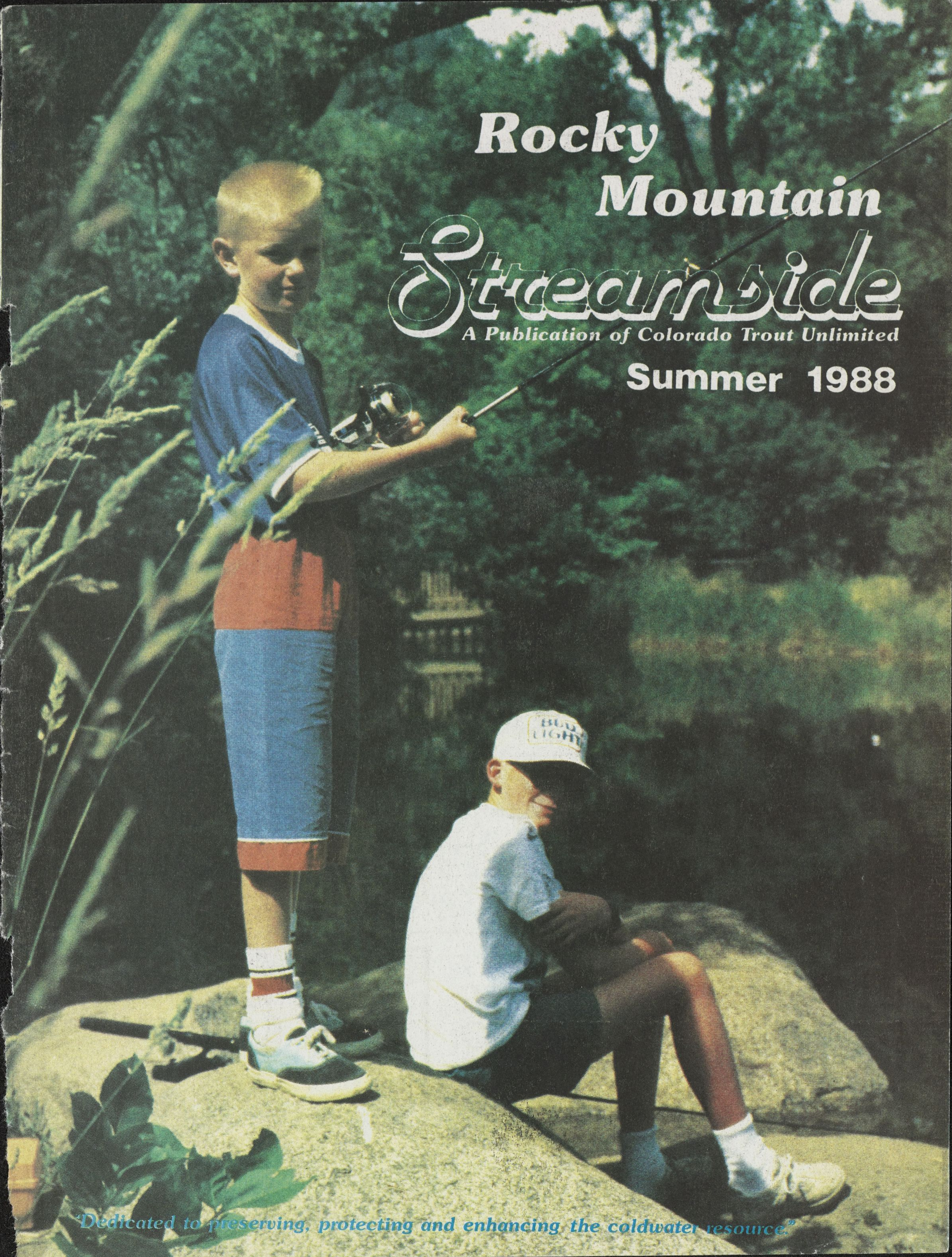
Gear	Origin[a]	% Mortality	# of Studies	N
Barbed Flies	Combined	5.1	4	787
	Hatchery	4.3	2	619
	Wild	8.9	2	168
Barbless Flies	No studies			
Barbed Lures	Combined	4.5	3	1413
	Hatchery	3.4	2	1202
	Wild	10.8	1	211
Barbless Lures	No studies			
All artificials	Combined	4.7	4	2200
	Hatchery	3.7	2	1821
	Wild	9.9	2	379
Bait	Combined	9.8	3	700
	Hatchery	5.7	2	600
	Wild	35.0	1	100

[a] definition in text

Rocky Mountain Streamside

A Publication of Colorado Trout Unlimited

Summer 1988



"Dedicated to preserving, protecting and enhancing the coldwater resource."

CTU

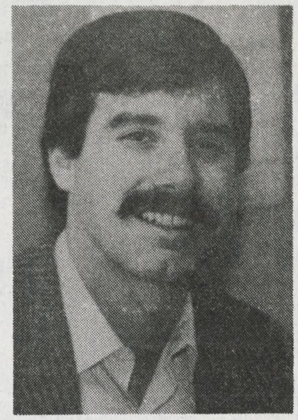
Colorado Trout Unlimited

Rocky Mountain Streamside

Editor — Dave Taylor
Contributing Editors — Hugh Gardner, Steve Trammel, Jack Sayers
Production Manager — Bob Bush
Photography — Tony Oswald
Advertising — Dave Taylor, Hugh Gardner, Steve Trammel

Rocky Mountain Streamside is published four times per year by Colorado Trout Unlimited. Send all editorial correspondence to 1557 Ogden Street, Denver, CO 80218. Phone 837-1908.

FIRST CAST



Letter from the Editor
by Dave Taylor

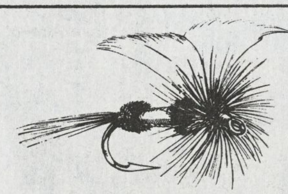
As a wise TUer once said, "Conservation without money equals nothing." Indeed, those are words of wisdom. Without bucks to support itself, Trout Unlimited and coldwater conservation are dead in the water.

Thankfully, through the support of members, businesses and large corporations, TU manages to do a decent job of preserving and protecting our trout fisheries. I don't mean to imply that we don't need more support. The more money we have, the more effective we can be. With more money, we can do more than just a decent job.

In March, Colorado TU held its premier fund raiser, our annual Denver auction. This year's results were superb. More than 200 people attended and bidding was spirited. More than 175 auction items were donated by members, fly shops, guides, outfitters, tackle manufacturers, businesses and corporations from throughout the country. Their desire to donate auction and raffle items is firmly rooted in the fact that they believe in Trout Unlimited. They are willing to pay the price for conservation. They are willing to help pick up the TU tab.

With more than 400 TU chapters across the nation, our supporters—particularly the local fly shops and outfitters—are constantly bombarded with requests to aid fund raisers. Keep in mind that most of these are small businessmen, and most are already carrying more than their fair share. When you do ask, please be courteous in your requests and be understanding if shop owners or guides are not able to donate to your particular cause. There is a limit to what they can afford to donate.

With that in mind, I ask you to please read the list of 1988 TU auction and raffle donors in this issue. Their support is amazing. These are not rich folks. They are damn committed, though. On behalf of all TU members, I thank them dearly. Because they support Trout Unlimited—because they pay for trout conservation—I ask you to thank them too. One easy way is to support their businesses.



COVER PHOTO:

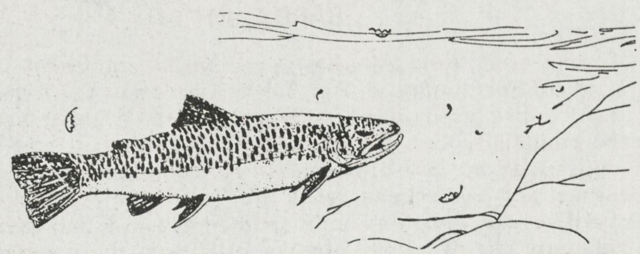
SUMMER FUN !
Boulder Kids Pond
photo: Bob Bush

Thoughts on Barbless Hooks

by Bob Behnke

A few months ago, I served as the "summarizer" for the 1987 Catch-and-Release Symposium held in California. In my symposium paper, to be published in the proceedings, I discussed problems of fish management and people management. An important consideration for broader implementation of special regulations concerns public acceptance of proposed regulations: The broader the base of support, the larger the role that special regulations will play in a state's management program. There are two aspects affecting broad-based public support. The first concerns agency credibility; that is, demonstrating the biological expertise of an agency by carefully selecting waters and trout populations that will most favorably respond to reduced angling mortality—establishing a record of success. The second aspect concerns the proportion of all anglers that may be excluded from special regulation waters because of gear restrictions (the magnitude of the potential opposition to special regulations).

It is clear that for trout fisheries where a high proportion of caught-and-released fish must survive if catch-and-release is to succeed, bait fishing must be banned. Thus, we potentially antagonize a large segment of license buyers and voters and must recognize the potential for a buildup of opposition that can result in a backlash (bills have been introduced into some state legislatures to prohibit all catch-and-release regulations). What other types of angling besides bait fishing should be banned from catch-and-release waters? A recent survey in Colorado determined that about 11% of our licensed anglers are solely or predominantly fly fishers, but only a small fraction of this 11% might be considered no-kill, barbless-hooks-only people. This small group of purists typically generate zealous lobbying for more catch-and-release waters, which is important to spread the word of the vital significance of special regula-



tions for wild trout fisheries. Unfortunately, many of them also have a zealous and unshakable faith that catch-and-release regulations are meaningless without a barbless-flies-only restriction. A barbless-flies-only restriction shrinks the potential base of support for special regulations from about 50% of the licensed anglers (who fish with flies and artificial lures) to less than one percent, which obviously raises the question: Are barbless hooks necessary for high survival of released fish (95% or higher survival)?

In the 1977 Catch-and-Release Symposium, a paper was presented which reviewed all studies on hooking mortality from trout caught and released with single, treble, barbed and barbless hooks under various conditions. The conclusion: "Use of barbless hooks does not significantly reduce mortality and restrictions requiring the use of barbless hooks are not biologically justified." In 1984, the Washington Department of Game had another review made on all hooking mortality studies with the conclusion: "There is no valid technical basis for requiring single barbless hooks." If any disbelievers would like to critically examine all of the studies on which these conclusions are based, I can provide the references, but I doubt that the gut feeling and mind-set of a true believer can be changed by any amount of factual evidence. For example, the winter 1988 issue of *Flyfisher* has an article by Lefty Kreh on releasing fish. Lefty says: "I know about the supposedly scientific studies conducted that claim fish mortality is no different with barbed or barbless hooks. Some scientists also claim that treble hooks make no real difference in harming fish than do single hooks." Of course, Lefty can't believe these "supposedly scientific" studies—common sense and experience tell him otherwise. Although Lefty "knows" of these studies, has he read them and critically examined the evidence to arrive at an informed opinion? The difference between "scientific" and "supposedly scientific" studies evidently is determined by whether the studies agree or disagree with one's beliefs.

What appears to be a common-sense belief that barbless hooks must cause less mortality than barbed hooks, or single hooks less than treble hooks, relates to "handling time" of the released fish. It is virtually impossible to induce lethal stress in a healthy trout existing in good quality waters at low temperatures by catching and releasing. Almost all mortality of released fish is due to rupturing of blood vessels in the gill filaments or in the roof of the mouth (most bleeding fish will die). Barbless hooks have no advantage (actually a disadvantage) for avoiding lethal hooking (hooking causing bleeding).

Factors that increase mortality of released fish include water temperature (when water temperature warms to 60°F and above, mortality of released fish can be expected to significantly increase) and water quality such as low pH and low oxygen (but at levels rarely encountered in waters inhabited by trout). Under these "abnormal" conditions it is likely that trout caught, played to exhaustion and released on light tackle using barbless flies would suffer higher mortality than trout caught and quickly horsed in on a spinning lure.

CONT.

BARB CONT.

In any event, Americans have a general antipathy against state controls hinting of Big Brotherism. Thus, the fewer restrictions placed on special regulation waters, the lesser the probability for a backlash of opposition.

Although the use of barbless flies connotes a proper respect and reverence for trout, the use of barbless hooks should be voluntary and not mandated by law. To increase voluntary use of barbless hooks, articles in the popular media such as the one by Lefty Kreh will help, but if it can be demonstrated that a higher percentage of trout can be landed on barbless hooks than on barbed hooks, then the voluntary use of barbless hooks would greatly increase. A recent paper in California Fish and Game Journal reported that a higher percentage of chinook and coho salmon were landed on barbless hooks in comparison to barbed hooks. If most anglers believe they will land more trout on barbless hooks, they will use them.

To put the issue in perspective, however, one must seriously ask: How important is the controversy over barbed vs. barbless hooks as a genuine conservation issue? In relation to the big issues such as better multiple use management on federal lands with which Trout Unlimited is involved, and where annual increases of millions of pounds of trout and salmon are possible, divisive wrangling over barbed vs. barbless hooks is as if the main concern of an army at war is the type of buttons on the soldiers' shirts. If it were, I wouldn't expect many battles to be won.

TROUT
The Magazine for Trout and Salmon Anglers

13 July 1988

Mr. Pat Trotter
4926 26th Avenue S.
Seattle, WA 98108

Dear Mr. Trotter:

Thank you for the opportunity to review your article on hooking mortality. The article is obviously well-researched and well-written

There are a couple of reasons why we, unfortunately, cannot publish it in Trout. First and foremost, all of our editorial space is booked up through 1989. We will not be seeking new manuscripts until early next year. Secondly, I'm afraid your article is a bit long and on the technical side for our readership.

Your idea to publish it as a monograph or special publication may very well be your best bet. Pamela McClelland is Trout Unlimited's Resource Director. She would be your best contact within the national office. Her address is: Trout Unlimited, 501 Church Street NE, Suite 103, Vienna, VA 22180. You might also contact: Gilbert Radonski, Editor, Sport Fishing Institute, 1010 Massachusetts Avenue, NW, Washington, D.C. 20077. He may have some ideas for you as well.

Good luck.

Sincerely,

James A. Yuskavitch

James A. Yuskavitch
Associate Editor

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Post Office Box 6225
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4926 26th Ave S.
Seattle, WA 98108
July 25, 1988

Pamela McClelland, Resource Director
Trout Unlimited
501 Church Street NE, Suite 103
Vienna, VA 22180

Dear Ms. McClelland:

As you will see from the enclosed letter, I was referred to you by the editorial staff of Trout, the quarterly magazine of Trout Unlimited.

Enclosed is a manuscript on hooking mortality that I have been shopping around in the hope of getting it published. I think it brings some insight to an issue that continues to generate controversy, even after several years of debate.

The article itself doesn't seem that long, but the charts, graphs and extensive bibliography are evidently viewed by some editors as excess weight. Several national outdoor magazines have already turned it down for that reason. I feel that the bibliography is especially useful, because it identifies for the non-technical person just where the reports and papers documenting hooking mortality results can be found. This has never been done before. Anglers can search them out and read them for themselves if they wish.

Several of my T. U. friends have suggested that rather than giving up, I approach the national organization about having it published as a monograph or some kind of special publication. Of course if it is accepted I would want to be paid for it, since I have far too many hours and dollars in it now to let it go gratis.

I would certainly appreciate your looking at my manuscript with a view to turning it into a T. U. publication. I wrote it to stand alone, but as you will see when you read it, I also intended it to be but the first of a series on trout management issues. Many thanks.

Very truly yours,

Patrick Trotter

HOOKING MORTALITY OF TROUT:
THE SCIENCE BEHIND THE ISSUE

By

Pat Trotter

Can fishing methods really affect the health of a trout fishery?

When I first sat down to write this, my home state of Washington had just completed its first year of operation under a comprehensive new fishery management plan. This plan emphasized wild fish. Stocking of hatchery-reared trout was eliminated in certain designated waters, and regulations were set up to give the wild stocks a chance to show that they could not only fluorish in these waters and provide improved fishing, but also that this could be achieved at a fraction of the cost of hatchery operations.

There is really no longer any question that wild-fish management works. One has only to look at California's Hat Creek, a wild-trout stream that is now one of the most popular streams in the state. Or Montana's Madison River, truly worthy of its designation as a blue ribbon trout stream. Or Idaho's Kelly Creek, a long drive in over single-track logging roads, but being fished harder than ever these days even so. Or the waters of Yellowstone National Park, easy to reach for the most part, yet rated by many as the best trout fishing in the west.

In all of these cases and more, the same or even heavier angling pressure is being supported entirely by wild trout populations at little or no cost to the state or agency involved. And it can also be shown that these fisheries return significantly more to local economies than comparable fisheries sustained by hatchery trout.

But a key element of every wild-fish management plan is some type of terminal gear restriction to prevent excessive hooking mortality. Most often, as in Washington's plan, this takes the form of a ban on the use of bait in wild-fish streams.

This, sadly, has proved to be a terribly divisive issue. One national organization devoted to conservation of the resource (to which I happen to belong, by the way) took the stand that fishing with bait (worms, salmon eggs, marshmallows, cheese balls, and the like) does no harm to a wild-fish resource if one is careful in handling and releasing hooked fish. Another national organization devoted to conservation of the resource (I also belong to this one) took just the opposite view. Meanwhile, here in Washington, lobbyists and politicians turned the argument into a young vs.

old, rich vs. poor, baitfisher vs. spinfisher vs. flyfisher, purist vs. "regular Joe" kind of issue that pretty well watered down our plan before it ever got a chance to show what it could do.

Why all this divisiveness? The biologists and fishery managers who develop these wild-fish plans claim, after all, to have good, sound, scientific evidence for the gear restrictions they propose. They can cite study after study, every one of them conducted under carefully controlled conditions, that tell them what percentage of fish will die when hooked, then released, on a given type of terminal gear. But what studies are these? Who did them and how well? And in words of one syllable, what do they really say?

Before dealing with that, let's ask first why this question of hooking mortality is so important anyway. The answer lies in population dynamics. Even if there is no fishing at all, a certain percentage of the catchable-size fish in a population will die off during the year. Predators will get them, or disease will, or they'll simply succumb to old age. The actual percentage varies widely, depending on the specific population, but for trout it turns out that mortality due to these natural factors averages about 50 percent of the catchable-size trout.

It also turns out that up to about that same percentage, angling mortality is compensatory. In other words, if anglers harvest ~~angling mortality is~~

significantly less than 50 percent of the ~~in the average case,~~ the catchable-size fish in the population's the number of fish ~~lost to angling~~ lost to angling ~~are~~ is made up for by that many fewer fish succumbing that season to natural causes. It also means that there should be more older (and presumably larger) fish in the population the following year. On the other hand, if the angling mortality equals or exceeds ~~that percentage~~ 50 percent, the population will decline.

The whole objective in a wild trout fishery, then, is to keep the angling mortality from exceeding that magic compensatory level: 50 percent in the average population, or whatever number happens to be truly operative for the population in question. Even if hooked fish are returned to the water by anglers, the program would fail if those fish later died as a result of the experience in numbers that would approach or exceed the compensatory mortality level.

Understanding this compensatory relationship is important---so much so that it deserves a chapter of its own. That will be the subject of the next article in this series. But for now just remember that it's this relationship, a consequence of population dynamics, that makes what we fish with so important. If enough fish die from the experience of being hooked, EVEN WHEN WE RELEASE THEM APPARENTLY UNHARMED, a wild trout program could be completely wiped out.

What I did to satisfy myself about hooking mortality of trout was ~~to~~ dig out every published paper and report on the subject and read it for myself. I too am a scientist and have access to the technical literature, so I could find these reports without much trouble. I felt I could also translate them into layman's terms, and have tried to do that here. But I have also included the bibliography at the end of this article so you can locate them too if you wish.

When you examine the bibliography, you will see that fishery managers have been concerned about hooking mortality for a long, long time---over 50 years in fact. The first such study was conducted in Michigan, on brook trout. Since then, almost all the other salmonids have been covered: rainbow trout, brown trout, cutthroat trout, landlocked salmon, lake trout, chinook and coho salmon, and even arctic grayling. There's even a report on mortality of trout caught and released while ice fishing. Both wild and hatchery fish have been studied in lake, pond, stream, and even marine environments.

In many of the earlier studies, researchers were concerned only about the "throwback" mortality of fish less than some minimum size, say 6 or 8 inches. But as other forms of fishing regulation have been implemented (slot limits for example, or catch and release regardless of size), the size range of the fish included in the tests has expanded, so that by now fish of all sizes have been covered.

The objective has always been the same however: to determine the losses attributable to different types of terminal gear and fishing methods. Flies, lures of various kinds, and bait have all been compared, as have barbed and barbless hooks and a wide range of hook sizes. The bait studies have focused preponderately on worms, but occasionally salmon eggs have been included and in at least one study, done on immature chinook salmon in a marine environment, strips of herring were used.

How are hooking mortality studies actually carried out?

There are two general approaches. I'll call the first the catch-and-observe approach because hooked fish are, well, held for observation. This has evidently been a very popular way to conduct hooking mortality studies, because only one study cited in the bibliography was NOT done using this approach.

I'll call the other kind of study the snorkel-and-count approach, because that's pretty much what the investigators do: they snorkel a section of stream repeatedly over the course of a season and count carcasses. One of the most recently published hooking mortality studies, that of Schill, Griffith and Gresswell on the heavily fished section of the Yellowstone River just downstream from Yellowstone Lake, was done by this method.

In the catch-and-observe kind of study, the principal investigator first has to set out some ground rules. The study has to be designed in advance so that any differences observed between terminal-gear types are truly significant according to accepted statistical methods.

Now somebody has said, "There are lies, damn lies, and statistics." That's a bum rap. What we normally think of as "statistics" are really the mathematical rules used to determine how closely some attribute of a sample comes to describing the entire population from which that sample was drawn.

Fortunately, one of those rules makes it possible for our hooking mortality investigator to compute in advance the number of fish that must be captured for each test and control in order that the results WILL reliably describe what would happen to the whole population under the same circumstances. Other equations will be used at the end to make the actual significance tests.

Once the plan is set, a group of anglers is picked to do the actual fishing. Sometimes, for convenience, the participants are restricted to fish and game personnel or fishery students. Other times, interested volunteer anglers are recruited. I hold that the best studies are those involving volunteer anglers---not because the students or agency people are any more or less skilled at handling fish than anglers, but simply because participating anglers develop a sense of ownership of the results and are less inclined to reject any findings handed down to them later by the "experts." This is important when you have a particularly contentious issue to deal with as we seem to have here.

But regardless of who does the fishing, care can be taken in other ways to insure that the level of fish-handling experience will not bias the outcome. This can be done for example by specifying precisely how long the fish are to be played, exactly how the hook is to be removed, and any other details of the handling process that can be conveniently specified.

To further account for effects of handling, and to get a measure of the effects of transporting and confining the fish, a control group is collected by a method known not to kill them or to kill very few. Electroshocking is typically used, but beach seines and traps have also been employed. These control fish are deliberately exposed to all the same rigors of handling, transport, and confinement as the hooked fish, except of course the actual removal of a hook. The number of deaths among the control fish gives a measure of mortality due to these other factors. Thus, differences in mortality between the control group and angler-caught groups can be attributed to hooking with a high level of confidence.

All fish captured in the study are marked in some distinctive way, with a unique fin clip, a punch, or perhaps an easily attached tag, using a separate mark for each group of fish in the study.

Some kind of live box may be provided so that the captured fish can be held temporarily, but it is best if they are transported as quickly as possible to a large floating holding pen (if in a lake) or a restricted area (if in a stream) set up in such a way that the fish can't get out and predators and other fish can't get in.

These holding areas are checked at regular intervals, typically once a day, for as many days as the investigator chooses to continue observing the fish. Dead fish are collected at each interval, tallied according the their unique mark as to type of bait or lure, hook size, or whatever else is being evaluated. Then the results are toted up.

Up to this point, the study is strictly a numbers game. You can stop right here, as many of the studies cited in the bibliography have done, and let those mathematical equations I mentioned earlier tell you in a totally impartial manner just how the results came out. Your study would be perfectly valid. But several of the investigators went further. They decided to autopsy all of the dead fish to learn just what did kill them. And in a couple of cases, at the end of the observation period even the survivors were sacrificed in order to learn where they had been hooked and what kind of damage they had sustained but survived. This has provided valuable insight into just what happens to hooked fish that the statistical correlations alone cannot yield.

Now, hooking mortality studies of the catch-and-observe kind have been criticised from two standpoints. First, the fish do have to be confined, and the stress of confinement might result in overestimates of hooking mortality, controls notwithstanding. Second, this kind of study does not tell you what might happen to fish caught more than once in a relatively short period of time, as might happen to fish in special regulation waters receiving intense levels of angler use.

That's where the snorkel-and-count method comes in. The one hooking mortality study reported to date that was done in this way examined a population of cutthroat trout that was subject to so much fishing pressure that each fish in the study area was hooked and released an estimated NINE TO TEN TIMES during the season.

Prior to the season opening, snorkelers surveyed the study area to locate places where dead fish might settle and accumulate. Then the ability of the snorkelers to find dead trout was tested by periodically releasing carcasses of about the same sizes as trout normally hooked by anglers. In this particular study, the snorkelers consistently found 31 percent of the carcasses released. This number was used to factor up the numbers of dead trout found later, during the hooking mortality part of the survey. The river was searched just prior to the season opener to get an estimate of natural mortality, and snorkeling was also used to get an estimate of the total trout population present. Then, during the season, the river was searched methodically, the same snorkeler covering the same route three times a week until the study was over. Volunteer Angler Report information along with spot-check creel surveys gave the investigators an estimate of how many trout were actually captured and released during the survey.

When the surveys were all completed, the investigators used the information to estimate the percentage of the total cutthroat trout population that died after capture and release by anglers. They also estimated the single-capture mortality that would have had to occur to account for that total mortality. Of course the river where this study was conducted was a catch-and-release, barbless flies and lures only piece of water, so the results give a measure of hooking mortality for that type of gear only.

So that's how hooking mortality studies are conducted. Now what do they tell us?

Well, the first major conclusion is that the use of bait causes significantly higher hooking mortality than the use of lures or artificial flies. Mortality associated with the use of bait has ranged between 20 and 50 percent of the fish hooked, depending on the species, while mortality from the use of lures and artificial flies has been less than 10 percent, in every study on record. Paul Mongillo of the Washington Department of Wildlife summarized the hooking mortality data available up to 1984 in a report which he issued that year. I show his graphs for the hooking mortality of several species of wild trout and charr in figures 1 through 5. Sorry, bait people, there it is. There is simply no way around these results---except in the one instance that I note below.

The one exception to the hooking mortality results with bait comes in fishing with eggs for winter-run steelhead. In this case, the hooking mortality on adult fish appears to be less than 10 percent. This is based on a 1983 communication from ~~B. Hooten of the~~ British Columbia Fish and Wildlife Branch, Nanaimo~~, B. C.,~~ and another 1983 communication ~~from~~ R. Paulsen of the Washington Department of Wildlife, Aberdeen, WA, ~~which were~~ cited in Mongillo's report. On the other hand, the hooking mortality on juvenile steelhead falls within the values shown for rainbow trout in figure 1: greater than 20 percent mortality when hooked on bait.

and another communication from R. Hooten of the British Columbia Fish and Wildlife Branch, Nanaimo, B.C., who reported that among 3715 steelhead captured on conventional gear (i.e., bait and barbed hooks) to provide brood stock for hatchery programs, only 127 — 3.4 percent — mortalities occurred

I have not shown the numbers in chart form, but there is some indication from the studies that larger single hooks fished with bait, say size 1/0 or so, are less lethal than single hooks in the 6 to smaller size range. But trolled bait or bait attached to a retrieved lure produces about the same hooking mortality as stillfished bait or drifted bait.

I'd also point out that the bait mortality figures charted in figures 1 through 5 do show a species dependence. Wild cutthroat trout seem to be most susceptible, followed closely by wild brook trout. At the other end of the scale, wild brown trout seem to be best able to survive. Wild rainbow trout (with the exception noted above of adult winter steelhead) are intermediate in their response to being hooked on bait then released.

A second major conclusion, and this one has caused more than one flyfisher I know to raise his eyebrows, is that there are no significant differences in hooking mortality between flies and any artificial lure studied to date. Sorry again, gals and guys, but hooking mortality studies alone don't provide much support for those flies-only regulations we fly fishermen cherish.

Another big surprise, again I think especially to fly fishermen because of the strong stand many of them have taken on the subject, is that there are no significant differences in hooking mortality between barbed and barbless hooks!

I think what makes this conclusion so particularly hard to accept is that it seems to defy logic. Reason tells us that all the extra gripping and squeezing and horsing around required to extract a barbed hook, not to mention the damage inflicted by the barb itself when it comes free, has just GOT to load extra stress on a fish---and this simply MUST be reflected in higher mortality. Sorry again, gang, but the numbers say otherwise. Evidently a trout is tougher than we have been led (or have led ourselves) to believe---provided of course that the hook itself has not penetrated a critical spot. We'll come back to that later, but first I need to deal with another issue that has been raised concerning the use of barbless hooks: the so-called "stiletto effect."

At the Wild Trout III symposium, held in Yellowstone National Park in September, 1984, John Deinstadt, a biologist with the California Department of Fish and Game, remarked that anglers were reporting that in their experience barbless hooks penetrated into vital organs easier than barbed hooks. Thus the "stiletto effect," and they feared hooking mortality with barbless hooks might actually be higher as a result.

This "stiletto effect" is being picked up on and repeated in the literature. Dr. Robert Behnke, the noted trout authority from Colorado State University, brought it up again most recently in an article he did for "Trout," the fine publication of Trout Unlimited. But to put the "stiletto effect" in proper perspective, John Deinstadt himself wrote me recently that no experimental work was done to confirm those angler reports, and Mongillo's 1984 analysis of the available hooking mortality data failed to turn it up. Furthermore, John said in his letter, he has received not a single "stiletto effect" report from anglers in the last two years. So this issue, I think, can be treated as a false alarm and thus put to rest.

Another barbed vs. barbless hook issue may be emerging to take its place, however. I attended the Catch and Release Symposium held at Humboldt State University last fall, where I heard several fishery managers talking about all the "scarfaced" fish being reported by anglers fishing popular catch and release areas. These are fish that presumably have had the hook uncerimoniously removed before release. While we don't seem to have a mortality problem here, we may have a cosmetics issue to deal with.

The next conclusion is not so well supported by the numbers as the ones I've already listed, but here again, just the idea that it could be true seems to fly in the face of reason: treble hooks produce less hooking mortality than single hooks. Here logic would seem to argue that more than one barb would just multiply the damage and thus the chances that a hooked fish would die. But the few numbers that have been compiled on treble vs. single hooks say our logic is wrong here.

And here is another finding worth a reflective moment or two. Mongillo, in examining the hooking mortality literature for his 1984 report, discovered that wild salmonids suffer 2 to 4 times greater hooking mortality than hatchery fish when taken on flies and lures. His results are shown in figure 6. IN NO CASE DID THE MORTALITY EXCEED 10 PERCENT, MIND YOU, but wild fish always came in at the high end of the range while hatchery fish scored consistently at the low end.

Why is this so? That is something the available studies do NOT make clear. If anything, the literature on the physiological responses of trout would seem to suggest just the opposite: that wild fish are better able to cope with the stresses of being hooked and played than hatchery fish (I have included a couple of papers on the stress responses of trout in the bibliography; see Wydoski et al 1976 and Castillas and Smith 1977 for example). One can only theorize (as Mongillo did) that wild fish strike a lure more aggressively and fight more frantically when hooked than hatchery fish, leading to a greater chance of the hook penetrating further to damage a vital organ than it might otherwise do. But beyond this, it's anybody's guess.

On bait, with the exception of hatchery-reared landlocked salmon, mortality is always high and Mongillo could find no significant differences between wild and hatchery fish. And here, even the low mortality of bait-hooked hatchery landlocks can be explained.

The landlocked salmon studies were conducted by Kendall Warner of Maine's Department of Inland Fisheries and Wildlife. They involved worm-fishing for young (age I+ or II) salmon in hatchery raceways. Fish were hooked as soon as they were observed to have accepted the bait, and were not allowed to ingest it deeply. In his 1979 report Warner wrote: "It was noticeable during angling that salmon took worms very gingerly and rarely ingested the bait deeply." Therefore, it was easy for his anglers to lip-hook the hatchery fish. On the other hand, when they fished for wild landlocks in a natural setting (for an account of this experiment, see Warner's 1978 paper), they had no opportunity to control how deeply the fish took the bait and mortality was substantially higher.

Speaking of fish that do take the hook deeply, the studies show that there is indeed truth to the old admonition to clip the leader and leave the hook in. Swallowing a hook is a serious consequence for the fish regardless, but its chances of survival are approximately tripled over what they would otherwise be if the hook is left in. Mason and Hunt, in a study conducted in 1967, found that nearly 95 percent of deeply hooked rainbow trout died when the hook was removed. That figure dropped to just over 30 percent when the hook was left in. Hulbert and Engstrom-Heg reported similar results for brown trout in a paper published in 1980. Overall hooking mortality was lower in their work; only 60 percent of the deeply hooked brown trout died when the hook was removed. But leaving the hook in lowered the mortality to 20 percent.

What happens to the hooks? Evidently they dissolve or work their way loose and pass on harmlessly through the fish. Hulbert and Engstrom-Heg reported that fish surviving with the hook left in could feed and grow normally, and when these fish were killed and autopsied two or three months later, many of the hooks had simply vanished.

Of the fish that WILL die from the trauma of being hooked, landed and released by anglers, how long can they linger before death actually occurs? How long a delay can there be?

The vast majority of them die of their injuries within the first 48 hours, and the majority of those, within the first 24. A few of the less seriously injured ones may survive up to a week or ten days, but their numbers are extremely small.

Well, so much for the numbers that describe hooking mortality with different kinds of terminal gear. Now what actually kills the fish? Let's first see what role stress plays.

For better than a decade now, the notion has prevailed that hooking a fish, playing it to exhaustion, then handling and releasing it will cause its death, particularly if the fish is a big, old trophy-sized lunker. Many of my angling acquaintances believe this so deeply that they use only the stoutest of terminal gear, literally horsing the fish they hook into the net for a quick release and return to the water. About the only sport they enjoy is inducing the fish to strike in the first place. Is this really necessary?

At a 1977 symposium on catch and release angling held at Humboldt State University, Arcata, California, R. S. Wydoski reviewed the literature on physiological responses to hooking and handling.

Blood chemistry definitely does change and the buildup of chemicals related to stress and exhaustion, such as lactic acid, certainly does occur. And it often takes a fish several days before these factors get back to normal levels. But there is little evidence to support the notion that this causes the fish's death!

In fact, biologists Leo Marnell and Don Hunsaker tested this theory directly on wild, lure-hooked cutthroat trout at Yellowstone Lake back in 1970. Fish in the control groups were hooked and reeled in immediately (all fishing was done with small treble-hooked lures, by the way). Other groups of fish were played for exactly five minutes (a mechanical timer with a bell announced the end of the period) and still other groups were played for exactly 10 minutes. Fish in the test groups were forced to keep swimming for the duration of the period by lateral movement of the rod tip. Thus the trout were "played" up to and well beyond the point of total exhaustion. Upon being landed, the trout were held in live boxes for 10 days. The investigators found that <u>mortality was only about 5 percent for each group, and there was no significant difference between groups</u>! In other words, the fish played for 10 minutes fared just as well as the fish played for 5 minutes, and both groups fared as well as the controls that were reeled in at once.

So where did the idea that physiological changes are an important factor in hooking mortality come from? Well, several workers, going back to Parker and Black in 1959, have claimed that severe exhaustion brought about by capture with hook and line can cause delayed mortality in fishes, and that fatigue induces other forms of stress, such as attack by disease organisms, that can also kill fish. Even more to the point, Bouch and Ball, in 1966, reported an alarmingly high 87 percent delayed mortality in hatchery-reared rainbow trout hooked on artificial lures. Most of the deaths occurred on the third day and were thought to have been caused by blood coagulation.

But other workers, including Horak and Klein, who performed a study similar to Bouch and Ball's in 1967, also using hatchery rainbows, failed to confirm the earlier results. Horak and Klein got less than 8 percent mortality in 10 days of observation while In another test, published in 1982, Thurston Dotson reported that hatchery cutthroat trout hooked and played until they could no longer maintain their equilibrium in the water, suffered less than 7 percent mortality over a 30 day observation period.

The evidence thus shows that even though marked changes do occur in a trout's blood chemistry, these are changes the trout can survive. Far, far outweighing these stress effects, and <u>unquestionably THE major cause of hooking mortality, is hooking injury itself</u>.

Four major hooking mortality studies, those of Shetter and Allison (1955) in Michigan, Stringer (1967) in British Columbia, Falk et al (1974) also in Canada, and Warner (1979) in Maine, have each examined hooking injury and the site of hooking. From these studies, it is possible not only to draw conclusions about how mortality relates to the site of hooking, but also to describe how different gear types affect the frequency of hooking in critical areas.

Figure 7 is a cutaway composite photo showing a long-shank size 8 hook in the esophagus of a 6-1/2 inch rainbow trout. It shows very nicely the relationship of the hook to the vital organs of the fish, and graphically illustrates the critical areas where hooking the fish would likely prove lethal.

Look next at figure 8, which was taken from Mongillo's report. This shows the percent mortality suffered by three salmonid species when hooked in each of the areas pictured in figure 7. Figure 8 shows that the esophagus and gills are clearly the most deadly places to hook a fish. The eyes and tongue are also critical areas. On the other hand, hooking in the mouth and jaws (the term jaws as used here being synonymous with what many anglers call lips, as in a lip-hooked fish) presents little threat to the life of the fish.

The next step is to determine if different types of terminal gear produce higher likelihoods of hooking in critical areas. Mongillo did this for us as well. Figure 9, also taken from his report, presents those results quite clearly for the critical areas of esophagus, gills, eyes and tongue. Baited hooks (worms were used in all of the cases cited) penetrated critical areas roughly 50 percent of the time. Artificial lures and flies hooked critical areas only about 10 percent of the time, except in two hooking mortality studies of fly-caught rainbow trout reported by G. E. Stringer in 1967. Stringer's trout, taken at Penask Lake, British Columbia, were frequently hooked in the eye for some reason.

Before summing up, a comment should be made about bleeding fish. In going through the several hooking mortality studies cited, I have followed the authors' leads in placing emphasis on WHERE the fish are hooked and what the likelihood would be that death will result. Only one study, that of Warner and Johnson, published in 1978, gave any numbers on bleeding fish. Warner and Johnson reported that 86 percent of bleeding fish in their study died, which just reinforces another old adage: If the fish in your hands is bleeding, no matter where or how it was hooked, the chances are VERY good that it's a dead fish.

In summary, then, carefully controlled and conducted hooking mortality studies going back over 50 years and covering most every salmonid species, affirm the following points:

- Mortality of fish hooked on bait then released can be expected to range from 20 to 50 percent, depending on the species (the one exception to this is adult winter steelhead, whose hooking mortality on bait is similar to that on lures and flies).

- There is little difference between stillfishing bait, drifting bait, trolling bait, or attaching bait to a retrieved lure. Hooking mortality is about equally high in all cases.

- Mortality of fish hooked on flies and lures and then released can be expected to be less than 10 percent.

- There are no differences in hooking mortality between artificial flies or lures, with or without barbless hooks.

- Treble hooks may actually produce less hooking mortality than single hooks when used with artificial lures; ditto for very large hooks used with bait.

- Wild salmonids suffer about twice the hooking mortality of hatchery fish when caught on artificial flies or lures, but even so this is less than 10 percent. They suffer about the same hooking mortality as hatchery fish, i.e., 20 to 50 percent depending on the species, when caught on bait.

- Virtually all of the deaths from hooking occur within 48 hours of release, but a fish destined to die within that period CAN swim away appearing otherwise in good health.

- When it comes to causing the death of a fish, playing and handling stresses don't matter nearly as much as hook injury itself.

- Leaving the hook in a deeply hooked fish approximately triples its chances of survival---unless it is already bleeding, in which case it will almost certainly die.

- Fish hooked in the esophagus, gills, tongue or eye are in greater peril of their lives (about four times greater) than fish hooked in the mouth or jaws.

- Using bait (with the exception of adult winter steelhead as noted above), you can expect to hook a fish in a critical area about one out of every two times. With artificial flies and lures, these odds drop to one out of every ten times.

So now back to the original question: can the type of terminal gear we fish with really harm a fishery? After all this, the answer can still be yes or no.

The answer is obviously YES if you have a catch-and-release management situation and you need to preserve every one of the 20 to 50 percent mortalities that fishing with bait would lose you. Here is an example drawn up from testimony given before the House Natural Resources Committee of the Washington State Legislature.

Suppose we have a stream with a wild population of cutthroat trout. Two anglers come along, one fishing with bait and the other with artificial lures. Each angler hooks, lands, and releases 20 fish---and each fish is released in an apparently healthy condition, i.e., no bleeders. Figure 2 tells us that of the 20 wild cutthroat trout released by the angler using artificial lures, one will probably die within 48 hours of its release. The other 19 will survive, none the worse for their experience, and will make their ultimate contribution to building and maintaining the population.

Of the 20 wild cutthroat trout caught and released by the bait fisherman, 10 will die within 48 hours of their release. Only 10 will be left to contribute to the well-being of the population.

In this case, the individual effects of the two fishermen are alarmingly different. The bait fisherman has TEN TIMES the deleterious impact on the fishery (in terms of fish mortality) as the lure fisherman. If, in this example, the fishery were being managed to save and rebuild a depleted stock, there is no way it could even maintain the present depleted level, let alone experience any measurable recovery, if fishing with bait were allowed. Of course, if the population were so critically low that the loss of even one fish per 20 released would be serious, then no form of angling whatsoever should be permitted.

Now if the two anglers in our example were fishing over a wild brown trout population, the impact would not be quite so severe. One fish out of 20 released would still succumb to the lure fisherman's activity (see figure 4 for wild brown trout), but now only four fish out of 20 released would be lost because of the bait fisherman's effort. The bait fisherman still has four times the individual impact on the population as the lure fisherman, but that's far less difficult for a brown trout population to deal with---unless, of course, it is so weak to begin with that even a four fish loss per 20 released would be pivotal.

I pointed out earlier that for HEALTHY trout populations, about 50 percent of the breedable-size fish will probably die anyway from the beginning of one season to the beginning of the next, even if there were no angling. I also pointed out that angling mortality compensates for, or offsets, these other losses up to about that 50 percent level. Given this, allowing bait fishing over ANY wild cutthroat population is an iffy proposition. On the other hand, a healthy, self-sustaining brown trout population might handle the situation very well. Then the only question would be, how much TOTAL fishing pressure is there on the population, because there is a finite limit to the number of fish a body of water can carry in a self-sustaining, self-perpetuating mode.

Hatchery augmented populations? That's a different story. But then hatchery management is what wild fish programs are trying to get us away from. And that's why the terminal gear/hooking mortality issue is so vitally important to us all.

Footnote

Dr. Trotter is a scientist himself and has been for 30 years now. So as not to mislead, his Ph.D. is in chemistry, not fish biology. But for close to 20 of his professional years he has managed or directed research in the biological sciences, and because of his deep and avid interest in understanding the creatures that he fishes for, he has studied salmonid biology intensely for nearly all of those years.

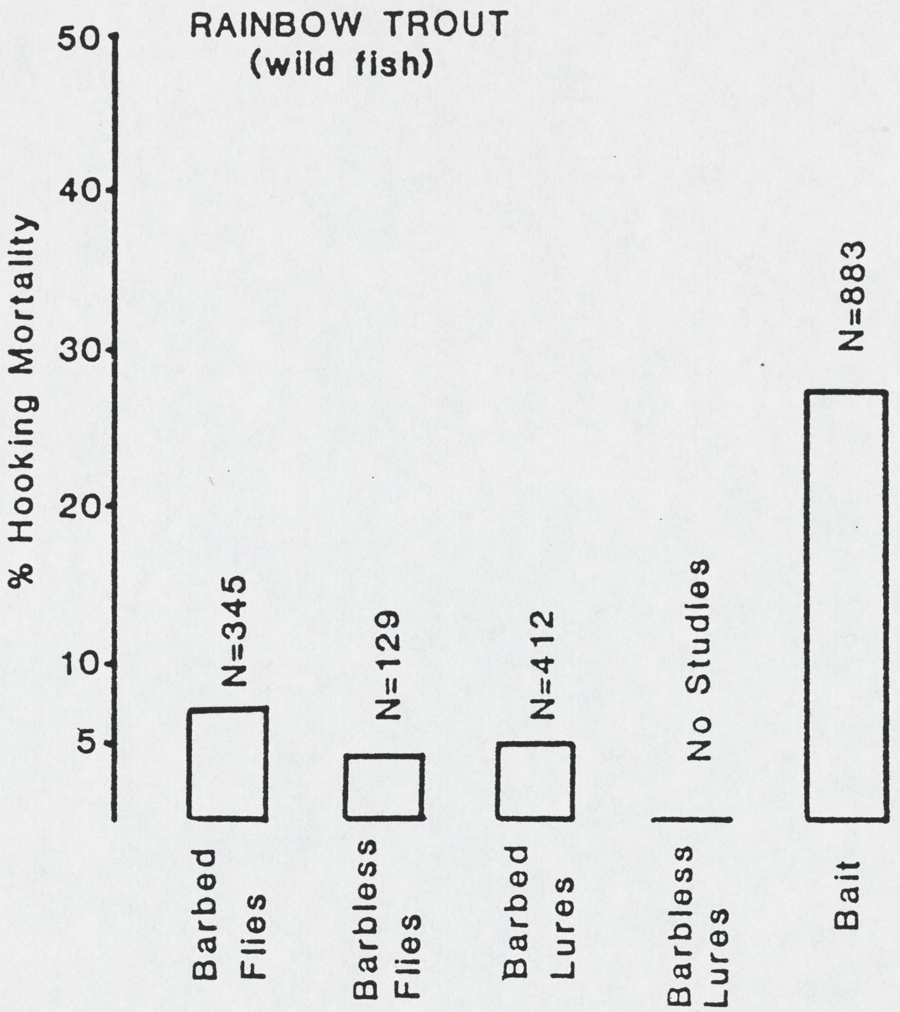

Figure 1. Hooking mortality associated with various gear and bait.
(From Mongillo 1984).

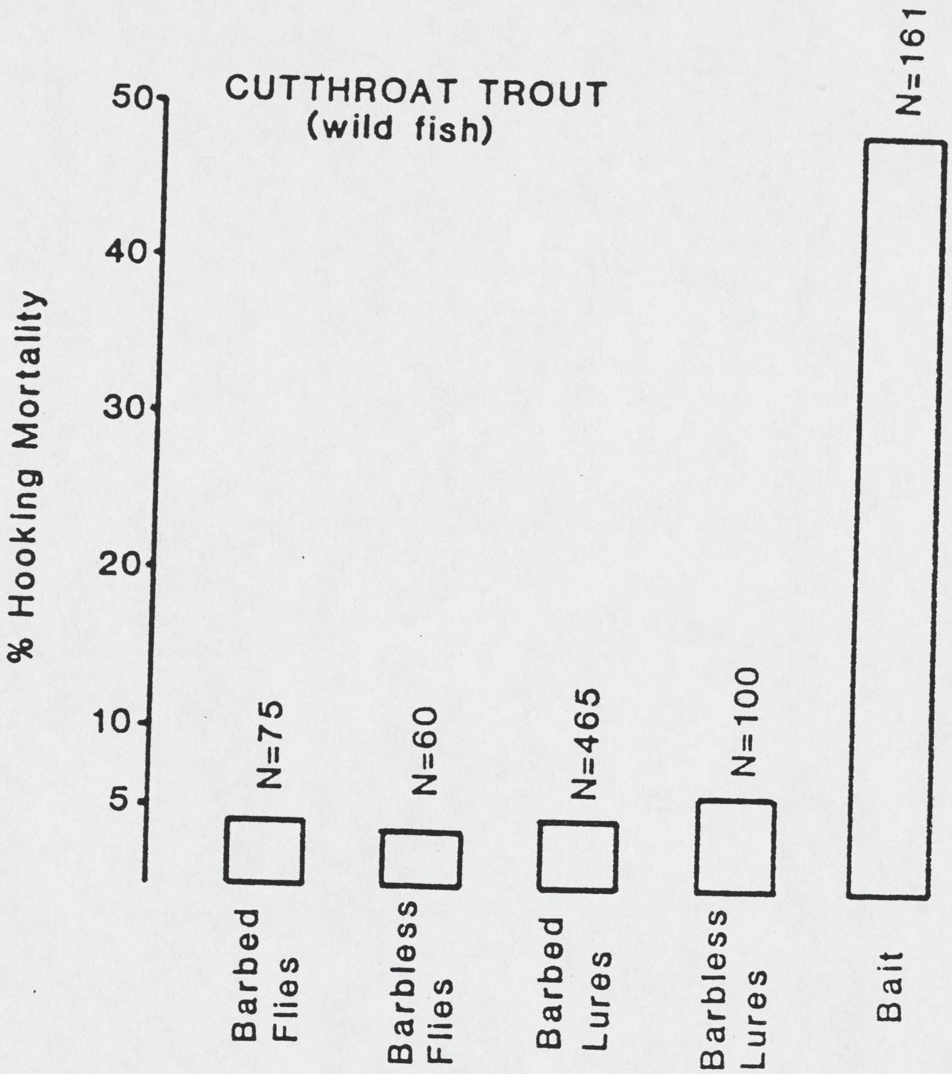

Figure ~~3~~ 2. Hooking mortality associated with various gear and bait. (From Mongillo 1984).

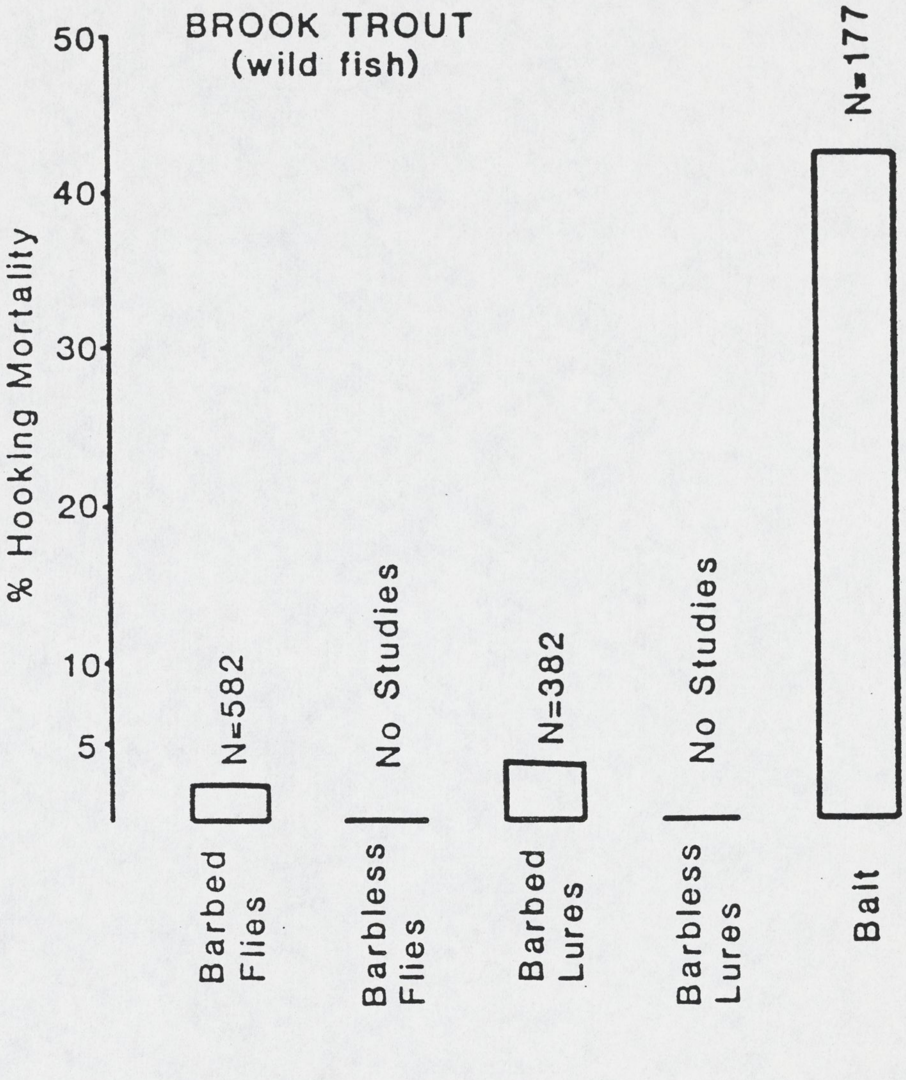

Figure ~~4~~ 3. Hooking mortality associated with various gear and bait (From Morgillo 1984).

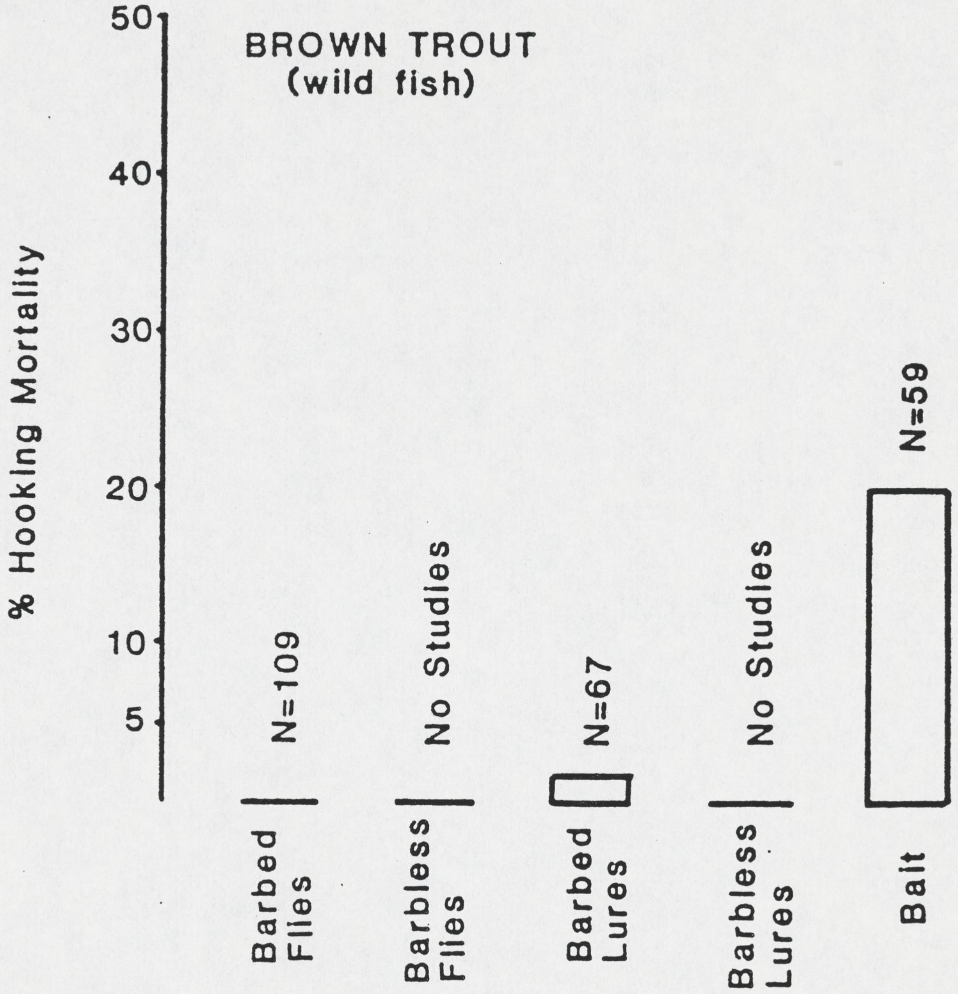

Figure ~~5~~ 4. Hooking mortality associated with various gear and bait (From Mongillo 1984).

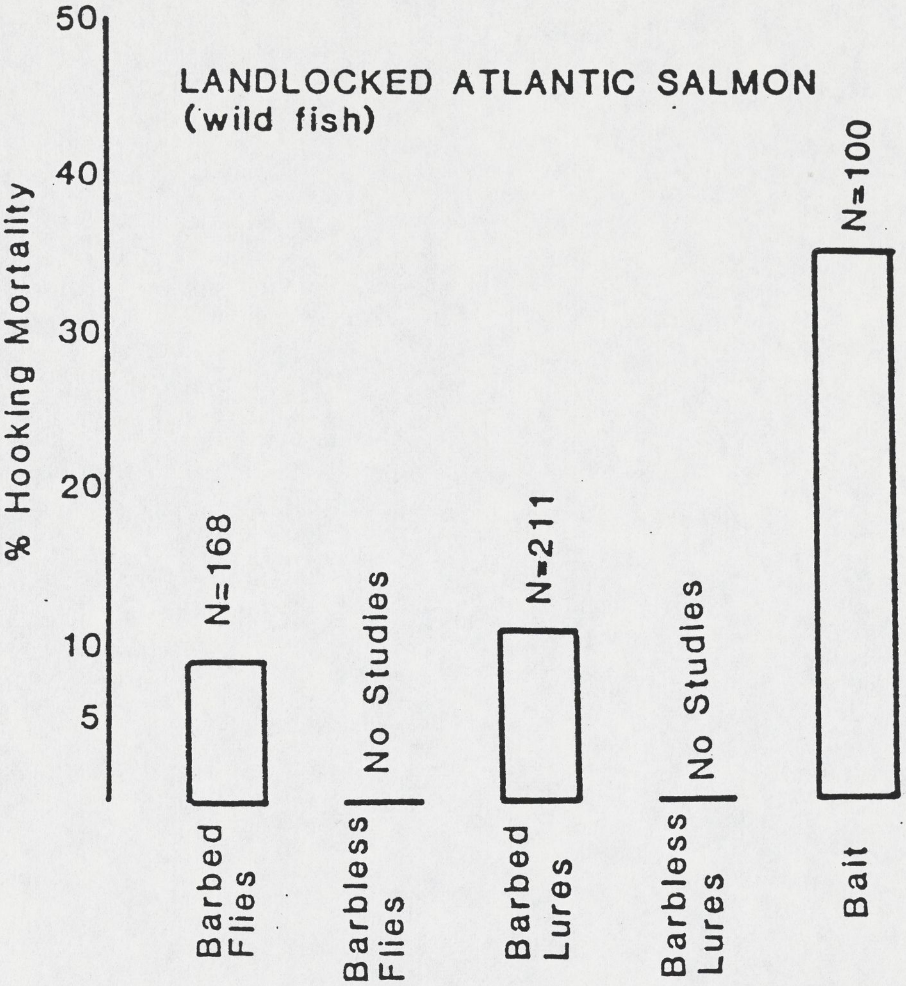

Figure ~~6~~ 5. Hooking mortality associated with various gear and bait.
(From Mongillo, 1984).

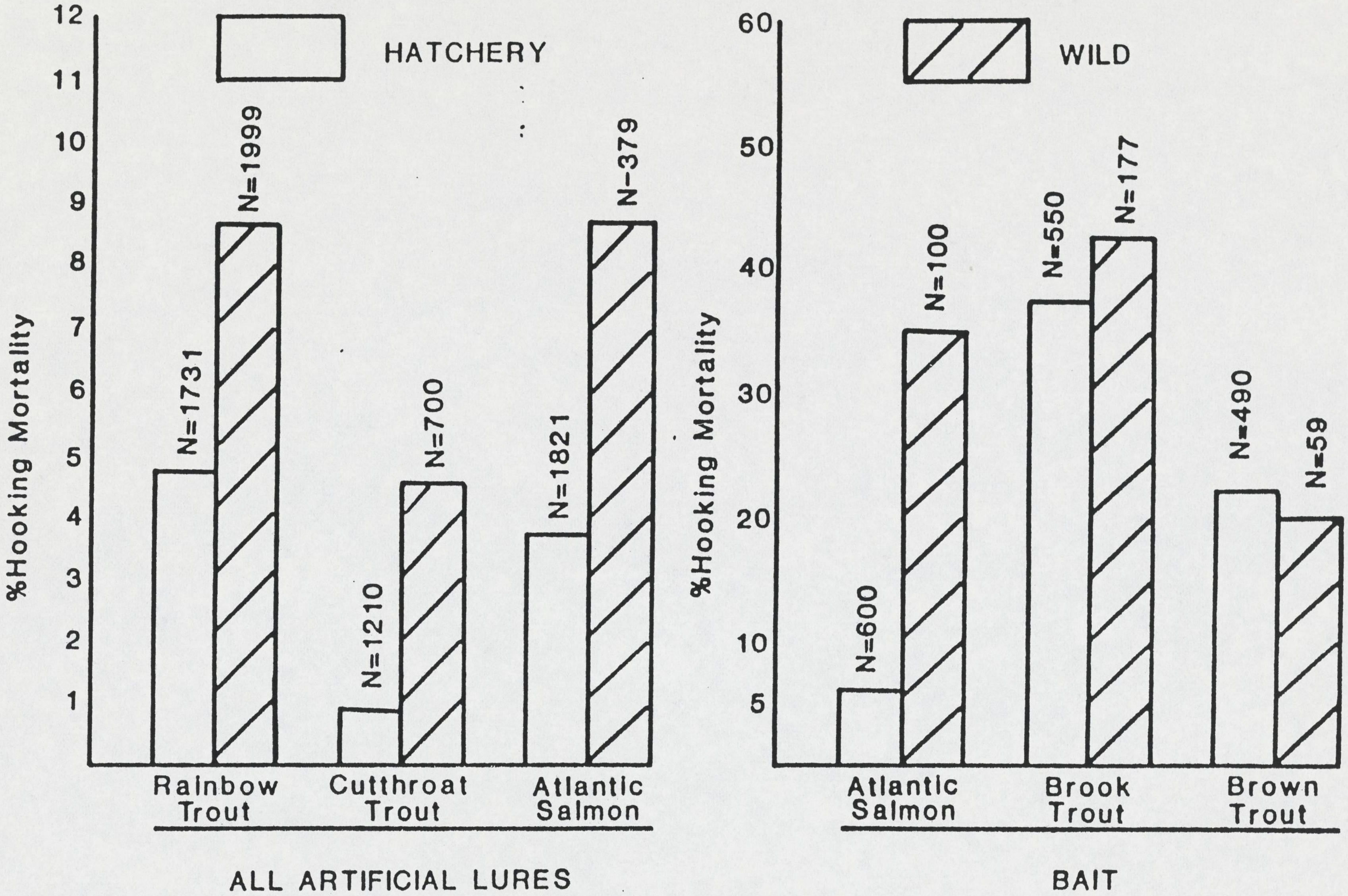

Figure ~~1~~ 6. Comparison of hooking mortality between fish adapted to hatchery and wild environments. Only species with similar experiments done on hatchery and wild fish were included. Atlantic salmon are landlocked.

(From Mongillo, 1984; Cartographer Susan Peterson)

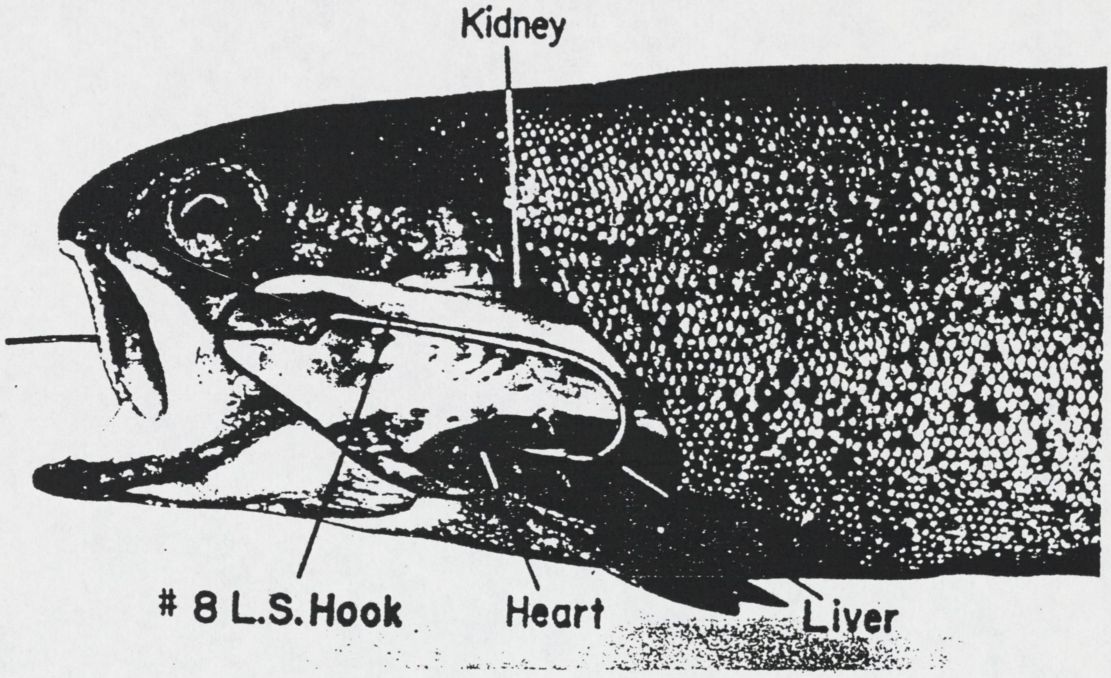

Figure ~~8~~7. Cutaway composite photo of a long shank size 8 hook in the esophagus of a 6½ inch rainbow trout, showing proximity of vital organs and critical hooking sites. (Photo courtesy of Michigan Department of Natural Resources, Institute for Fisheries Research).

Original B/W print will be provided if the article is accepted. P.C.T.

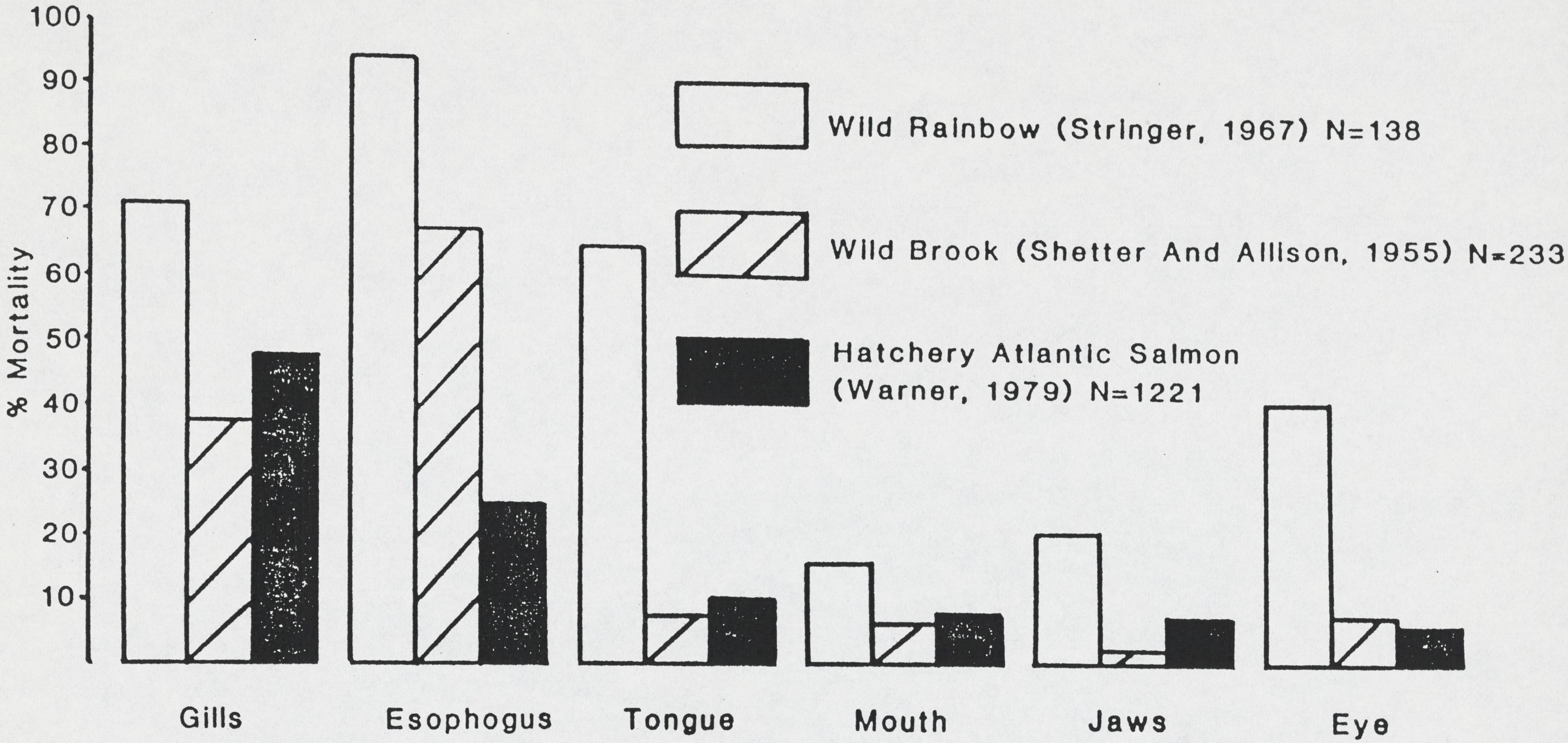

Figure ~~11~~ 8. Mortality of three species of salmonids caught on various gear types related to anatomical hooking site.
(From Mongillo 1984)

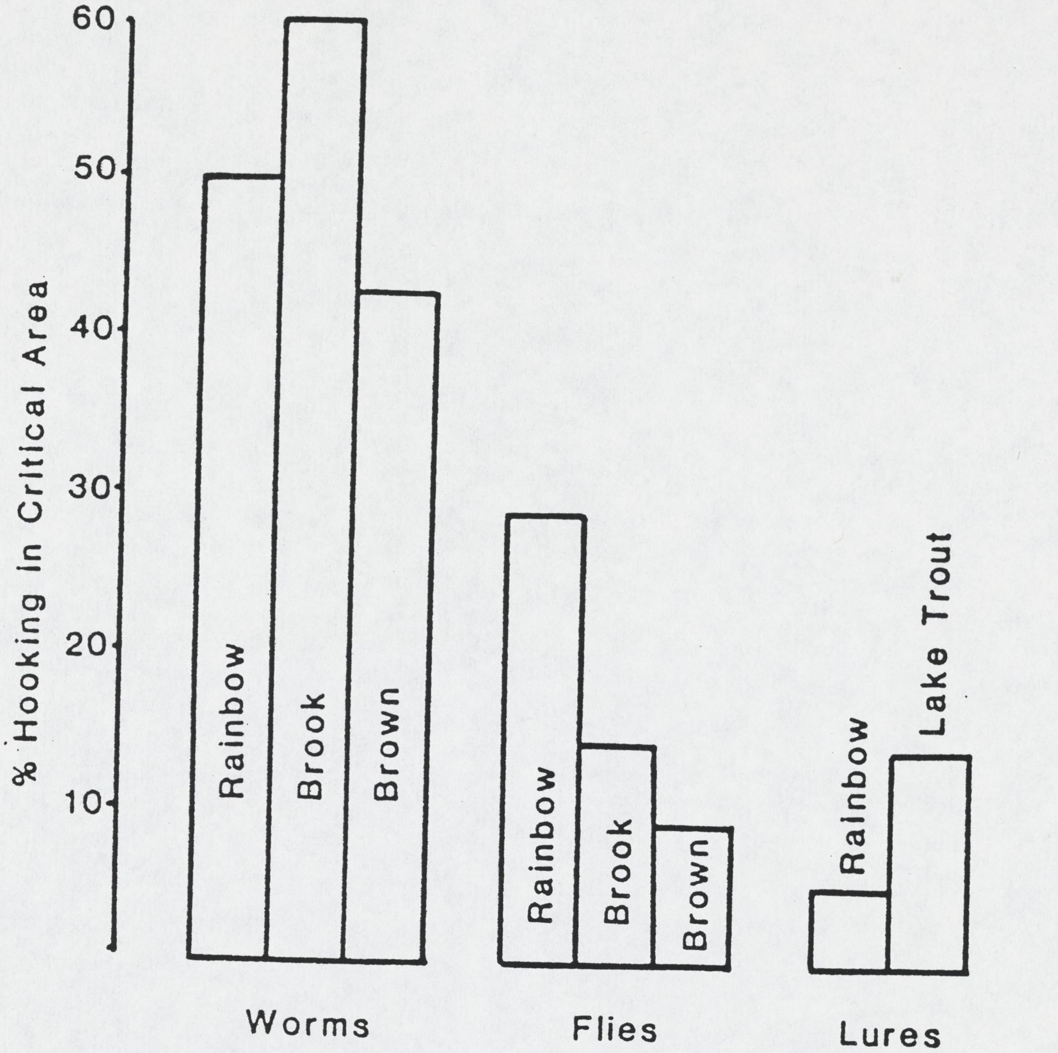

Figure ~~15~~ 10. Percent hooking occurance in critical areas (Esophogus, gills, tongue, eye) for various species and gear types. Data from Shetter and Allison (1955), Falk et al. (1974) and Stringer (1967).

(From Mongillo, 1984; Cartographer Susan Peterson)

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GJS [1992]

Physiological Effects of Brief Air Exposure in Exhaustively Exercised Rainbow Trout (*Oncorhynchus mykiss*): Implications for "Catch and Release" Fisheries

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Ferguson, R. A., and B. L. Tufts. 1992. Physiological effects of brief air exposure in exhaustively exercised rainbow trout (*Oncorhynchus mykiss*): implications for "catch and release" fisheries. Can. J. Fish. Aquat. Sci. 49: 1157–1162.

Rainbow trout (*Oncorhynchus mykiss*) which were air exposed for 60 s after exhaustive exercise initially had a much larger extracellular acidosis than trout which were only exercised. In both groups, however, plasma pH returned to normal by 4 h. Blood lactate concentrations were also greater in the air-exposed fish and continued to increase throughout the experiment. During air exposure, there was retention of carbon dioxide in the blood, and oxygen tension (Po_2) and hemoglobin:oxygen carriage ($Hb:O_2$) both fell by over 80%. After 30 min of recovery, however, blood gases resembled those in fish which were only exercised. Finally, survival after 12 h was 10% in control fish and 88% in the exercised fish but fell to 62 and 28% in fish which were air exposed for 30 and 60 s, respectively, after exercise. These results indicate that the brief period of air exposure which occurs in many "catch and release" fisheries is a significant additional stress which may ultimately influence whether a released fish survives.

Des truites arc-en-ciel (*Oncorhynchus mykiss*) exposées à l'air pendant 60 s après une activité physique épuisante ont présenté, tout d'abord, une acidose extracellulaire beaucoup plus élevée que celles qui n'avaient pas été exposées à l'air. Dans les deux groupes, toutefois, le pH plasmatique est revenu à la normale dans les quatre heures suivantes. La concentration de lactate sanguin était également plus élevée chez les poissons exposés à l'air, et elle a continué à augmenter tout au long de l'expérience. Pendant l'exposition à l'air, on a enregistré une rétention de dioxyde de carbone dans le sang, la tension en oxygène (Po_2) et le transport de la molécule d'hémoglobine oxygénée ($Hb:O_2$) diminuant tous deux de plus de 80%. Cependant, après 30 min de repos, les gaz sanguins se situaient à des niveaux comparables à ceux des poissons n'ayant pas été exposés à l'air. Finalement, le taux de survie après 12 h était de 100% chez les témoins et de 88% chez les poissons ayant été soumis à des exercices épuisants, mais il a chuté à 62 et à 28% chez ceux qui ont été exposés à l'air pendant 30 et 60 s respectivement après ces exercices. Ces résultats indiquent que, dans de nombreux cas de pêche avec remise à l'eau des prises, la courte période pendant laquelle les truites sont exposées à l'air représente un stress supplémentaire important, qui peut en fin de compte, avoir une incidence sur la survie des poissons relâchés.

Received July 9, 1991
Accepted December 16, 1991
(JB118)

Reçu le 9 juillet 1991
Accepté le 16 décembre 1991

An integral component of the management strategy in commercial and recreational fisheries is the release of a significant portion of the catch. In commercial fisheries, this may include species caught out of season or individuals which do not meet size restrictions. In recreational fisheries, "catch and release" policies have also been implemented to offset the impact of increased angling pressure on limited fish stocks. For example, recreational fishermen on Canada's east coast must now release all multi-sea-winter salmon (i.e. over 63 cm in length) and all smaller salmon over and above the daily or seasonal limit. Similar legislative restrictions apply to a diversity of species throughout North America (Barnhart 1989). Furthermore, in a number of sport fisheries, individuals as well as tournament organizers are promoting the live release of fish even in the absence of legislation.

Fish caught either by commercial or recreational methods often struggle to the point of complete exhaustion. Black (1957a, 1957b, 1957c, 1958) has shown that a significant percentage of these fish may die from the ordeal. Death does not occur immediately, but often well into the recovery period. While other investigators have documented similar mortalities in exhaustively exercised fish (Bouck and Ball 1966; Beggs et al. 1980; Graham et al. 1982; Wood et al 1983), some studies indicate that exhaustive exercise is not associated with significant mortality (Wydoski et al. 1976; Tufts et al. 1991). It is clear nonetheless that the period of exhaustive exercise associated with angling or struggling in commercial fishing gear results in a significant physiological disturbance in a fish (Wood and Perry 1985). Furthermore, complete recovery is not guaranteed simply because the exhausted fish is eventually released.

In both commercial and recreational fisheries, exhaustive exercise is often followed by a brief period of air exposure prior to release. During this time, the gill's delicate lamellae will collapse and gas exchange may be largely inhibited. The importance of this additional stress on the disturbance associated with exhaustive exercise and on the process of recovery has not previously been investigated. The purpose of the present study was therefore to examine the additive effect of brief air exposure on the physiological disturbance associated with exhaustive exercise in the rainbow trout (*Oncorhynchus mykiss*). In view

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of the rapidly growing importance of catch and release policies in the management of fisheries, it is hoped that this study will provide some insight into an additional stress which has often been overlooked, but which may ultimately influence the survival of released fish.

Methods

Animals

Freshwater-adapted rainbow trout (300- to 500-g males and females) were obtained from a local supplier and were maintained for at least 1 mo prior to experiments in dechlorinated Kingston tap water (8–10°C). The animals were fed to satiation every other day with commercially prepared trout pellets. At least 2 d prior to surgery, feeding was halted and the animals were transferred to an acclimation tank at the experimental temperature (15°C).

Surgery

The fish were anaesthetized in a 3-aminobenzoic acid ethyl ester (MS-222, Sigma) – $NaHCO_3$ – dechlorinated tap water mixture (1 : 2 : 10 000, w/w) prior to surgery. During surgery, the gills were continuously irrigated with a MS-222–$NaHCO_3$ mixture (10^{-1} the original concentration). The dorsal aorta was cannulated with PE 50 tubing (Clay Adams) filled with heparinized (20 $U \cdot mL^{-1}$, Sigma) freshwater teleost saline (Hoar and Hickman 1983). Following the 5- to 10-min surgical procedure, animals were revived and placed in blackened perspex chambers with flowing dechlorinated tap water (15°C) where they remained for 24–48 h of recovery. This procedure allows the collection of dorsal aortic blood from unrestrained animals (Smith and Bell 1964).

Experimental Protocol

Following recovery, an 800-μL blood sample was removed from the resting fish with a Hamilton gas-tight syringe. The fish was then moved to a cylindrical tank where it was exhaustively exercised by manual chasing. After about 10 min, the fish would no longer respond to chasing and the exercise period was terminated. At this point, another blood sample was removed and the fish was returned to the blackened perspex box. Additional blood samples were taken 30, 60, and 240 min after exercise. A second group of fish was subjected to a similar protocol. However, these fish were moved to a damp cloth for 60 s immediately following the exercise period and the second blood sample was removed at the end of this brief period of air exposure. Finally a third group of control fish was subjected to a similar blood sampling procedure but was not exercised or air exposed.

Survival of fish was recorded after 12 h. For this data set, an additional group of fish was exercised and air exposed for 30 s but no blood samples were taken.

Analyses

True plasma pH (extracellular pH, pH_e) was determermiend with a PHM 73 pH meter and associated micro-pH unit (Radiometer, Copenhagen, Denmark) thermostatted to 15°C. Blood plasma was separated from the corpuscular component by 2 min of centrifugation in an Eppendorf centrifuge. Oxygen partial pressure in whole blood (Po_2) was measured with an E5046 oxygen electrode (Radiometer) thermostatted to 15°C and an associated oxygen meter (Cameron Instrument Co., Texas, USA). A similar oxygen electrode was used to determine the total oxygen content (To_2) of blood by the method of Tucker (1967). Total carbon dioxide contents (Tco_2) of whole blood and plasma were measured with a Corning model 965 CO_2 analyzer (CIBA Corning Canada Inc.). Hemoglobin (Hb) content of blood samples was measured by Drabkin's method using Sigma reagents and procedures (Sigma Bulletin No. 525). Whole-blood lactate concentrations were determined on neutralized perchloric acid extracts by the method of Lowry and Passonneau (1972). Measured values of true plasma total carbon dioxide and pH_e were used to calculate Pco_2 and true plasma bicarbonate concentration ($[HCO_3^-]_{tpl}$) via a rearrangement of the Henderson–Hasselbach equation with the values for pK′ and αCO_2 determined according to Boutilier et al. (1984). The concentration of metabolic protons added to the plasma ($\Delta[H^+]_m$) over any given time period (e.g. time 1 to 2) was calculated according to McDonald et al. (1989) using the following equation:

$$\Delta[H^+]_m = [HCO_3^-]_{tpl,1} - [HCO_3^-]_{tpl,2} - \beta(pH_{e,1} - pH_{e,2})$$

where β is the nonbicarbonate buffer value of true plasma.

Statistics

Two sample Student *t*-tests (unpaired) were employed to determine the significance ($p < 0.05$) of differences observed between treatment groups. A one-way ANOVA was followed, where appropriate, by Dunett's multiple comparisons test to determine significance ($p < 0.05$) between resting and recovery values within groups. All values are presented as the mean ±1 SE.

Results

One minute of air exposure following exhaustive exercise promotes more severe acid–base disturbances than does exercise alone. In trout which were exercised, the pH_e fell by 0.239 pH unit whereas in trout which were also air exposed, the

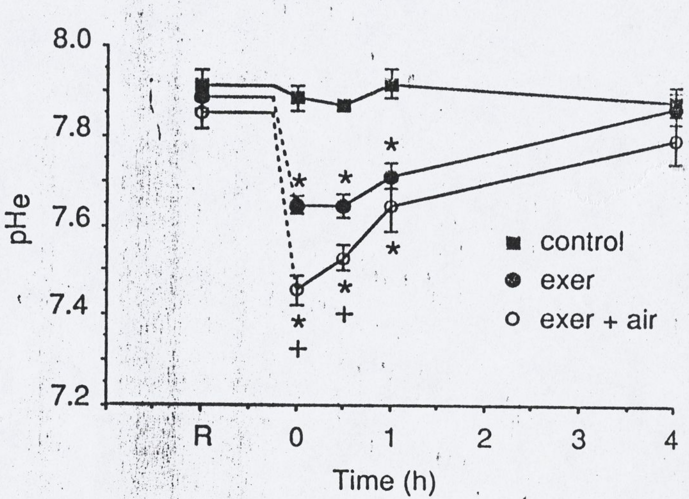

FIG. 1. Extracellular pH (pH_e) in rainbow trout at rest (R) and after 0, 0.5, 1, and 4 h under control conditions (■), following exhaustive exercise (●), or following exhaustive exercise plus 60 s of air exposure (○). Values are means ± SE (control, $N = 6$; exercise, $N = 8$; exercise + air, $N = 7$). An asterisk denotes a significant difference from the resting value. A plus sign denotes a significant difference between exercise and exercise + 60 s of air exposure.

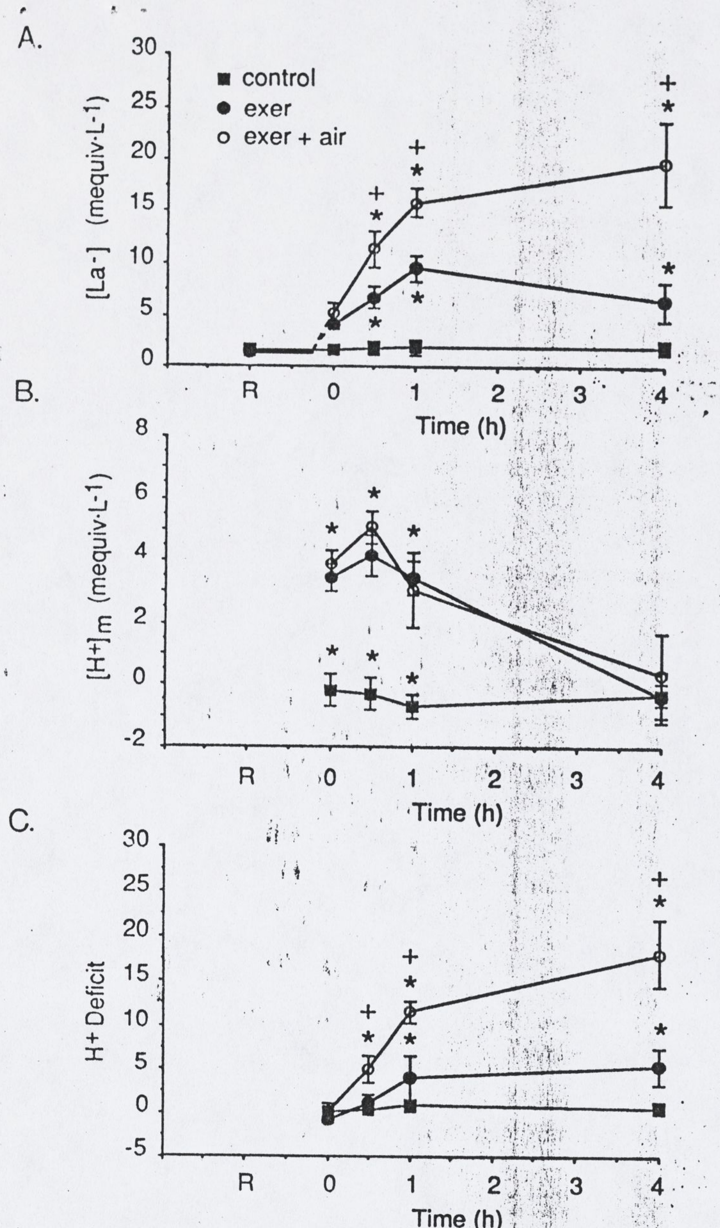

FIG. 2. (A) Blood lactate concentration ([La$^-$]), (B) metabolic proton load ([H$^+$]$_m$), and (C) proton (H$^+$) deficit in rainbow trout at rest (R) and after 0, 0.5, 1, and 4 h under control conditions (■), following exhaustive exercise (●), or following exhaustive exercise plus 60 s of air exposure (○). Values are means ± SE (control, $N = 6$; exercise, $N = 8$; exercise + air, $N = 7$). An asterisk denotes a significant difference from the resting value. A plus sign denotes a significant difference between exercise and exercise + 60 s of air exposure.

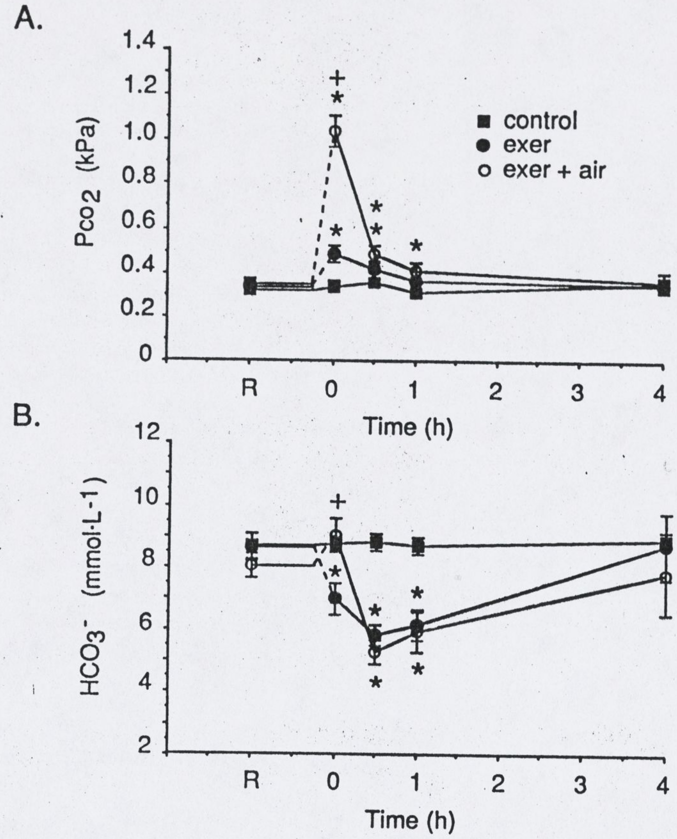

FIG. 3. (A) CO_2 tension (P_{CO_2}) and (B) bicarbonate concentration ([HCO_3^-]) in rainbow trout at rest (R) and after 0, 0.5, 1, and 4 h under control conditions (■), following exhaustive exercise (●), or following exhaustive exercise plus 60 s of air exposure (○). Values are means ± SE (control, $N = 6$; exercise, $N = 8$; exercise + air, $N = 7$). An asterisk denotes a significant difference from the resting value. A plus sign denotes a significant difference between exercise and exercise + 60 s of air exposure.

decrease in pH_e was 0.396 pH unit (Fig. 1). The pH_e remained significantly lower in the air-exposed group until the 1-h sample. By 4 h, the pH_e of both groups had returned to values which were no longer significantly different from those at rest.

A large increase in blood lactate was observed following exhaustive exercise as well as exhaustive exercise followed by brief air exposure (Fig. 2A). In the latter, the amount of lactate accumulated was significantly greater than that seen following exercise alone. The peak blood lactate in the exercise group was 9.6 ± 1.3 mequiv·L^{-1} and occurred after 1 h of recovery. In contrast, the blood lactate in the air-exposed fish continued to increase throughout the experiment and the maximal concentration of 19.8 ± 3.9 mequiv·L^{-1} was observed at 4 h. There were no significant differences in the blood metabolic proton loads of the two groups throughout the recovery period (Fig. 2B). Thus, due to the greater blood lactate concentrations, the air-exposed fish had a much greater proton deficit during the recovery period (Fig. 2C).

The acidosis following exercise also contains a respiratory component (Fig. 3). Although there is a significant reduction in plasma T_{CO_2} immediately after exercise, there is a 44% increase in P_{CO_2} (Fig. 3A). After air exposure, however, there is a significant increase in T_{CO_2} and a much greater increase (200%) in P_{CO_2}. Air exposure after exercise also causes a significant increase in plasma [HCO_3^-] rather than the observed decrease in fish which were only exercised (Fig. 3B). Following 30 min of recovery, there were no longer any significant differences between these groups of fish, and by 4 h, these variables had returned to resting values.

Blood P_{O_2} was significantly reduced by 28% after exhaustive exercise, but there were no significant changes in hemoglobin:oxygen carriage (Hb:O_2) (Fig. 4). P_{O_2} returned to resting values after 1 h. In contrast, these variables were reduced by 82 and 87%, respectively, when the fish were also exposed to air for 1 min. Again, after 30 min of recovery in water, there were no significant differences between the two groups.

Exercise and brief exposure to air after exercise both had an impact on survival of the fish during the next 12 h (Fig. 5). Survival after 12 h ranged from 100% in the control fish to 28%

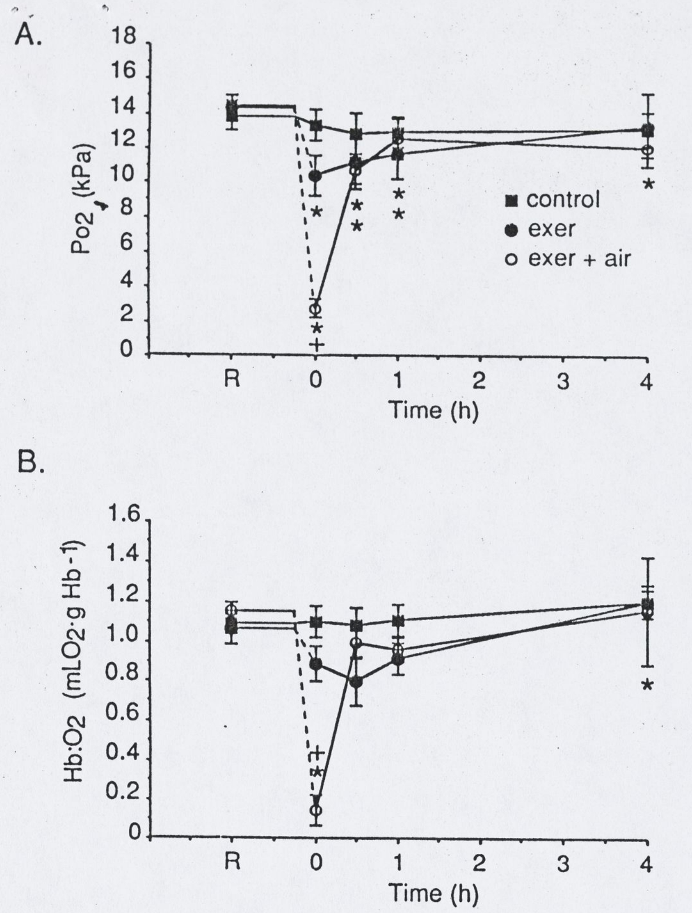

FIG. 4. (A) Blood oxygen tension (Po_2) and (B) hemoglobin:oxygen carriage ($Hb:O_2$) in rainbow trout at rest (R) and after 0, 0.5, 1, and 4 h under control conditions (■), following exhaustive exercise (●), or following exhaustive exercise plus 60 s of air exposure (○). Values are means ± SE (control, N = 6; exercise, N = 8; exercise + air, N = 7). An asterisk denotes a significant difference from the resting value. A plus sign denotes a significant difference between exercise and exercise + 60 s of air exposure.

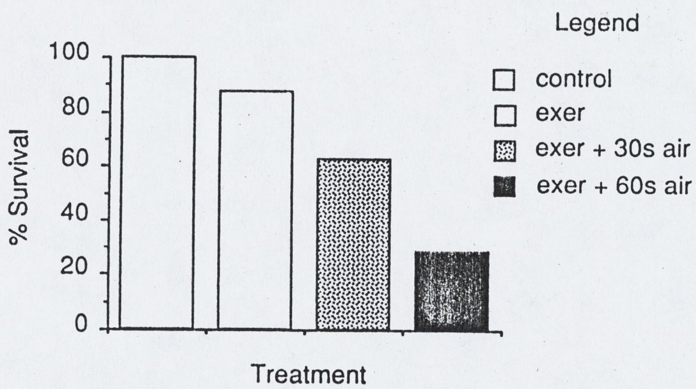

FIG. 5. Survival of rainbow trout 12 h following control conditions, exhaustive exercise, exhaustive exercise plus 30 s of air exposure, and exhaustive exercise plus 60 s of air exposure.

in the fish which were exposed to air for 60 s after exercise. When the period of air exposure was reduced to 30 s, survival increased to 62%, and in fish which were only exercised, survival was 88%.

Discussion

Physiological responses to exhaustive exercise have been well described in a number of fish species (e.g. reviewed in Wood and Perry 1985; Heisler 1986). The magnitude of the disturbance we observed in exhaustively exercised rainbow trout and the dynamics of the recovery process were very similar to that documented by previous investigators (Holeton et al. 1983; Turner et al. 1983; Milligan and Wood 1986; Primmett et al. 1986; McDonald et al. 1989; Tang et al. 1989). However, the impact of brief air exposure on exhausted fish has not been examined previously; thus, the following discussion will focus primarily on this aspect.

In many commercial fisheries, fish which have struggled to exhaustion during capture are routinely exposed to air for sorting and identification prior to release. Similarly, in recreational fisheries, exhausted fish may be exposed to air for photos, measurements, or weighing before release. Indeed, this is common practice during angling contests and tournaments which have become very popular in recent years.

As demonstrated in previous studies, exhaustive or "burst" exercise in rainbow trout is associated with a considerable extracellular acidosis (Fig. 1). In fish which were also air exposed, the fall in plasma pH was much greater. After exhaustive exercise, the extracellular acidosis is normally composed of both a metabolic and a respiratory component (Wood and Perry 1985; Heisler 1986). The metabolic acidosis is caused by anaerobic production of lactate in the poorly perfused white muscle and subsequent release of the associated protons into the extracellular fluid. Our results indicate that the production of lactic acid is probably greater in fish which are briefly air exposed after exhaustive exercise (Fig. 2A). In the air-exposed fish, the blood lactate concentration was higher and it continued to increase throughout the experiment. Thus, even 60 s of air exposure following exhaustive exercise appears to cause a much greater degree of anaerobiosis within the muscle. Despite the higher plasma lactate concentrations, however, the metabolic proton load in the plasma of the air-exposed fish was not significantly different from that of the exercised group (Fig. 2B). Consequently, the proton deficit was larger in the air-exposed group. (Fig. 2C). This suggests either that there was a greater excretion rate of protons in the air-exposed fish after they were returned to water and/or that a significant portion of the metabolic proton load remained within the muscle. These two possibilities cannot be differentiated in the present experiments. However, according to Wood et al. (1983), mortality after exhaustive exercise is probably caused by the extent of the intracellular acidosis within the muscle. Thus, the increased mortality in the air-exposed fish may be evidence that a significant portion of these metabolic protons were retained within the muscle (Fig. 5). Clearly, further study into the muscle acid–base status of air-exposed fish is warranted and may explain the observed differences in survival.

In teleost fish, the majority of gas and ion transfer takes place across the delicate secondary lamellae which are aligned on the gill filaments. These lamellae are largely supported by the water flowing between them and, with few exceptions, the lamellae of most species will collapse if exposed to air (Boutilier 1990). Our results indicate that this reduction in respiratory surface area upon air exposure causes an almost complete inhibition of gas transfer across the gills in the rainbow trout (Fig. 3 and 4). In exhaustively exercised fish which remain in water, there is a significant reduction in the Tco_2 of plasma wherein bicarbonate is titrated by metabolic protons to form carbon dioxide which is excreted (Fig. 3). This results in a transient increase in P_{CO_2} and a reduction in plasma bicarbonate after exhaustive exercise (Turner et al. 1983; Wood and Perry 1985; Heisler 1986; Milligan and Wood 1986; McDonald et al. 1989) (Fig. 3). However, in fish which are also air exposed following exhaustive exercise, T_{CO_2} significantly increases, indicating that gas transfer is largely inhibited while the animals are in air. The marked rise in blood P_{CO_2} during air exposure also explains the significantly greater reduction in blood pH (Fig. 1). Upon return to water, normal gill function is restored and the dynamics of carbon dioxide excretion are not significantly different between the two groups of fish (Fig. 3).

The large reduction in the oxygen content of blood during air exposure is possibly the most critical effect of exposing exhausted fish to air. This reduction was not attributable to any differences in hematocrit or total blood hemoglobin concentration but can be explained by the 81% reduction in P_{O_2} and associated 87% reduction in the amount of oxygen bound to hemoglobin after 60 s of air exposure (Fig. 4). The normal physiological responses of an exhaustively exercised fish combine to enhance oxygen transport to the tissues to compensate for the increased oxygen requirements immediately following exercise (Nikinmaa et al. 1984; Wood and Perry 1985; Primmett et al. 1986; Milligan and Wood 1987). Our results indicate, however, that if the fish is even briefly exposed to air immediately after exhaustive exercise, the tissues will be temporarily deprived of oxygen during this critical period. Indeed, the large difference in plasma lactate concentration created by the air exposure is probably evidence of the detrimental effects of brief air exposure on the tissue metabolism of exhausted fish (Fig. 2A).

The issue of mortality in exhaustively exercised fish is an important management concern in catch and release fisheries. Black (1957a, 1957b, 1957c, 1958) originally demonstrated that significant mortality may occur in exhaustively exercised fish. Similar results have been obtained by a number of other investigators (Bouck and Ball 1966; Beggs et al. 1980; Graham et al. 1982; Wood et al. 1983). In contrast, there is also considerable evidence that mortality from exhaustive exercise is possibly very minimal in many catch and release fisheries (Wydoski et al. 1976; Barnhart 1989; Tufts et al. 1991). Differences in observed mortality may be due to a large number of variables which will undoubtedly be the focus of a great deal of study as the importance of both commercial and recreational catch and release fisheries continues to increase. In this regard, our study clearly demonstrates differences in mortality between exhaustively exercised fish and those which were also briefly exposed to air (Fig. 5). In fact, only 28% of those fish which were exposed to air for 60 s after exercise survived the next 12 h as compared with 88% of those fish which were only exercised. In each case, the extracellular acid–base status of the fish initially appeared to be returning toward normal, but the animals died between 4 and 12 h later. This "delayed mortality" has been observed by other investigators and, in the wild, could give the false impression that released fish always survive (Black 1958; Wood et al. 1983).

The purpose of the present experiments was not to predict actual percentages of mortality in the wild when exhausted fish are briefly exposed to air. The use of hatchery fish and repetitive blood sampling may have influenced our results in this regard. On the other hand, our results clearly indicate that the brief period of air exposure which commonly occurs in many catch and release fisheries is an important additional stress in an exhausted fish and may ultimately have a significant impact on the number of released fish which survive. Finally, as the importance of catch and release fisheries continues to increase, fisheries managers may wish to place greater emphasis on the proper handling of exhausted fish.

Acknowledgements

This study was supported by a Natural Sciences and Engineering Research Council (NSERC) of Canada operating grant to B.L.T. and NSERC postdoctoral fellowship to R.A.F.

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A Word about Burping and Puncturing

Some publicized catch-and-release instructions include advice to "burp" or puncture fish with over-inflated swim bladders brought on by depressurization. Burping involves kneading or massaging the fish's distended belly and sides in hopes of expelling trapped bladder air through the mouth.

Puncturing entails just that—inserting a needle or ice pick through the body wall on either side of the fish. *If correctly done*, puncturing can vent pent-up gas from the bladder through the puncture hole. Burping is difficult, but physiologically possible in those fish whose swim bladder is directly connected to the gut. This type of swim bladder is called physostomus. Notable examples of physostomus fish include salmon and trout. Physoclistous swim bladders found in largemouth and smallmouth bass, perch, striped bass, cod, hake, and black sea bass are *not* connected to the gut, and thus one should *never* attempt to deflate the swim bladders of these fish by burping.

Very few reported studies validate the effectiveness of burping or puncturing in the post-catch survival of released fish. Either method, *if not carried out with care and skill*, could seriously increase physical stress on the fish because of the additional handling and out-of-water time involved. Moreover, damage to internal organs may occur when either technique is applied with less-than-expert skill.

Puncturing is currently being advocated by at least two fishery management agencies under very specific conditions.* Available release/survival research for the species and situations found in New York waters, however, suggests that these extraordinary resuscitation methods are not normally necessary to achieve good survival after release.

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* The California Department of Fish and Game Warmwater Fishery Board suggests puncturing the swim bladder of largemouth bass if the fish appears bloated. The research behind this advice was conducted on bass retrieved from deep warm-water habitats—a situation unlikely to be encountered by New York anglers. This technique remains controversial, given that poor puncturing technique can cause more harm than good. Anglers who wish to learn the correct procedure are referred to the following publication: *Live Release of Bass - A Guide for Anglers and Tournament Organizers*, available from Bass Research Foundation, P.O. Box 99, Starkville, MS 39759. The National Marine Fisheries Service's Southeast Regional Office similarly advocates the puncturing of swim bladders in various snappers and other reef fishes caught from deep water (typically greater than 60 feet) in the Gulf of Mexico and South Atlantic. A videotape entitled *Pass It On* shows the technique. It is available from: NMFS, 9450 Koger Blvd., St. Petersburg, FL 33702; phone (813)-893-3141.

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Acknowledgements

The authors wish to thank Eileen Brennan of the New York Sea Grant Extension Program; Chet Zawacki, Phil Briggs, and Steve Heins of the New York State Department of Environmental Conservation; Andrew J. Loftus of the Sport Fishing Institute; and Carl Safina of the National Audubon Society for their generous assistance in preparing or reviewing this publication.

Cover photo: William A. Muller, Wave Crest Books, Deer Park, N.Y.

Figure 4 (line drawing): Norm Frisch, SUNY College at Brockport, N.Y.

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Cornell Cooperative Extension

This publication is issued to further Cooperative Extension work mandated by acts of Congress of May 8 and June 30, 1914. It was produced with the cooperation of the U.S. Department of Agriculture, Cornell Cooperative Extension, New York State College of Agriculture and Life Sciences, New York State College of Human Ecology, and New York State College of Veterinary Medicine, at Cornell University. Cornell Cooperative Extension provides equal program and employment opportunities. Lucinda A. Noble, Director

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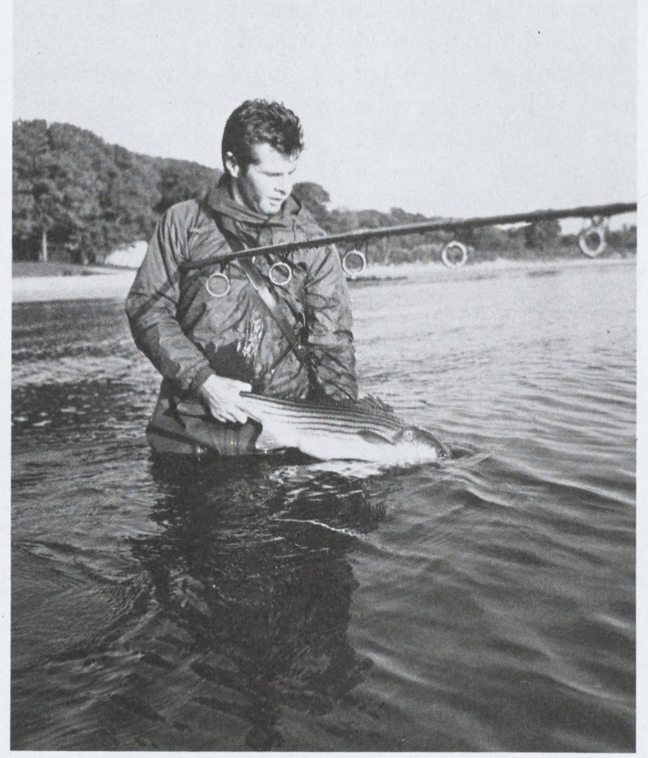
SEA GRANT

CORNELL COOPERATIVE EXTENSION

Guidelines To Increase Survival of Released Sport Fish

Mark H. Malchoff, Michael P. Voiland, and David B. MacNeill
Sea Grant Extension



Angler releasing a striped bass.

Release of live fish by recreational anglers is an everyday occurrence in New York and elsewhere for several reasons. Fisheries management regulations, designed to allow young fish to mature and spawn, frequently require anglers to throw back sub-legal size fish or "shorts." These minimum-size regulations are a prime tool for managing inland and Great Lakes populations of walleye, bass, trout, northern pike, and muskellunge. Several marine species similarly regulated include winter flounder, striped bass, cod, pollock, fluke, blackfish, and weakfish. Even where natural reproduction is negligible (e.g., the salmon population in the Great Lakes), minimum-size regulations are established to develop a quality "put, grow, and take" sportfishery.

Voluntary catch-and-release practices have been called for by fishery management agencies, the outdoor media, fishing clubs, and conservation organizations. Growing numbers of anglers are releasing some portion of their day's catch which might have been legally kept. Perhaps the two best examples of voluntary catch-and-release programs include those encouraged by organized black bass (largemouth and smallmouth) angler groups, and the practices followed by recreational shark fishermen in marine waters.

This fact sheet suggests some guidelines, practices, and equipment to ensure that released fish are in the best possible condition to survive capture and live to enhance another angler's outdoor experiences.

Why Release Legal Fish?

Given the cost of a typical fishing trip, the uncertainties of angling success, and the appeal of a fish dinner, why should anglers adopt the practice of catch-and-release? Aside from the legal requirements discussed above, there are good reasons for releasing a portion of the catch alive. First, catch-and-release offers a way to extend the fishing trip when a reasonable (or legal maximum) number of fish are already in the cooler. If the fishing trip involves a guide or charter service, catch-and-release can prolong a unique, enjoyable, and "paid for" recreational opportunity.

Second, as anglers gain expertise in a particular fishery or technique, they often develop interest in "limiting their kill" instead of "killing their limit." This change in preference and behavior over time has been seen in or suggested by several studies in recent years. As fishing technology continues to improve, this evolution in angler behavior may likely continue.

Third, catch-and-release practices can positively influence both the *density* and *structure* of fish populations. Density is simply the number of fish per mile of stream or volume of water. High fish density does not guarantee fishing success, but most anglers would argue that having more fish in the water is preferable, and certainly more tempting.

Perhaps more important than density, however, is structure—the makeup of a fish population in terms of its age or size classes. In an unexploited, balanced fish population, for example, one would expect to find many size groups (or age classes) of fish, with medium sizes making up the bulk of that population, along with good numbers of both small and large fish (Fig. 1a). In populations subject to fishing pressure ("angling effort"), fish of all sizes may get caught, but the intentional removal of larger fish significantly alters the population structure (Fig. 1b). The result is an unbalanced popula-

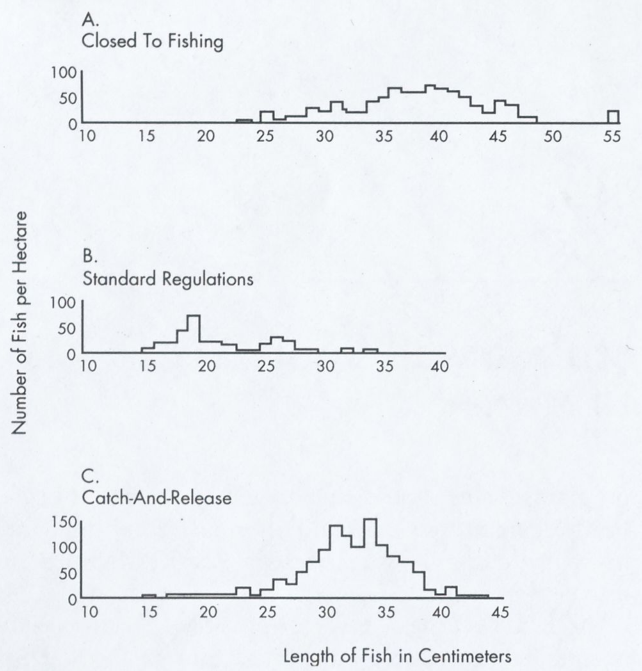


Figure 1. Length-frequency distribution of rainbow trout in three sections of the South Platte River, October 1980. Catch-and-release practices can result in a population structure more like that of unexploited fisheries. (Source: Anderson, R. and R. Nehring, 1984.)

tion, and, under heavy fishing pressure, a less-stable population consisting of fewer size or age classes and fewer adult fish available to reproduce.

In many "no-kill" trout fisheries, the management goal is to prevent this shift in population structure by minimizing fishing mortality in the older year-classes of fish. If widely practiced, voluntary catch-and-release can achieve the same effect (Fig. 1c). Since natural mortality removes most fish before they get to be "lunkers," lowering fishing mortality helps ensure that bigger fish exist in the population. For catch-and-release fishing to benefit the population structure, however, it is important that released fish do, in fact, survive.

Hooking Mortality—How serious? What are the causes?

Some critics of catch-and-release practices argue that stress and wounds inflicted upon sport-caught fish are too-often lethal. In fact, research on freshwater species indicates that hooking mortality may be as low as 0 or as high as 78 percent, depending on the species, season, water temperature, type of terminal tackle, and other variables. In marine waters, mortality estimates from 0 to 36 percent have been calculated for red snapper, rockfish (*Sebates* sp.), and striped bass. In any case, tag returns from both coastal and large ocean-roaming (pelagic) species (such as tuna) show that survival after catch/tag-and-release is common. For example, tuna caught, tagged, and released in the western waters of the Atlantic Ocean have been recaptured off Africa in the eastern Atlantic; and recently a sandbar shark was recaptured 25 years after it was caught, tagged, and released.

Fish that are captured and released may die for a host of reasons, but the two primary causes are *stress* and *wounding.*

In angling stress, the fish's response follows a fairly well understood pattern. First, as with most animals, vigorous physical exertion causes lactic acid to accumulate in the fish's muscles as a result of fighting the rod and reel. This can lead to blood acidification and a temporary disruption of many metabolic processes. If the animal is able to restore its blood acid (pH) level to pre-stress or normal levels, normal physiological processes return and the fish may live to fight another day. In some cases, blood chemistry balance is not restored and the fish may die—perhaps as long as 72 hours after the catch.

Since the amount of lactic acid generated is directly proportional to the duration and intensity of muscular activity, a quick retrieve and capture of the fish would thus tend to lessen muscular exertion and metabolic stress. The traditional sporting ethic of using light tackle (to give fish a 'fighting chance') can lead to long retrieve times while the fish is slowly and carefully played. Research tells us, though, that it may be more sporting to disavow such practices if successful catch-and-release is the objective.

Wounding by the hook is the other major mortality factor, but the evidence here is not easily summarized. As one might suspect, injuries caused by fishhooks can range from minor to lethal, depending upon wound location, hook style, size, and number, type of hook plating, presence or absence of a hook barb, use of artificial lure or live bait, and fish species and size. A brief review of research reports, involving marine salmon, walleye, and striped bass suggests these general conclusions:

- Higher mortalities in sport-caught fish are associated with hook wounds to the gill and stomach areas; intermediate mortalities occur with wounding of the lower jaw, isthmus, and eye areas; and lowest mortalities are related to hooking in the snout, upper jaw, corner of mouth, and the cheek (Fig. 2).

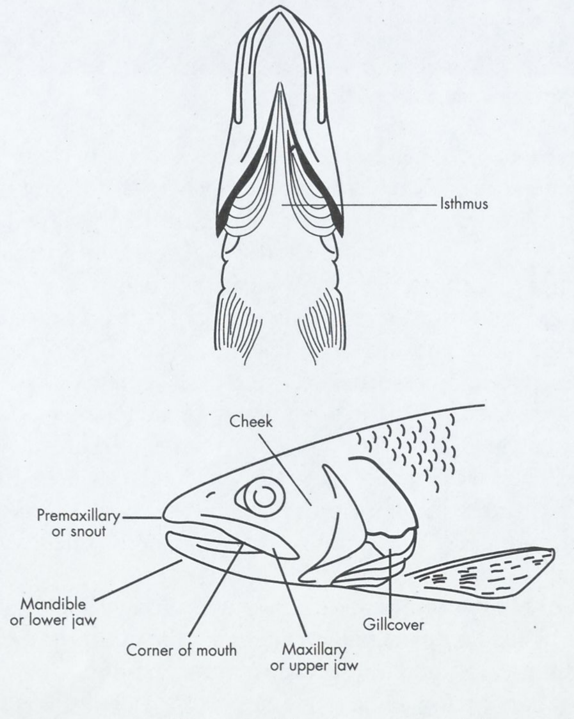


Figure 2. Lowest wounding mortalities of sport-caught fish occur when related to hooking in the snout, upper jaw, corner of mouth, and cheek.

- Baited hooks are more likely than artificial lures to cause serious injury. This is expected, given that live bait is often taken deeper into the gullet, nearer the gill area (large striped bass caught on live eels seem to be a notable exception to this pattern).
- Barbless hooks facilitate release and therefore "out-of-water time," but may not significantly reduce mortality, especially when used with bait.
- Fish are quite capable of rejecting hooks imbedded in the gullet or stomach region, although it may take up to 120 days. The type of metal coating used on the hook may influence the time required by a fish to reject or expel a hook. In one study, bronzed hooks were rejected sooner than stainless steel or nickel-plated hooks. Long retention times, however, do not necessarily mean high mortality rates. The researchers found that although tin/cadmium hooks often broke (probably from electrolysis) and were rejected in less than 60 days, mortality was high, possibly from the toxic effect of these metals. Conversely, no mortality was seen in striped bass carrying stainless steel hooks, despite long retention times (often greater than 120 days).
- Other kinds of physiological stress can lead to higher mortalities in released fish. Fish with swim bladders, when brought to the surface from depths greater than 40 feet or so, may not be able to readily adjust to changing pressures, or the normally higher surface-water temperatures (see following sections). Depressurization can also result in embolism as bubbles form in blood vessels or body tissues when dissolved gasses come out of solution. Also, when a fish is handled or comes in contact with dry surfaces, its protective mucous layers may be partially removed, presenting an opportunity for bacteria or pathogens to invade the skin.

Guidance and Recommendations

The following is the best available advice on how to address some of the points raised above. These catch-and-release guidelines provide basic information on the release of most small- to medium-size freshwater and marine fish. Species- or group-specific information for larger fish or special circumstances is also given following the general guidelines.

General Catch-and-Release Recommendations for All Species

1. If you plan to fish with plugs and spoons, consider replacing treble hooks with single hooks. Single hooks are quicker and easier to remove, especially when dealing with such predators as bluefish and northern pike.
2. Plan your release strategy. Decide whether to keep or release any fish *prior* to angling or at least before removing the fish from the water. Familiarize yourself with any creel restrictions in effect, and gather any items that will facilitate the handling and releasing the fish.
3. When a fish is hooked, use a steady, deliberate retrieve. This can reduce the amount of stress a hooked fish undergoes when pulled up from the depths too quickly, or when physically exhausted from an overly slow retrieve.
4. Once the fish surfaces and comes into view, decide (if not done earlier) to either release or keep it.

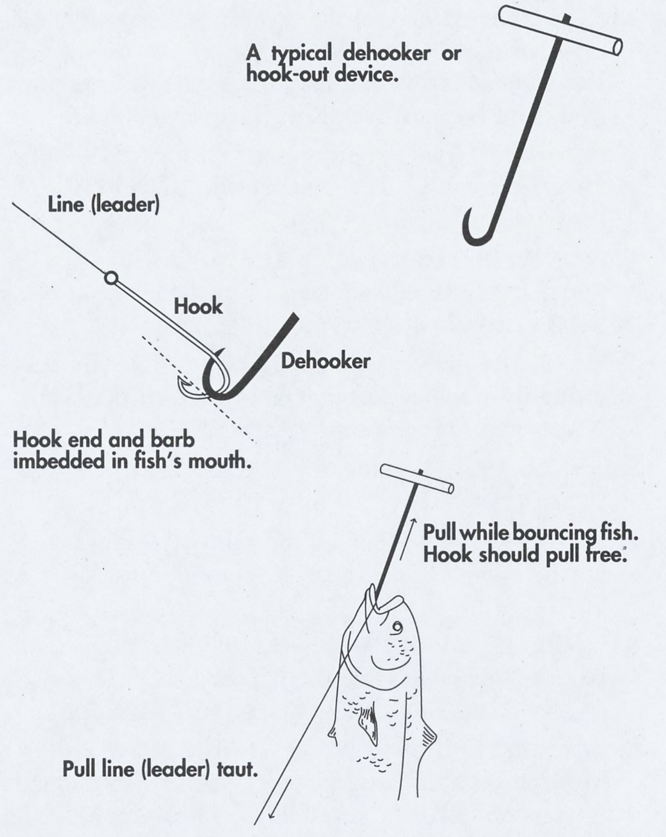


Figure 3. A dehooker can make it easier to pull the hook free with minimal handling.

5. If the fish is not to be tagged, avoid netting or even removing it from the water if possible. Use needle-nose pliers to pry the hook (lures only) from the fish while it is still in the water. Fish that can be lifted by the leader can easily be released over the rail using a "dehooker" (Fig. 3). These devices, whether homemade or purchased, are gaining in popularity in the bluefish fishery (to avoid that species' nasty teeth!) and would be useful for releasing a number of other species. If live bait or a lure is deeply engorged in the fish's gullet, cut the leader as close to the fish's mouth as possible.
6. When landing and/or tagging the fish, it is important to *minimize* out-of-water time and any contact the fish has with surfaces or objects. Therefore—
   - Avoid the use of landing nets if possible and (obviously) gaffs.
   - If you must use a landing net, use one with a neoprene bag rather than natural twine. Neoprene removes less of the fish's slime.
   - Keep your hands moistened. This helps to avoid removal of the fish's natural protective mucous ("slime") layer, and reduces the chance of subsequent infections of the fish's skin.
   - Minimize handling, particularly of the gills and the soft underbelly. Gently prevent the fish from battering itself on the boat deck, beach, jetty, or bank. Experienced fish taggers often place the fish on an old piece of foam cushion and place a wet rag or gloved hand over the fish's eye. These two actions can do much to subdue even unruly tuna and bluefish.
7. If tagging is planned, be prepared with all materials at hand. Attach tags only as specified by that tagging program's literature and, if possible, record length or any other requested data.
8. Return fish to the water gently and headfirst, if possible.

Specific Recommendations

Marine offshore species—The National Marine Fisheries Services' (NMFS) Game Fish Tagging Program advises anglers to simply tow sharks and tuna slowly alongside the boat for tagging and before release. After (or in lieu of) tagging, fish should become revived due to the forced flow of water through the gills created by the towing. Cutting pliers can then be used to cut the leader as close to the hook as possible, and then release of the revived fish can occur.

Tuna and sharks can also be released using a gaff as a dehooker. This requires using a V-notched canoe paddle or similar device to depress the leader while the gaff is slid back to the hook and lifted vigorously. Recovering the terminal tackle may minimize hook wounding/retention problems, although no research evidence for this is yet available.

Marine demersal species (bottom fish) — In New York's marine waters, bottom fish typically encountered in the sportfishery can be grouped as: flatfish (fluke and flounder), gadids (cod, haddock, hake, pollack, and cusk), wrasses (blackfish), and sea basses. For releasing flatfish, follow the General Recommendations given above. Members of the three other groups listed may suffer from depressurization. Blackfish appear to be only slightly affected by this problem and are normally quite capable of submerging to depth immediately after release. Members of the cod family, along with black sea bass, are quite likely to exhibit swim bladder over-inflation when brought up from depths exceeding 40 feet, and may be temporally unable to submerge. Eventually compensation occurs and most fish are able to descend. In most cases the best advice is simply to release the fish even if it is unable to submerge (see 'A Word about Burping and Puncturing'). The headfirst plunge technique developed for lake trout (see below) may be effective for marine species as well, but no research information exists on its effectiveness with marine species.

Warm-water freshwater species—Warm-water fish may be particularly vulnerable to stress because of their higher oxygen demand and rapid accumulation of toxic metabolic end products in tissues. This, compounded by lower oxygen concentrations in warmer waters, will inevitably prolong the recovery of stressed fish. Often, complete recovery can take up to a week following release. One well-proven technique that promotes increased survival of stressed warm-water fish is a simple modification of the "ram injection" method described above. First, choose a nearby release site over deeper and cooler water (if possible) to permit more rapid recovery. Release the fish as described in the General Recommendations. If the fish fails to revive and swim away, recover it. Next, grasp the dehooked fish firmly by the peduncle (the narrow stem just forward of the tail) gently cradling the fish under and behind the gill cover with the other hand. Avoid touching the gills or depressing the gill cover. With the fish in the water, apply a steady, deliberate back-and-forth motion of sufficient force to alternately open and close the mouth and compress/flare the gill covers. Repeat until the fish shows signs of recovery. In extreme cases, it may be necessary to continue this for several minutes. Observe the fish after release; even a successfully revived fish may remain near the surface momentarily before submerging.

A word of caution: Fish in the pike family (muskies, northerns, and pickerels) have special valves just inside the mouth that reduce water backflow from the gills. When applying this technique to pike, the forward stroke can be the more effective step and, consequently, extra time may be required to revive these fish.

Trout and Salmon Taken from Greater Depths—Deep lake salmonine (trout and salmon) species are commonly taken at depths having significantly greater water pressures and lower temperatures than found on the surface. When forced to the surface by hook and line, these fish can be affected by stress or "shock" resulting from the sudden change in pressure and temperature. The fish's survival after release depends upon reducing the time it remains on or near the surface, and quickly getting it back to its preferred, deep-water habitat.

Unfortunately, a fish pulled from deep waters may be unable to swim back down due to depressurization and the resulting expansion of its swim bladder. Such a fish may appear bloated and "bug-eyed," and its stomach—forced forward by the over-inflated swim bladder—may be protruding from the mouth. The fish will lie lazily on the surface, unable to "swim down," and therefore subject to injury from continued stress or predation by gulls and other birds.

To increase the chances for survival of such "surface-shocked" fish, quickly follow the recommendations offered above. Then cradle the fish with one hand around the peduncle (the narrowing in front of the tail) and the other supporting the fish's side at the pectoral region (just behind the gills). As a last step, vigorously push or heave the fish back into the water *head first and straight down* toward the bottom. This literally gives the wearied and stressed fish a solid headstart back down to the pressures and temperatures from which it was taken (Fig. 4).

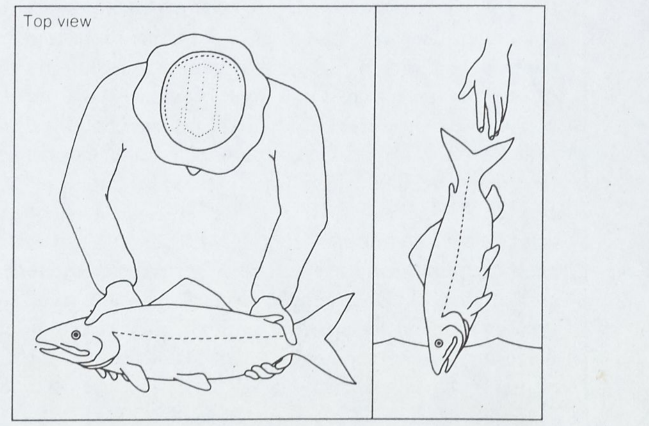


Figure 4. Releasing a "surface-stressed" fish with the headfirst plunge method may help it return more quickly to comfortable water depths. (Source: NY Sea Grant Extension and US Fish and Wildlife Service, 1986.)

Comparisons of Hook Types:
A Summary of Past Studies

George Schisler and Eric Bergersen

Colorado Cooperative Fish & Wildlife Research Unit

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January 11, 1995

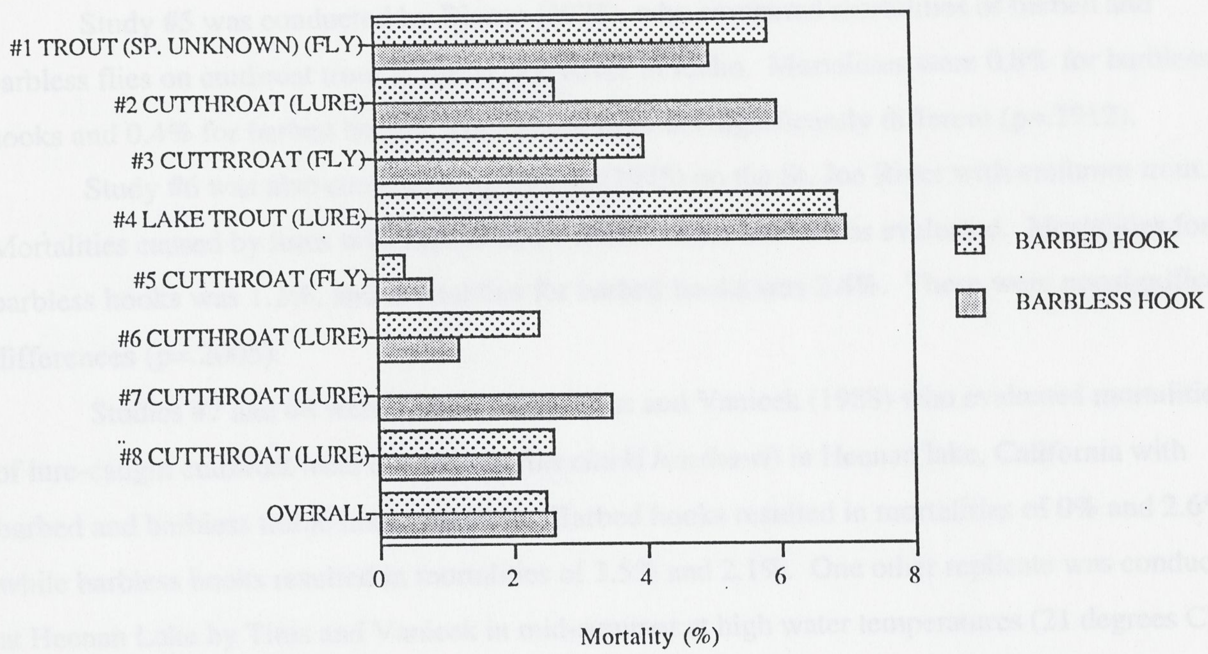
Introduction

Debates over benefits of barbless versus barbed hooks or single versus treble hooks have been going on for decades. Proponents of barbless hooks have argued that they are easier to remove and thus cause less tissue damage to the fish than barbed hooks. Opponents claim barbed hooks cause lower mortalities because the barb prevents the hook from penetrating areas like the roof of the mouth too deeply. Anglers in favor of single hooks make the argument that treble hooks become embedded in more than one location and are harder to remove than single hooks. Others favor treble hooks and maintain that the relatively large size of the treble hook prevents fish from swallowing the hook entirely, which prevents internal organ damage. Intuitive reasoning may give anglers different opinions on these debates depending on individual experiences with different fly and lure types or hook sizes. Many scientific studies have been conducted to evaluate the differences between barbed, barbless, single, and treble hooks. This paper is a summary of past studies that could be found in the literature where direct comparisons of salmonid mortality were made between hook types

Barbed Versus Barbless Hooks

A summary of studies where direct comparisons were made between barbed and barbless hooks is shown in the following graph. Descriptions of the studies shown will follow. Sample sizes, along with numbers of fish that lived and died in each experiment are shown in Table 1. Statistical tests of significance between hook types were evaluated using were two-tailed tests for comparing binomial proportions (Ott 1993) with an alpha level of 0.05.

COMPARISON OF BARBED AND BARBLESS HOOK MORTALITY



Study #1 is the oldest recorded study of this kind found in the literature. It was conducted by Thompson (1946) on an unknown species of trout in New Mexico. Comparisons were made between mortalities of trout caught on barbed and barbless flies. Barbed hook mortalities were 5.9%, and barbless hook mortalities were 5.0%. No significant difference was found between the two hook types (p=.4013).

The second study was conducted by Hunsaker, Marnell, and Sharpe (1970) at Yellowstone Lake, Wyoming. Cutthroat trout (*Oncorhynchus bouvieri*) were captured on lures with barbed and barbless treble hooks. Mortalities were 6.0% for barbless hooks and 2.7% for barbed hooks. The difference was not significant (p=.1131).

Study #3 was also conducted by Hunsaker, Marnell and Sharpe (1970). Again on cutthroat trout in Yellowstone Lake, Wyoming. Comparisons were made between barbed and barbless flies. As with the other studies, no significant differences (p=.4207) were found between barbed (4.0%) and barbless hooks (3.3%).

The fourth study, conducted by Falk, Gillman, and Dahlke (1974) evaluated mortality of lake trout (*Salvelinus namaycush*) with barbed and barbless treble hooks on the Great Slave Lake in Canada. While barbless hooks caused slightly higher mortalities (7.0%) than barbed hooks (6.9%), the results were not significantly different (p=.4920).

Study #5 was conducted by Bjornn (1975), who compared mortalities of barbed and barbless flies on cutthroat trout in the St. Joe River in Idaho. Mortalities were 0.8% for barbless hooks and 0.4% for barbed hooks. The results were not significantly different (p=.2912).

Study #6 was also conducted by Bjornn (1975) on the St. Joe River with cutthroat trout. Mortalities caused by lures with barbed and barbless treble hooks was evaluated. Mortalities for barbless hooks was 1.2%, and mortalities for barbed hooks was 2.4%. These were nonsignificant differences (p=.2005).

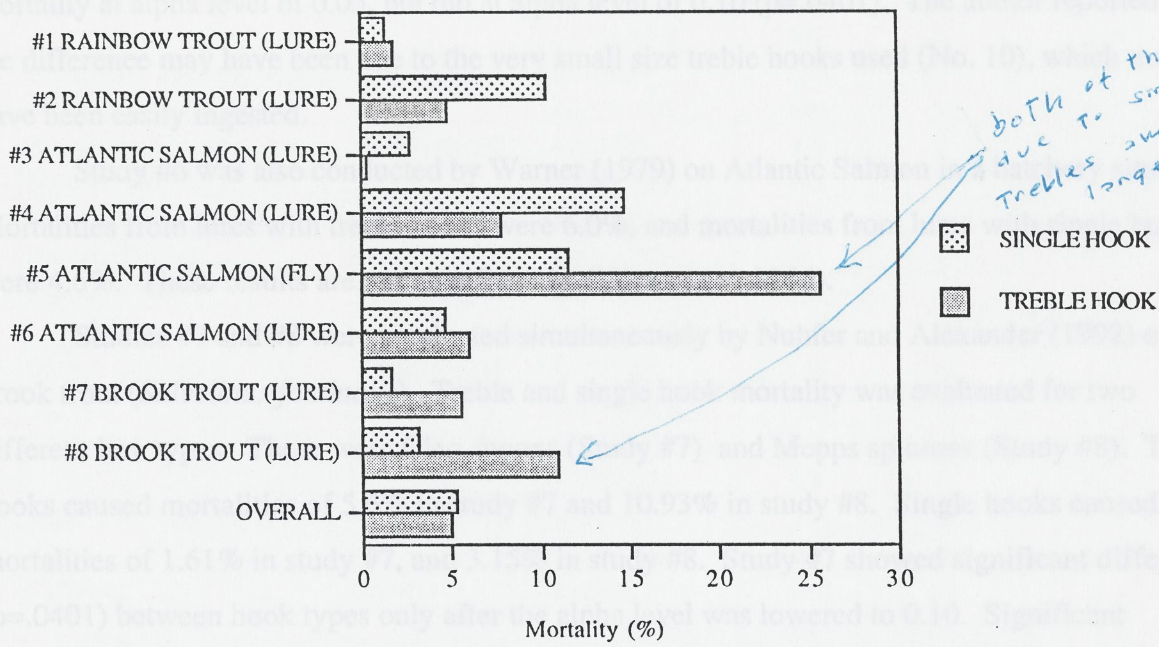
Studies #7 and #8 were conducted by Titus and Vanicek (1988) who evaluated mortalities of lure-caught cutthroat trout (*Oncorhynchus clarki henshawi*) in Heenan lake, California with barbed and barbless treble hooks on lures. Barbed hooks resulted in mortalities of 0% and 2.6%, while barbless hooks resulted in mortalities of 3.5% and 2.1%. One other replicate was conducted at Heenan Lake by Titus and Vanicek in mid-summer at high water temperatures (21 degrees C). Barbed hooks caused mortalities of 48.1% and barbless hooks caused mortalities of 35.3%. Cutthroat trout reach their upper lethal temperature at 21 to 24 degrees C., so the results of that replicate experiment were heavily influenced by the high water temperatures. Because of the confounding effect of high water temperature, we left that replicate out of the data set shown in figure 1. Study #7 resulted in nonsignificant differences between hook types (p=.1660), as did study # 8 (p=.4129).

The overall results include the combined total mortality from barbed and barbless hooks in all of the studies shown in figure 1. These mortality values average 2.5% for barbless hooks and 2.6% for barbed hooks. These values are not significantly different (p=.4247). Mortalities for both barbed and barbless hooks on artificial flies and lures are generally very low. <u>The results of all studies thus far indicate that there is no benefit to using barbed or barbless hooks.</u>

Treble Versus Single Hooks

Mortalities caused by treble and single hooks have been evaluated as extensively as barbed versus barbless hooks. A summary of past studies on treble versus single hooks is shown in the following graph. Descriptions of those studies will follow. Sample sizes and numbers of mortalities are shown in Table 2.

COMPARISONS OF TREBLE AND SINGLE HOOK MORTALITY



both of these are due to small sized trebles and relatively large fish which engulf small lure

Studies #1 and #2 (Klein 1965) compared mortality of rainbow trout (*Oncorhynchus mykiss*) caught and released on lures with single and treble hooks in a rearing pond. Mortalities were 1.3% for trout caught on single hooks, and 1.8% for those caught on treble hooks in the first replicate experiment. Mortalities in the second replicate experiment were 10.3% for fish caught on single hooks, and 4.8% for fish caught on treble hooks. No significant differences were found in study #1 (p=.3336), although single hooks caused significantly higher mortalities than treble hooks (p=.0078) in study #2.

The third study, conducted by Warner (1976) evaluated mortalities of Atlantic salmon (*Salmo salar*) caught in a hatchery environment on lures with barbed treble and barbed single hooks. Mortalities were 0.3% for treble and 2.7% for single hooks. Mortality from single hooks was significantly higher than mortality for treble hooks in this study (p=.0057).

The fourth study was conducted by Warner (1978), and evaluated mortalities of Atlantic salmon caught on lures with treble and single hooks in a lake situation. No significant differences were found between the treble (7.8%) and single (14.7%) hooks (p=.0526).

Study #5 was conducted by Warner (1978) on Atlantic Salmon in a lake environment, and compared treble versus single hook flies. Treble hook flies resulted in 25.6% mortality, while single hook flies resulted in 11.5% mortality. Treble hook flies did not cause significantly higher mortality at alpha level of 0.05, but did at alpha level of 0.10 (p=.0401). The author reported that the difference may have been due to the very small size treble hooks used (No. 10), which may have been easily ingested.

Study #6 was also conducted by Warner (1979) on Atlantic Salmon in a hatchery situation. Mortalities from lures with treble hooks were 6.0%, and mortalities from lures with single hooks were 4.6%. These results are not significantly different (p=.2266).

Studies #7 and #8 were conducted simultaneously by Nuhfer and Alexander (1992) on brook trout (*Salvelinus fontinalis*). Treble and single hook mortality was evaluated for two different lure types. These were Cleo spoons (Study #7) and Mepps spinners (Study #8). Treble hooks caused mortalities of 5.6% in study #7 and 10.93% in study #8. Single hooks caused mortalities of 1.61% in study #7, and 3.15% in study #8. Study #7 showed significant differences (p=.0401) between hook types only after the alpha level was lowered to 0.10. Significant differences (p=.0075) were found in study #8 at alpha level of .05.

All studies combined result in overall mortalities of 5.3% for single hooks, and 4.9% for treble hooks. No significant difference between treble and single hooks was found with the combined totals (p=.3483). These data suggest that there is no benefit to using either treble or single hooks.

Summary

Very little evidence has been found to support any particular hook type to reduce catch and release mortality. No consistent patterns can be found in past studies that favor one hook type over another. Individual preference should dictate what hook type an angler uses. We recommend that if anglers want to fine tune their ability to release fish alive, they should try different types of hooks, and depending on the size of the fish being captured, voracity of the fish, fishing location, and other factors, decide for themselves what hook type works the best to minimize mortality.

TABLE 1. Mortality studies of barbed versus barbless hooks.

Author	Species	Hook Type	Caught	Killed	Mortality (%)
Thompson (1946)	UNKNOWN	BARBED	51	3	5.9
		BARBLESS	60	3	5.0
Hunsaker, Marnell, and	CUTTHROAT	BARBED	113	3	2.7
Sharpe (1970)		BARBLESS	100	6	6.0
Hunsaker, Marnell, and	CUTTHROAT	BARBED	75	3	4.0
Sharpe (1970)		BARBLESS	60	2	3.3
Falk, Gillman, and	LAKE TROUT	BARBED	72	5	6.9
Dahlke (1974)		BARBLESS	57	4	7.0
Bjornn (1975)	CUTTHROAT	BARBED	256	1	0.4
		BARBLESS	264	2	0.8
Bjornn (1975)	CUTTHROAT	BARBED	209	5	2.4
		BARBLESS	166	2	1.2
Titus and Vanicek (1988)	CUTTHROAT	BARBED	27	0	0.0
		BARBLESS	29	1	3.5
Titus and Vanicek (1988)	CUTTHROAT	BARBED	77	2	2.6
		BARBLESS	95	2	2.1
OVERALL	MIXED	BARBED	880	22	2.5
		BARBLESS	831	22	2.6

TABLE 2. Mortality studies of single versus treble hooks.

Author	Species	Hook Type	Caught	Killed	Mortality (%)
Klein (1965)	RAINBOW TROUT	SINGLE	233	3	1.3
		TREBLE	224	4	1.8
Klein (1965)	RAINBOW TROUT	SINGLE	272	28	10.3
		TREBLE	271	13	4.8
Warner (1976)	A. SALMON	SINGLE	296	8	2.7
		TREBLE	333	1	0.3
Warner (1978)	A. SALMON	SINGLE	95	14	14.7
		TREBLE	116	9	7.8
Warner (1978)	A. SALMON	SINGLE	52	6	11.5
		TREBLE	39	10	25.6
Warner (1979)	A. SALMON	SINGLE	302	14	4.6
		TREBLE	300	18	6.0
Nuhfer and	BROOK TROUT	SINGLE	124	2	1.6
Alexander (1992)		TREBLE	125	7	5.6
Nuhfer and	BROOK TROUT	SINGLE	127	4	3.2
Alexander (1992)		TREBLE	128	14	10.9
OVERALL	MIXED	SINGLE	1501	79	5.3
		TREBLE	1536	76	4.9

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Spec. Regs
— White et al.

ethics

hooking
mortality

DENVER, CO
JAN
17
1995
PM
802

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Ted Kerasote

Pain - C & R

- catch again
- hook in fish
- electrofishing

fractured vert.

- anadromous
salmon [illegible]

sea lions - wounds
by bites.

no change
growth
[illegible]

/spec. regs,
water

- tagging
- floy tag.
- jaw tags
(slow growth)
- [illegible] tags

-

TO--Bob Behnke
From--Ted Kerasote, phone--307/733-1871, fax--307/733-8505

Dear Bob:

Below please find the section in which I describe some of your thoughts and findings about catch and release fishing and whether fish feel pain. Please feel free to change anything that I misconstrued or that you don't like, and please feel free to make any additions.

Thank-you very much for all the time you've devoted to this.

Sincerely,

Ted

NOT FAR from where John Betts fishes on Colorado's South Platte River another angler, Bob Behnke, Professor of Fishery Biology at Colorado State University, ponders these same questions. In fact, he has been doing research on catch and release fishing for more years than lots of us have been walking up and down streams.

His work, and his popularization of other's research, has put paid to several angling myths. For one, that catch and release fishing can help to increase the size of trout in a stream. It can't. "Terminal size and age is determined by environmental conditions and can't be changed by special regulations," he states in no-nonsense sciencese. For another, that barbless hooks are necessary for successful catch and release fishing and that the

-only under [illegible]

size vs. growth

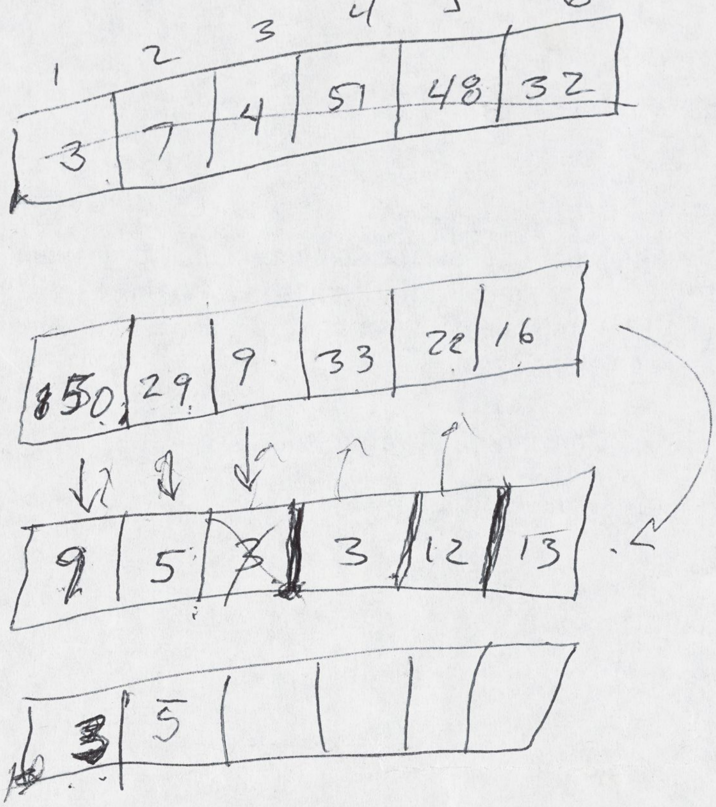
yes: size can increase - but only where environments allow for good growth older age see figures - Yellowstone

< 8%, - 40%, > 4x, 1974-1984

Gunnison also 10x in ≥ 14" but 3x brown

St. Joe 10-2-x > 12"
reduce mort 75-50%
4-5-6-7 - 5-6 x.

50
29
9
10



MIN
9

9
5
3

single hook is less injurious than the treble hooks used on spinning lures. No and no again. Behnke cites controlled studies in which mortality did not increase with barbed hooks nor with treble ones. Such evidence infuriates the purists with their hat brims studded with expensive flies. "Among them," says Behnke, "I'm regarded as an evil person."

Ironically, the hate swarms not only from some in the angling community but also from those in the animal rights movement, for Behnke maintains that fish don't experience the sort of pain that a human might

extreme - Trauma (hospital

experience with a hook in his mouth. "If it ~~was~~ a harsh experience," he says, "you would not likely do it again within a day. Yet you can catch the same fish

in Y. River

every day by dangling a lure in front of it. Yellowstone cutthroats are caught and released about ten times each season. They would learn not to be caught

'severe or [illegible] trauma

again if they were experiencing pain."

He does note that cutthroats are notoriously easy to catch as compared to brown trout, with rainbows someplace in between. Do brown trout thus feel more pain than cutthroats? Or are they just smarter? Anglers contend that brownies are the brainiest of trout, but no one knows for sure.

About Stoskopf's' hypothesis that fish feel pain because they display mammalian-like reactions to stress, Behnke counters, "Similarities don't mean that they're feeling the same kind of pain. Fighting a fish for a long time will change the blood chemistry. Eventually you can produce a lethal effect if

overly

the blood becomes acidified. Pain, I'm not sure."

exhaustion + (warm water)

Degree of pain - only fish know but circumstancial evidence - no way comparable to humans subjected to some stimulus - nervous [illegible] activity - electrofishing - tagging - hook in gullet - salmon, steelhead [illegible] gaping wounds + sea lions - sand sharks

Then, like Williams, he points out that whether individual fish actually feel what we know as pain is not really the issue. "Catch and release is a management tool. Without catch and release you wouldn't be able to maintain quality fishing."

Extracting an essay that he wrote for *Trout*, he points out the following data. In 1989 Colorado sold 800,000 angling licences and projects that angling demand will continue to increase. The average angler fishes 10 days per year, which gave the state eight million angler days in 1989. Twenty-nine percent of these angler days are spent on coldwater streams for a total of 2.3 million angler days trout fishing. The Division of Wildlife sets a goal for each angler of 2.8 fish per day, which may not make most anglers ecstatically happy but is designed to send them home sufficiently satisfied. Do the math and you find that Colorado's trout streams have to produce an annual catch of 6.44 million fish, which is about five million more fish than all of the streams in Colorado can yield.

Ah, but there are hatcheries, maintain those enamored of technological fixes for environmental limits. These put-and-take fisheries, goes their argument, can bridge the gap between the supply of wild trout and angler demand. "Not a chance," says Behnke. Colorado hatcheries produce less than five million catchable trout ~~fish~~, most of them stocked in lakes. ✓

Hence, the need for catch and release. Behnke uses the words, "Recycle trout to maintain acceptable catch rates in heavily fished waters." Lee Wulff, indisputably one of the greatest fly anglers of this century, said the very same thing in 1939 and with a bit less technospeak: "Game fish are too valuable to be caught only once."

From a political and economic standpoint the reasoning of both men is impeccable. Anglers vote and buy fishing licences. They also buy tackle and clothing, stay in motels, and eat in restaurants. There isn't a chamber of commerce in the land that weighs a fish's pain against its community's annual fishing revenues.

You have to seek out a guy like Turner to see the crack in this economic armor. "We're dealing with a group of people," he says, "fishermen, climbers, boaters, whose idea of fun and sport is more important than the good of the environment. I have a great respect for restraint. We could limit access to the resource. Maybe have a lottery like in the Grand Canyon. Raise the cost of licences. We don't have to give everyone unlimited fishing opportunities. Maybe this is something that can't be done everyplace. But it could be done in Yellowstone and Grand Teton parks. Ultimately people have to give."

When I point out to Turner that this would turn America into Europe, where only the wealthy get to fish for trout, he sighs. He has principles, not easy solutions.

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February 22, 1995

Mr. John Randolph
Fly Fisherman
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Dear John:

It has been awhile since we've communicated. The article on hooking mortality by Pat Trotter in the latest issue of *Fly Fisherman* stimulated me to send some comments on the subject. Pat did a commendable job of reviewing and synthesizing the literature. It's apparent he did his homework.

Overall, I agree with his general conclusions. I would only caution against confusing "science" or "scientific" research with precision when dealing with natural phenomena such as the dynamics of population mortality. Precise data such as 2.5 or 3.2% mortality of trout caught and released on specific types of gear are based on site-specific and time-specific tests. One should not expect complete replication of results if the identical test were conducted on another water or even on the same water with the same fish at another time, simply due to inherent variation in nature. Professional gamblers probably best understand the concept of random variation. When we accept a 95% confidence limit as "statistically significant" we demand to be wrong 5% of the time. For example, a situation where the true frequency of occurrence is 2% as with 100,000 marbles, 98,000 are white and 2,000 are black. To estimate the true frequency of black marbles, several random samples are drawn consisting of various sample sizes of 25, 50, or 100 marbles. The resulting estimates might range from 0 to 10% frequencies of black marbles, depending on sample size and random variation in drawing the sample. This example would be a completely controlled test; there would be no external influences causing nonrandom bias. It is quite different for fish mortality data where different people, different water temperatures, hook sizes, and many other factors can bias the results and superimpose nonrandom variation onto random variation. Also, "grouped" data of mortality from different studies to compare hook types (single vs. treble, barbed vs. barbless) have the apples and oranges comparison problem. One must be aware of the uncertainty involved in the literature dealing with hooking mortality despite the precise figures obtained.

I bring this matter up because a C.S.U. graduate student, George Schisler, is now writing his graduate thesis on hooking mortality. George's study, with the help of the outstanding statistical and mathematical modeling expertise of some of our faculty, is the most comprehensive, detailed, and statistically sound (the most "scientific") study yet on hooking mortality. The study was designed to obtain data on hooking mortality of trout caught on "power bait," a completely artificial, scented bait which presently conforms to the definition of "artificial" for special regulation waters in Colorado. The data base includes trout caught in a small pond, a large reservoir, and in a river. George will publish the results of his study in a fisheries journal. I can't reveal all of the details but will provide some of the highlights. Trout caught on power bait (fished as natural bait) have a mortality comparable to live bait. Water temperature has the greatest external influence on mortality of trout caught-and-released by any method. The higher the temperature, the higher the mortality. Holding a trout out of water can increase mortality after about three to five minutes. One to two minutes out of water causes insignificant increase in mortality. Increasing the time a fish is played (from hooking to landing) from one to five minutes can increase mortality (slightly); this increased mortality is more pronounced with smaller trout (9-10 inches) than with larger (16-18 inches) fish. The increased mortality from time out of water and playing time is strongly related to water temperature. Death is strongly associated with where the fish is hooked -- fish hooked in the stomach or esophagus (common with bait) or gill filaments (causing bleeding) have the highest probability of dying, but cutting the leader and leaving the hook in the fish can reduce this mortality by more than half.

George applied state-of-the-art statistical analysis to produce integrated, three-dimensional graphs which illustrate expected mortality based on gear, water temperature, time out of water, and playing time as they interrelate to each other. When George's study is published, I expect <u>Fly Fisherman</u> will receive letters about this scientific, state-of-the-art study on hooking mortality. I do believe it is the most comprehensive and sound study on hooking mortality to date and the first one which integrates, simultaneously, several factors influencing mortality. I again urge caution, however, in placing great faith in the precision of the graphs. For example, the graph might show that a 12-inch trout caught on a fly, played for three minutes in 55° F water, and held out of water for two minutes has a predicted mortality of 3.2%. It would be a mistake to accept this as a precise and universally true prediction. The data George put into the model is highly variable, due to natural, random variation, and probably also to uncontrolled bias. The statistical method uniformly smooths the data. Without critically analyzing the raw data used in the "idealized" model, and having some understanding of natural variation and statistical probability, one could readily be deceived to claim a degree of precision that is unreal. "Science" cannot remove variation from nature, only try to better understand it.

George and his professor, Dr. Bergersen, wrote a short paper for the Colorado Division of Wildlife on statistical analyses of literature studies on hooking mortality comparing barbed vs. barbless hooks and single vs. treble hooks. I'll enclose a few pages from the report, which concluded no statistically significant differences in mortality between barbed vs. barbless or single vs. treble hooks. I would point out, however, how "lumping" of data can be misleading and the need for critical analysis to avoid apples and oranges comparisons. In the single vs. treble hook comparisons, the overall, "lumped" comparisons do not differ, but note the Michigan study which found significantly higher mortality on trout caught on small spinning lures with treble hooks (about 5 and 10% mortality for trout caught on treble hooks in two studies vs. 2-3% for those caught on the same lures with single hooks). As mentioned, hooking mortality is associated with hooking deep within the mouth. These were relatively large trout which could engulf the small spinning lure (significantly more large trout, over 18 inches, were deeply hooked than smaller fish). The probability of a treble hook causing lethal damage, once the lure is within the mouth, is greater than that of a single hook. This relates to the size of the fish and the voraciousness of strike to engulf the lure during any particular time of fishing. Thus, this Michigan study of large brook trout in a lake could be cited as an example where treble hooks caused higher mortality than single hooks. One should be aware of the complete study, however. What is not depicted on the graph is the results of catching 126 large brook trout during this test on a Rapala lure with large treble hooks. Not a single mortality occurred in the 126 trout caught and released on a Rapala. They simply couldn't get the hooks inside the mouth to cause lethal injury. If the data from these 126 trout were added to the grouped analysis, treble hooks would, overall, show significantly less mortality than single hooks, but apples and oranges are being compared. There are large treble hooks on large lures which rarely get deeply inside the mouth and there are small treble hooks on small lures which are much more likely to be deeply engulfed by larger fish.

The bottom line conclusion is that studies showing survival advantage for a certain hook type are site-specific, time-specific, and condition-specific. They should not be broadly extrapolated to other sites and other conditions at other times. The grouping or "lumping" of numerous studies to obtain overall mean values superimposes nonrandom variation on random variation and will be tainted by apples and oranges comparisons.

Personally, I prefer to fish with barbless flies. Their most practical advantage concerns the hooking and releasing of humans. In waters where single barbless hooks are mandatory, a problem I have is that when action is fast and a fly is lost and a new fly is quickly tied on, I frequently forget to press down the barb and I could be cited as a law-breaker. I would question the credibility of a "barbless hook only" regulation unless it could be clearly demonstrated by factual data on a specific water that such a regulation significantly reduces hooking mortality. Otherwise, I prefer hook type to be the option of the angler. The use of barbless hooks would gain more favor if anglers were convinced that a higher percentage of strikes are hooked on barbless hooks, due to their ease of penetration. Some of your readers might test this hypothesis and send in the results. I would expect, however, that such test results would be contaminated by nonrandom bias.

Sincerely,

Robert Behnke

HOOKING MORTALITY OF TROUT

PATRICK TROTTER, PH.D.


PAUL UPDIKE PHOTOS

A review of the scientific studies

THIS ARTICLE WAS PROMPTED by a letter to the editor (July 1994) from Perk Perkins, president of Orvis. Mr. Perkins commented on Larry Tullis's earlier Forum, "Is Barbless Always Best?," in the February 1994 issue. Rather than debate the matter endlessly, Mr. Perkins suggested that FLY FISHERMAN publish an article summarizing the many scientific studies bearing on the issue.

I have been tracking the scientific literature on this subject since 1984, when the issue of hooking mortality of different types of terminal gear almost erupted into war among sport-fishing groups here in Washington State. There have been many studies—my stack of reprints is now more than nine inches deep. They have generally focused on the broader issue of bait versus lures and flies, but the question of barbed versus barbless hooks has not been overlooked. Although the findings have been written up many times in the angling press, the debate over the validity of these findings seems to have taken on a life of its own. What the original reports say may surprise you.

To begin, let's review why hooking mortality is important in the first place. The answer lies in fish population dynamics. Even if there is no angling at all, a substantial percentage of the catchable-size fish in a population die during the year. Predators get them, they succumb to disease, or they simply die of old age. The actual percentage varies from population to population, but for the sake of discussion, let's say it is 50 percent of the catchable-size fish. These are replaced, of course, by an equivalent number of recruits into the catchable size range each spring.

It also turns out that up to about that same percentage, angling mortality is compensatory. In other words, if angling mortality is significantly less than 50 percent in our hypothetical case, the catchable-size fish lost to angling are offset by fewer fish succumbing to natural causes that season and the population will maintain itself. (It may also mean that while the total number of fish may be no greater, there may be a higher proportion of older, therefore larger fish in the population in succeeding years.) On the other hand, if angling mortality equals or exceeds that percentage, it becomes additive with the natural mortality and the population will decline.

The whole objective in a catch-and-release fishery, then, is to keep the angling mortality from exceeding that magic compensatory level. Even if hooked fish are returned alive to the water by anglers, the program will fail if those fish later die from the experience in numbers that approach or exceed the compensatory mortality level.

Understanding this compensatory relationship is important—so much so that it probably deserves an article of its own. But for now, just remember that it's this that makes our terminal gear so important. If enough fish die from being hooked, even when we release them apparently unharmed, wild-fish programs maintained by catch-and-release angling are lost causes.

Digging Up the Reports

IF YOU DIG OUT EVERY REPORT you can find on the subject and read them for yourself, the first thing that may surprise you is how long fishery managers have been concerned about hooking mortality. This is not a recent phenomenon ushered in with the catch-and-release movement. The earliest study I found was one conducted on brook trout in Michigan and published in 1932. Since then nearly every species of coldwater (and most warmwater) gamefish has been covered. Both wild and hatchery fish have been studied in stream, lake, pond, and marine environments. What follows is drawn from the literature on salmonids, because those fish are my specialty. But warmwater aficionados need not feel left out; warmwater literature is equally ample, and it reaches the same conclusions.

All hooking-mortality studies are designed to determine the loss

Continued on page 18

Fly Fisherman
March 95

ROCKY MOUNTAIN Flycasters

THE FOURTH ESTATE

April 1995

Credibility

By Bob Behnke

We all remember taking a test or giving a talk in school. In reviewing a student's performance, it is not difficult for a teacher to assess which students have done their homework; how credible were their written and oral statements.

Every year or so I feel obligated to write something about hooking mortality in relation to hook type (such as single, treble, barbed, or barbless) in response to heated debate on the subject. I realize my attempts at education have all of the power of information penetration as water on a duck's back, but I still feel the obligation.

Thus, I recently wrote to Fly Fisherman in response to the ongoing barbed-barbless controversy. I attempted to point out that the desire to settle the matter once and for all by "scientific" study can never be fulfilled. The reason for this concerns an understanding of random chance, nonrandom bias from uncontrolled influences, and the problems of mixing oranges and apples when grouping data from different studies. I also mentioned that George Schisler, a Colorado State University graduate student, is currently completing a thesis on hooking mortality. George's study is the first to simultaneously integrate several factors, such as type of terminal tackle, water temperature, playing time, and time out of water, as they relate to mortality of trout caught and released.

I warned, however, that when George publishes the results of his research and anglers become aware of the most "scientific" study to date on hooking mortality,most will not understand that the statistical treatment has smoothed the various factors. ~~Most will not understand that the statistical treatment has smoothed the~~ variation in the raw data to give the illusion of great predictive precision. The precision is an illusion produced by the statistical model. The results of each study on hooking mortality is site-specific, time-specific, and condition-specific. Unless large and consistent differences are apparent among many studies such as comparing mortality between bait and artifical fly or lure-caught fish, no universal conclusions are warranted (for example, between treble vs. single hooks or barbed vs. barbless.)

Credibility
continued on page 2

FORWARD CAST

By Tom Post

The time has come; time to find out about the fantastic trip to Chile and Patagonis in search of the elusive and wily South American trout. In January of this year former President Bruce Biggi, Dr. Robert Behnke, Claudio Meyer and Brian Jannois went on an adventure flyfishing trip to the fabled southern hemisphere to sample the wine, scenery and of course the trout fishing! What transpired on their eventful two weeks in Chile will be told on April the 12th at 7:30 in the evening at the University Park Holiday Inn.

Having talked to Bruce a little about the trip I personally can not wait to see the slides and hear the tales. Please join with other TUers to be entertained at this meeting; remember, a Thomas and Thomas flyrod is always in the raffle! After a spring break spent fishing I am sure some tall tales other than the Patagonia story will be overheard in the room that evening.

BACKCAST

By Tom Post

For those people that attended our March 8th general meeting I am sure that fishing the Poudre River might seem a tad mundane after tasting a slice of exotic Russian fishing. The program presented by Mikhail Skopets was one of the more interesting and eye opening of the year! Mikhail regaled us with scenes of amazingly beautiful and wild places. Mikhail was born and raised in the shadow of the Ural mountains and his love of his country shines through in his photos and his words. He was educated at Ural University and after the opening of travel abroad for Russian citizens Mikhail began to come to the U.S. for pleasure as well as vocation. Thankfully for us he travels to the Fort fairly frequently! He manages a tour company called Talan, specializing in taking groups of ten anglers into an area that is a nature preserve and that is incredibly pristine. The anglers are transported by helicopter from the city of Magadan into the interior where each group has ten miles of water for their own use. The fishing is with fly rod for several types of salmon, char and grayling. Fifty fish days are not uncommon and mid August to mid-September are the best times because of the voracious insect life. They use double handed spey rods for most of the fishing with sink tips and shooting heads to get the fly down. This program elicited many comments from the audience who were obviously spellbound. The scope of the landscape and the variety of fishing opportunities to be had would make this trip "a trip of a lifetime".

Again a hearty thank you to Mikhail for his time spent with us!

Credibility, continued from page 1

George and his adviser, Dr. Bergersen, compiled information comparing mortality to hook type for the Colorado Division of Wildlife. They compared a great amount of data to demonstrate no statistical difference on mortality of trout caught and released on treble vs. single or barbed vs. barbless hooks. Actually, if they included data from a Michigan study concerning catching and releasing 126 large trout on a Rapala (with large treble hooks), in which not a single trout died, treble hooks would have shown significantly less mortality than single hooks -- but this would be the apples and oranges problem. There are large treble hooks which rarely get inside the mouth to cause lethal damage and there are small treble (and single) hooks which are more likely to be engulfed.

Concerning credibility, if a Trout Unlimited member were to make a plea to the Wildlife Commission to institute a single barbless hook regulation, such a plea could be made in the context of court testimony with all the implications of burden of proof based on factual evidence. The Commission will have a copy of the statistical analysis mentioned above. To counter this evidence with an emotional plea based on a gut feeling that we intuitively know what is true and good, would not likely hold up in court.

For those interested in doing some homework, I will have an article on whirling disease and wild trout in the spring issue of *Trout*. I also published a paper co-authored with three economists on the economics of catcheable trout fisheries in the February 1995 issue of the North American Journal of Fisheries Management (the true economic cost of catchables is considerably greater than what CDOW claims and we did not include such items as costs now attributable to whirling disease). I can assure you that these subjects concern much more substantial issues than barbed vs. barbless hooks.

Tackle Tips and Trips

SPRING CREEK - FLAT WATER DOWNSTREAM DRY FLY PRESENTATION

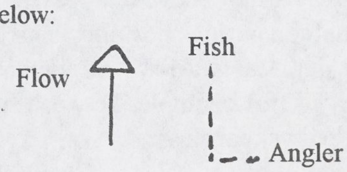
BY JEFF STONE

Fishing the smooth, flat water of a spring creek presents a fly-fisher with a number of difficult circumstances. The water is normally crystal clear and fairly shallow with a number of conflicting currents. The fish can be unusually spooky and particularly selective to the intricacy of the fly pattern.

Dealing with this situation and still having an opportunity to catch the fish requires a number of things from the angler. A quiet approach, good cast, drag free drift and an accurate representation of the insect on the water are those requirements. Due to space limitations, only approach and presentation will be discussed here.

The best opportunity for success in these situations requires fishing only to fish observed feeding on or near the surface. Approach the fish from an upstream direction and off to its side moving as slowly and quietly as possible. The angler's profile must be kept low by bending at the waist and knees. No bow waves can move ahead of the angler while moving through the water.

Move as close to the fish as possible but not so close as to spook it. Only experience can teach where that spot is. Final position should look like the diagram below:



SPRING CREEK Continued on page 3

SPRING CREEK
Continued from page 2

Notice the "L" shape, this is the general position for the downstream presentation. Now, wait for the fish to rise again so its precise location can be determined. The cast, a slackline reach cast, can now be made.

This cast is made aiming for a spot a couple of feet upstream of the fish and stopping or checking the cast high during the final casting stroke. After checking the cast, reach the rod towards the side the fish is on and allow some extra line to feed through the rod tip. The purpose of this cast is to get the fly to the fish first with some slack while at the same time having the fly, leader and line in the same current lane.

Finish this presentation by feeding some line into the drift by shaking the rod tip up and down while feeding slack with the hands. Only feed enough line to cover the fish with the fly. Do not allow the fly line to go over the fish or he/she will be gone. If the fish does not take, allow the fly to get just below the fish and then slide the line to the near side of the fish and retrieve enough line so a pick-up can be made without spooking the fish.

Use a roll-cast pick-up as this is the quietest way to get the fly off the water. This eliminates the "pop" caused when the fly is picked up normally. False cast away from the fish so the shadow of the fly line and the water droplets from it do not disturb the fish. Now repeat the presentation.

Rises in gentle water are slow and deliberate, therefore: wait until the fish returns below the surface with the fly before setting the hook! This can be very difficult to do. One can use the slip-set or say things like "God bless America", or "I've got this one now" before setting the hook. These can help with the timing but again only experience will help an angler hook most of the fish that rise to the fly.

I hope this information allows you to catch that tough spring creek fish the next time such an opportunity presents it's self!

THE PRESIDENT'S BEAT

By Rick Bauer

So far, 1995 is proving to be an exciting year for our organization. We have had three great programs with excellent attendance, successful fund raising raffles and banquet, membership is up, and things are "generally buzzing" with a new enthusiasm.

A couple of members have "answered the call" and stepped forward from the ranks to volunteer to participate with our board of directors in the running of our chapter. I need a few more of you to volunteer. I will be asking you to meet with me at our next few general meetings. Please don't be shy.

Spring is here, and all indications are that things are happening a little early this year, due to the exceptionally mild winter we have enjoyed. Soon we will all be basking in the spoils of our favorite streams, rivers, and lakes. We are all very fortunate to live in and play in one of the most beautiful parts of our country. Oh, but let us not be complacent. Let us not take it for granted, as the ever-turning "wheels of progress" have a tendency to grind the very things we love into things of the past. I feel that as residents of the area we each have somewhat of a responsibility as custodian and guardian of our great outdoors that we hold so dear.

That's what Trout Unlimited and The Rocky Mountain Flycasters are all about. That's why we do what we do. That's why we ask for your help. See you next month!

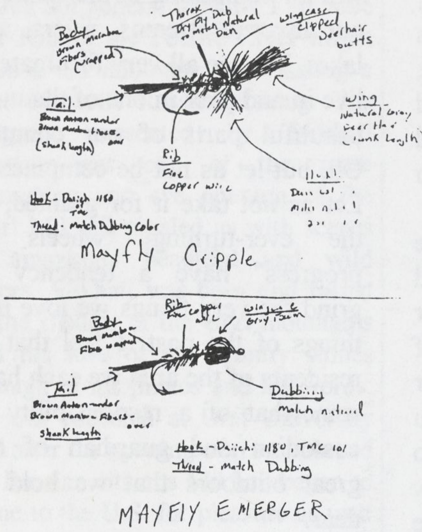
RMF RAFFLE ACKNOWLEDGMENTS

Meeting raffles are our Chapter's main source of operating revenue. Donations offer businesses and individuals an easy way to support coldwater resource enhancement efforts and Trout Unlimited. Please join the distinguished list of donors below?

Donations ForMarch Meeting

Fly Fishing The Magnificent Green - Jim Williams
Take Me Fishing - Jim Williams
Fly Fishing The Magnificent Green video - Jim Williams
Micro Pliers - St. Peters
Mid Stream Riffler - St. Peters
Two tee-shirts - Rocy Mountain Fly Shop
Meeting and Fishing The Hatches - Jim Shook
Dry fly assortment - Canvasback
Nympth assortment - Canvasback
Fly box - Longs Drug
Polarized glasses and case - Longs Drug
Cortland fly care assortment - Longs Drug
Fly Fishing Calender - Longs Drug
Wood net - Krina Galvin
T & T 9'6" 5wt rod and case - RMF
Stone flies - Greg Sheets

FLY OF THE MONTH
By Jeff Stone



ANGLER OPPORTUNITIES

Coming events, resource projects, and presentations open to the public.

VOLUNTEERS NEEDED**

April 12 RMF Public Meeting
April 19 RMF Board Meeting
April 21-22 1995 CTU Rendezvous

General membership meetings are held at the Univ. Park Holiday Inn

ARTICLES IN THIS NEWS LETTER ARE THE OPINIONS OF THE AUTHORS AND DO NOT NECESSARILY REFLECT THE VIEWS OF R.M.F.

HELP NEEDED
WE NEED HELP WITH THE RAFFLE, MEMBERSHIP, AND PLANNING COMMITTEES

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Rocky Bloskas	352-0901
Brian Shipley	482-0323

The TU/Rocky Mountain Flycasters Board of Directors meet monthly. Those interested in participating in the business of the chapter please phone Rick Bauer...............352-4312

NEWSLETTER CREDITS

Written and produced by Les Smith & Wendell Bragonier
Art donated by Neil Dewitt, Tim England, & Rick Payne
Illustrations donated by **RMF MEMBERSHIP**
Labeling and mailing by Wayne Mayoros, & Shelby Benikosky
Printing provided at discount by "The Printing Press".

THE ROCKY MOUNTAIN FLYCASTERS
830 Butte Pass Dr.
Ft. Collins, Co. 80526

NON-PROFIT ORG.
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Dedicated to the Preservation, Protection & Enhancement of our Nation's Coldwater Resource

TROUT UNLIMITED

Re. violations of special regulations--keep trout in no-kill zone, keep trout less than min. size, use of barbed hooks; use of bait, etc.

Very high compliance except for barbed hooks -ca. 20-30% violation rate of these, 75% do so by mistake.

- A big law enforcement problem that should be avoided.

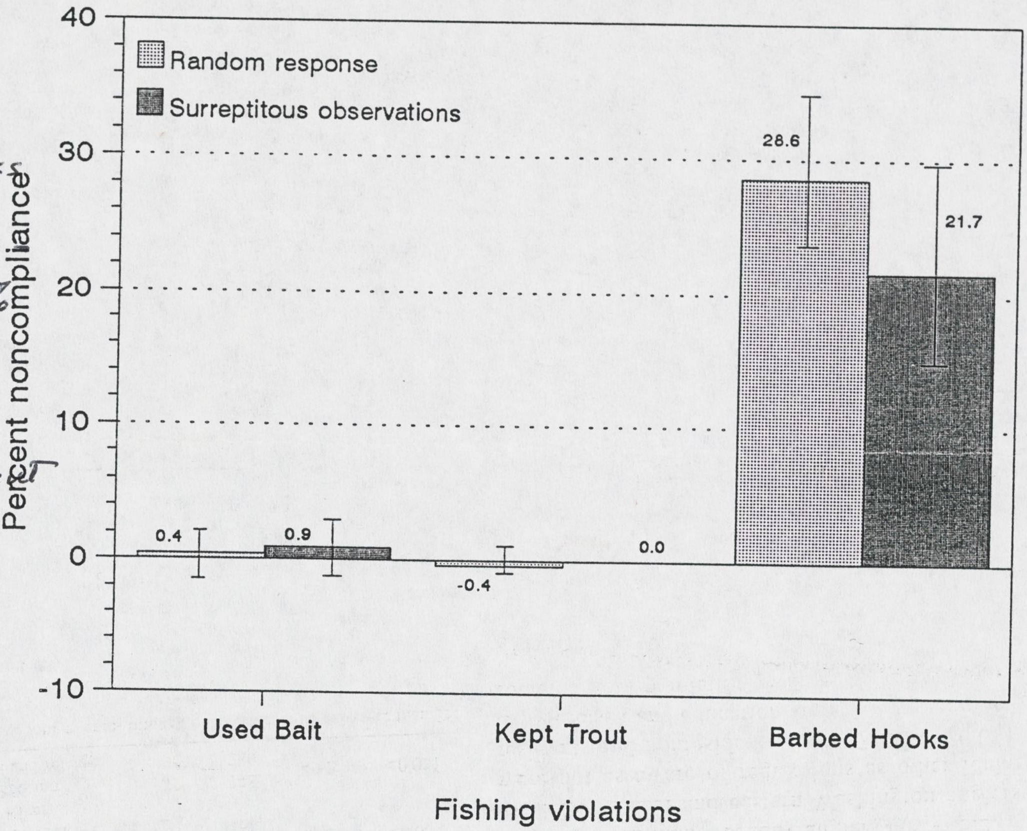

FIGURE 4.—Comparison of noncompliance estimates for the St. Joe River catch-and-release zone from random response interviews and surreptitious observations, May–August 1993. Bars denote 95% confidence limits.

ing the catch-and-release zone violated the barbless regulation each day. The enforcement officer observed that 9.6% of the anglers (11 cases) committed a barbless hook violation. If we include all individuals who quickly cut off their terminal gear as the officer approached, the estimate increases to 21.7%.

TABLE 2.—Regulation awareness for anglers fishing two Idaho special regulation waters, May–August 1993.

Water body regulation	Aware of regulation (%)	Sample size	χ^2 value	P
Coeur d'Alene River				
1 > 356 mm[a]	68	156	24.5	<0.001
Catch and release	91	164		
St. Joe River				
1 > 356 mm[a]	72	148	49.2	<0.001
Catch and release	96	280		

[a] 1 > 356 mm = creel limit of one cutthroat trout longer than 356 mm.

Angler Demographics

Angler awareness of regulations was higher in the catch-and-release zones than in 1>356 zones on both northern Idaho streams. An average of 94% of anglers interviewed in both catch-and-release zones could recite the regulations; 70% could do so in the 1>356 zones. Within both streams, these differences were highly significant (Table 2).

We also observed statistically significant associations between regulation awareness and several demographic categories. Young anglers (<30 years) were less likely to recite the regulations correctly (χ^2 = 29.3, P < 0.001). Bait and lure anglers gave fewer correct responses than fly fishermen (χ^2 = 6.0, P < 0.05). Weekend anglers were less informed than weekday anglers (χ^2 = 5.2, P < 0.024). Local and eastern Washington anglers were not as aware of regulations as other Idaho residents and nonresidents (χ^2 = 7.7, P < 0.05). Only the sex and education variables were not associated with regulation awareness (Table 3).

N. Am. Jour. Fish. Mgt. 1995. 15(4):721-31.

TABLE 3.—Pooled summary of regulation knowledge (percent able to recite current special regulations) and frequency of individual anglers responding yes to any random response question in four northern Idaho study sections, May through August 1993. Sample size is in parentheses. Only the sex and education variables showed no statistically significant association with awareness of regulations. Responses to random response questions did not differ significantly across demographic groups.

Measurement	Sex		Age (years)						Education[a]			Time of week[b]	
	M	F	14–20	21–30	31–40	41–50	51–60	>60	<13	13–16	>16	WE	WD
Able to recite regulation													
Percent	82	88	75	80	90	88	96	92	85	87	90	85	91
N	(813)	(108)	(80)	(172)	(229)	(251)	(99)	(104)	(335)	(431)	(167)	(668)	(276)
Replying yes to any random response question													
Percent	10	9	8	13	9	9	6	12	10	9	10	10	8
N	(817)	(109)	(98)	(197)	(264)	(272)	(110)	(108)	(384)	(485)	(178)	(768)	(290)

[a] Years of education achieved for those anglers more than 20 years old.
[b] WE = weekends; WD = weekdays.
[c] LOC = local anglers; ID = all other Idaho residents; EWA = anglers from the eastern one-third of Washington; Other = all other nonresidents.

We could not categorize likely violators by demographic groups. Within individual zones, no significant differences resulted when responses to random response questions were compared across demographic groups. In addition, none of the pooled data were significantly different (Table 3).

Discussion

A benefit of inquiring about sensitive topics with random response surveys is a reduction in refusals (Goodstadt and Gruson 1975). Three anglers in 1,061 (0.3%) refused to participate in the random response portion of the interview. Two of these refusals were in the North Fork Coeur d'Alene catch-and-release zone and one on Henrys Lake. The Henrys Lake angler was in obvious violation at the time of the refusal. If we assumed that all anglers refusing to participate were violators, recalculation of noncompliance estimates would have virtually no effect on our results.

Our results for accidental versus intentional violation of barbless hook regulations may have implications for fishery management agencies. Seventy-five percent of the reported barbless hook violations were accidental. Many anglers indicated they typically complied with regulations but sometimes forget to flatten barbs on individual flies and lures for short periods. Despite the recent paper of Taylor and White (1992), most past authors have concluded that hooking mortality does not differ between barbed and barbless hooks (Hunsaker et al. 1970; Falk et al. 1974; Wydoski 1977; Dotson 1982; Mongillo 1984; Titus and Vanicek 1988). If 75% of barbless hook citations are written to anglers attempting to comply with the law and the regulation violated has little or no demonstrated biological value, maintenance of such restrictions may be self-defeating for regulatory agencies. The animosity generated by issuing such citations to largely compliant anglers seems counterproductive.

An important limitation of our validation design is that anglers were observed for only a portion of their angling-day. We could not account for any night angling activity. In addition, only 28% of the anglers ($N = 30$) caught a cutthroat trout during observation periods. Thus, many anglers we observed did not have the opportunity to violate the creel limit. Additional creel violations possibly occurred if unsuccessful anglers moved to other areas on the stream and caught cutthroat trout. Despite the small sample size, none of the successful anglers were observed keeping a trout. This result agrees with our low random response estimate.

Anglers might violate the bait restriction elsewhere during their angler-day and not at the observation site, but this possibility seems remote. Anglers violating regulations because of a lack of awareness would do so all the time. We surreptitiously observed anglers for an average of 39 min and believe anglers intentionally violating bait restrictions would likely do so during that time.

There are several other limitations to our random response methods. We assumed anglers could accurately remember whether they committed violations on their last angling trip. Recall is often not 100% accurate in recreation studies (Hiett and Worrall 1977; Chase and Harada 1984). Accurate recall of barbless hook violations, particularly accidental ones, may be questionable and may be more of an estimate. However, we believe anglers violating the bait, bag, or size restrictions would accurately remember the violations.

MEMORANDUM

OREGON DEPARTMENT OF FISH AND WILDLIFE

INTRADEPARTMENT

DATE: January 22, 1996

TO: District Fish Biologists

FROM: Charlie Corrarino Charlie

SUBJ: Barbed vs. Barbless --

Attached are eight documents that discuss the barb/barbless issue. I found them interesting and thought you would too. Most of the material was supplied by Dr. Behnke at Colorado State University. I would appreciate brief written feedback by ***February 5th*** on this issue regarding the angling regulation process (existing and proposed regs). I will summarize your written comments and present them to Portland staff for further discussion.

Thanks!

cc:
DeHart
Brown
Anderson
Bohn
Hooton
McPherson
Smith
King
Frazier
Butler
Assistant Regional Supervisors for Fish
Lt. John Larson (OSP Salem)

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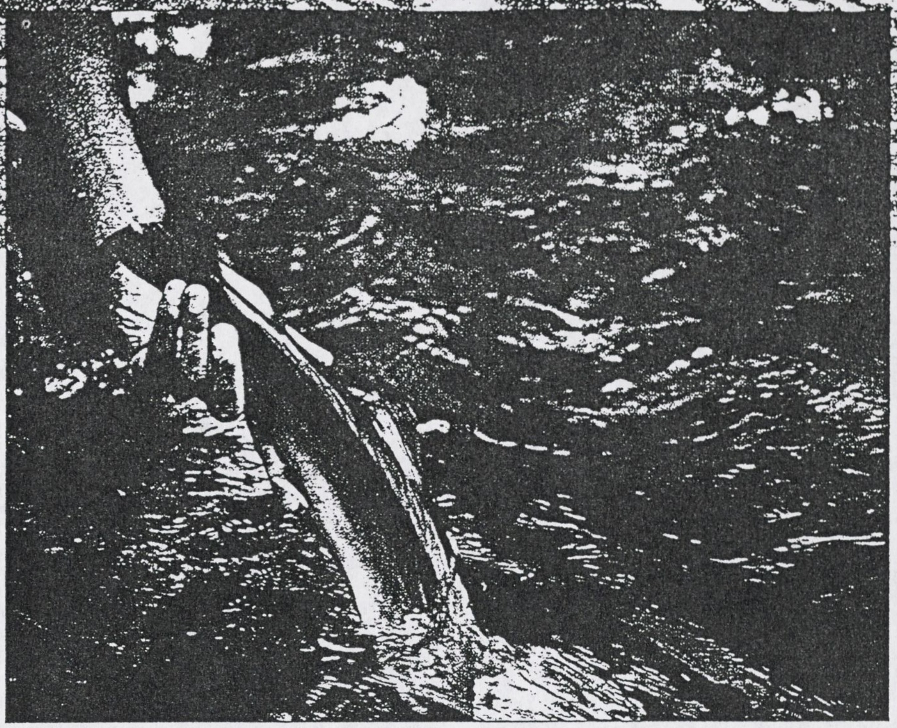
Most natural mortality after a trout's first few weeks of life occurs in winter.



Andy Anderson photo

erage. The overwinter mortality rate increased approximately seven times over normal; that is, it was "density dependent."

If fish and wildlife agencies have the personnel with the biological expertise to understand the points discussed above, they can institute special regulations with credibility. They should know the environmental limitations for success: which streams allow the recycling of two- and three-year-old fish and which streams have the potential for maintaining positive growth and good survival to ages five, six, seven years or more. Because resident adult trout typically move only short distances, a whole stream does not have to be placed under special regulations. Sections of one or a few miles can have special regulations for wild trout management, and roadside sites heavily used by the average angler can be stocked with hatchery trout to reduce conflicts.

I believe the fundamentals and principles of trout biology are now sufficiently established to set the stage for increased application of successful special regulation fisheries. The most important attribute for a management agency is its credibility. If agency personnel do a credible job and anglers observe successes, then new programs such as special regulations should have public support.

There is still a people management problem that must be recognized. First is the problem of "discrimination" perceived by many anglers. Special regulations for trout require the prohibition of bait-fishing to ensure high survival of the released fish. In a Colorado survey, 11 percent of license buyers said they were solely or predominantly fly fishers, whereas more than 50 percent said they fished at least occasionally with flies and artificial lures. Thus, a regulation allowing any type of artificial lure has the potential for much broader support than fly fishing only. This, however, raises another problem. Among the most ardent fly fisher no-kill purists, there are many with deep antipathy toward other methods of angling for trout, especially spin-fishing. Such purists will not believe that it could be possible that the survival rate of trout caught and released on a spinning lure (especially a treble hook lure) is similar to trout caught and released on a fly (especially a barbless fly).

Barbless Doesn't Matter

Gear restriction is still a major source of friction associated with special regulations. Many states prohibit all terminal tackle except single, barbless hooks for special regulation fisheries. Therefore, a logical conclusion might be that the agency personnel in these states must know what they are doing; they must have solid evidence that barbed hooks and treble hooks kill more released trout than single barbless hooks. Actually, this would be a wrong conclusion. It is an example of lack of agency credibility. More likely, the decisions to enforce a single, barbless hook regulation were made by a commissioner or a director of the agency, acting on a "gut" feeling. If staff biologists were consulted on the matter, their advice was ignored or the biologists were not familiar with the evidence compiled over many years on hooking mortality.

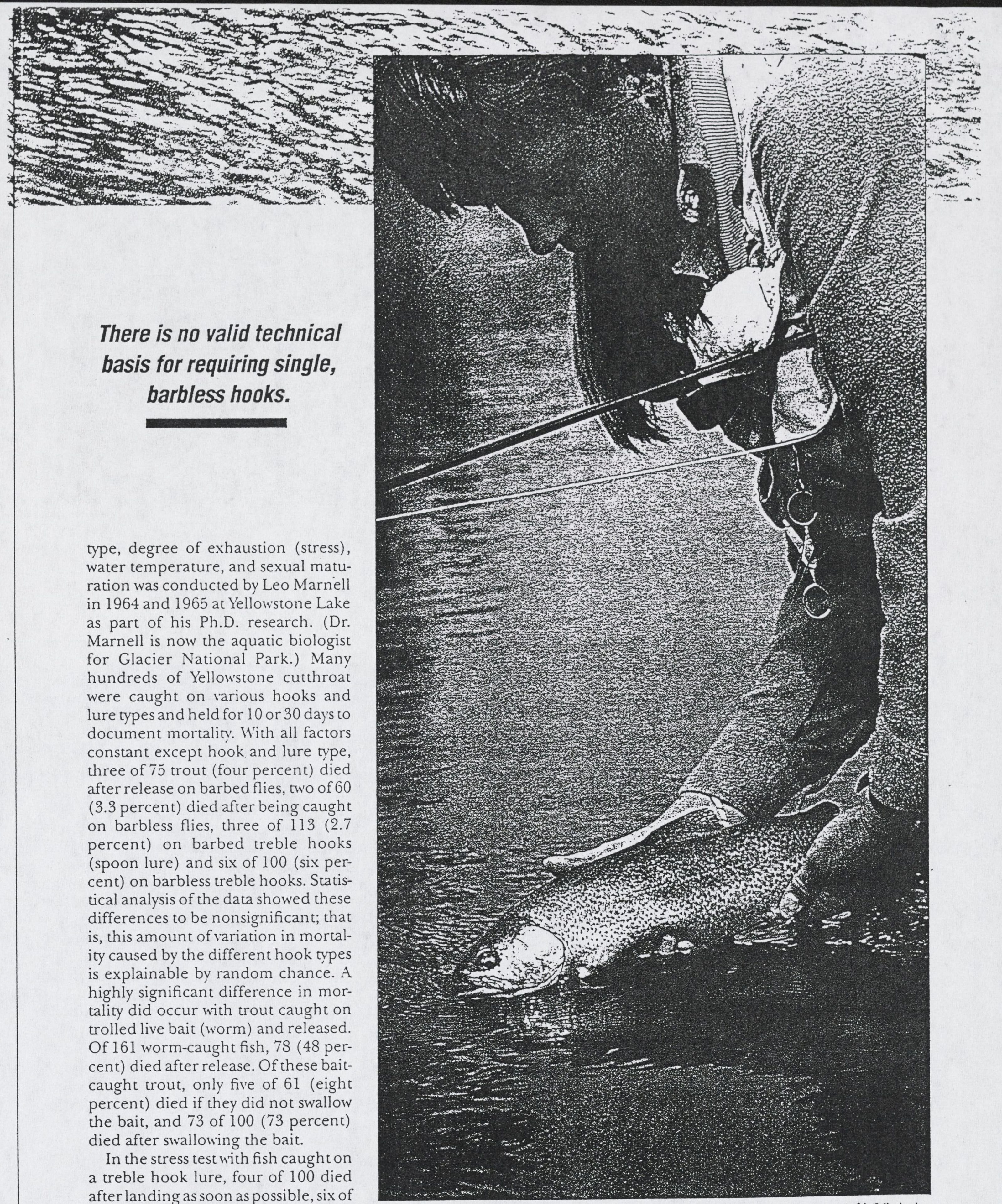
In the proceedings of the 1977 Catch and Release Symposium, all hooking mortality studies were exhaustively reviewed and summarized by Richard Wydoski, who concluded that "use of barbless hooks does not significantly reduce mortality, and restrictions requiring the use of barbless hooks are not biologically justified." In 1984, the Washington State Game Department had another review made of hooking mortality studies, including work preformed after 1977. The Washington report concluded, "There is no valid technical basis for requiring single, barbless hooks."

What is still the most comprehensive, in-depth analysis of hooking mortality of wild trout in relation to hook

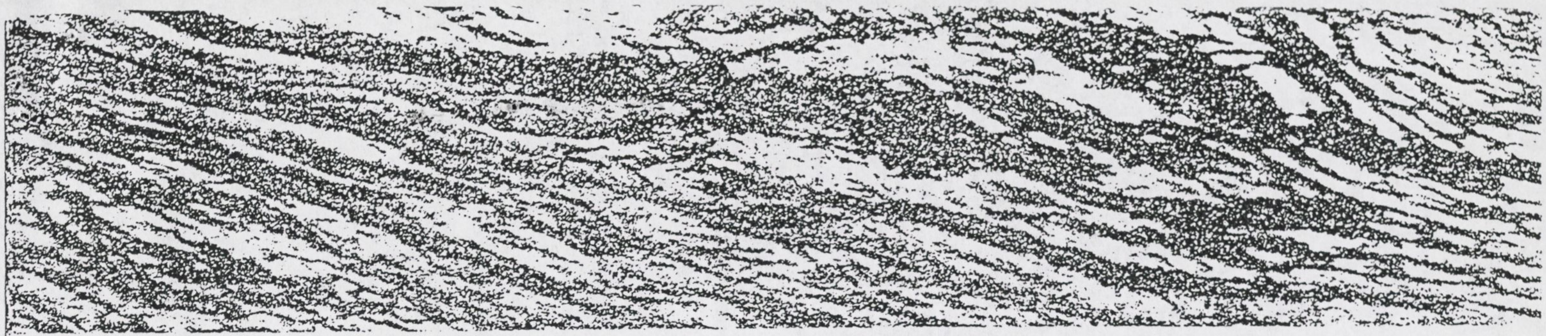
There is no valid technical basis for requiring single, barbless hooks.

type, degree of exhaustion (stress), water temperature, and sexual maturation was conducted by Leo Marnell in 1964 and 1965 at Yellowstone Lake as part of his Ph.D. research. (Dr. Marnell is now the aquatic biologist for Glacier National Park.) Many hundreds of Yellowstone cutthroat were caught on various hooks and lure types and held for 10 or 30 days to document mortality. With all factors constant except hook and lure type, three of 75 trout (four percent) died after release on barbed flies, two of 60 (3.3 percent) died after being caught on barbless flies, three of 113 (2.7 percent) on barbed treble hooks (spoon lure) and six of 100 (six percent) on barbless treble hooks. Statistical analysis of the data showed these differences to be nonsignificant; that is, this amount of variation in mortality caused by the different hook types is explainable by random chance. A highly significant difference in mortality did occur with trout caught on trolled live bait (worm) and released. Of 161 worm-caught fish, 78 (48 percent) died after release. Of these bait-caught trout, only five of 61 (eight percent) died if they did not swallow the bait, and 73 of 100 (73 percent) died after swallowing the bait.

In the stress test with fish caught on a treble hook lure, four of 100 died after landing as soon as possible, six of



B & C Beck photo



100 died after five minutes of playing, and five of 100 died after 10 minutes of playing (fish were not allowed to rest during playing). Again, there was no significant difference among groups experiencing different levels of exhaustion. In regard to the cause of mortality of released trout, Marnell found that, of 33 deaths (of 652 trout caught and released on artificial files and lures), 30 were the result of hooks causing bleeding – typically, from rupture of gill filaments. Only three of the 33 deaths were unknown causes, which might suggest lethal stress.

Enough studies have been done to allow for a prediction that 95 percent or more of trout caught and released on flies or artificial lures in streams will survive.

For those who want to examine the details of Leo Marnell's research (without wading through his Ph.D. thesis), he and his associates published two papers in 1970, one in the *Transactions of the American Fisheries Society*, Volume 99, Number 4, and another in the *Progressive Fish Culturist*, Volume 32, Number 4.

A trend for increased mortality with higher water temperatures was apparent only in the bait-caught trout in Marnell's study. Yet the highest temperatures in Yellowstone Lake during the study were only from 58° to 62° F. The accumulated evidence to date indicates a significant increase in mortality can be expected when water temperatures exceed 60° F.

Death by Warming

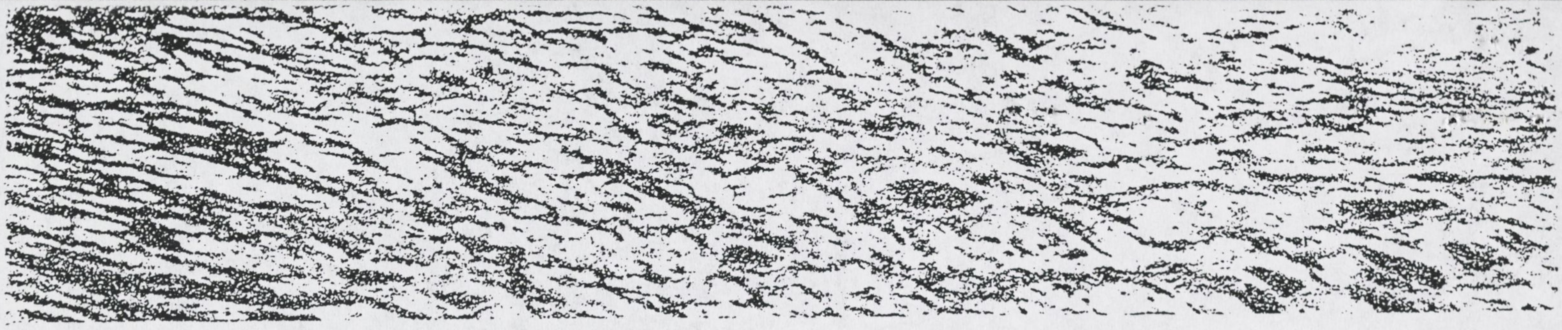
The most recently published study demonstrating the relationship between mortality of released trout and temperature, concerns the Lahontan cutthroat fishery of Heenan Lake in California. The lake is managed with no-kill regulations. Trout were caught on Phoebe spinning lures with single barbless, barbed treble and barbless treble hooks during early June, mid-July and September. Released fish were held in live boxes in the lake for four days to determine mortality. In the June and September trials – with water temperatures ranging from 50° to 60° – four of 282 (1.4 percent) and one of 82 (1.2 percent), respectively, of the released fish died. There was no significant difference among hook types. During the July trial, when surface water temperatures reaches 70° F, *82 of 169* (48.5 percent) trout expired after release. The highest mortality (55 percent) occurred with a single barbless hook.

A body of water such as Heenan Lake has special physical characteristics that differ from those of stream environments. About 15 feet below the surface in July, the temperature in the thermocline was only 57° F. During this period, I suspect, the trout live in the cooler layer with occasional forays into the warmer surface for feeding (if sufficient food is not available in the more comfortable thermocline zone). The holding of the caught-and-released trout in live boxes in the warmer surface water probably greatly increased mortality, compared with fish normally freed and allowed to seek deeper, cooler sanctuary. This experience does, however, confirm the assumption that a curve, depicting the mortality-temperature relationship of released trout, will show a sharp upward inflection between 60° and 70° F.

In streams, I would expect the temperature-related mortality problem to be more or less self-regulating. Trout feeding is sharply reduced as temperatures rise from 60° to 70° F. Thus the quality of fishing, the number of anglers and the trout caught at higher temperatures is greatly reduced. In a recent conversation with Richard Vincent of the Montana Department of Fish, Wildlife and Parks, he told me of a study on the Madison River in which catch rates were related to changes in temperatures. As the water rose to 60° and above, angler success showed an inverse relationship – the higher the temperature, the lower the catch rate.

Each stream or lake presents a special situation. If it is documented that excessive mortality occurs during a certain time of year, negating benefits of special regulations, then a seasonal closure of the fishery might be warranted.

There is a caveat. Higher mortality is not always bad. If the density of a trout population exceeds the limit of its growth rations, growth rates may significantly decline, and some additional thinning by angling mortality can be beneficial. This phenomenon was reported at the Wild Trout III symposium in 1984. Some New York State trout streams under no-kill regulations accumulated high densities of brown trout which exhibited reduced growth in comparison to the period under normal regulations. Age three trout declined from 12–14 inches to



Modern anglers often fritter away precious energies on controversies about allowable hook types while taxpayer-subsidized cattle herds continue to destroy thousands of miles of formerly excellent trout streams.

10–11 inches after no-kill was enforced. A change in regulation allowed limited take, density was reduced and the growth rate improved.

I suspect that mortality due to stress or acidosis is strongly related to water temperature. The most recent research paper I have read on acidosis mortality concerned hatchery rainbow trout that were stressed by continual prodding until they turned belly-up. Blood samples taken at regular intervals revealed a sharp drop in the blood pH to acid levels. This study verified that acidosis is not caused by lactic acid.

Roderick Haig-Brown, in his 1964 book *Fisherman's Fall*, reported on research at the University of British Columbia which demonstrated that lactic acid levels in stressed fish do not reach lethal levels. Although not caused by lactic acid, some unknown acid does cause acidosis. In those trout that recovered, the blood soon returned to normal pH; in those that died, the blood remained acidic. My suspicion is that the blood pH recovery rate may be related to water temperature and/or the intensity of acidosis is greater when temperatures are higher.

There is still some interesting research to be conducted before all of the precise mechanisms causing mortality are understood. There is not, however, need for further research before special regulations are more widely implemented, unless data are needed on specific trout populations to understand what might be expected from special regulations and what type of regulations would be best suited to a particular fishery. There is no need for further research on hooking mortality. Enough studies have been done to allow for a prediction that 95 percent or more of trout caught and released on flies and artificial lures in streams will survive if the water temperature is less than 60° F. The type of hook – single, treble, barbed or barbless – is not a significant influence on mortality. Virtually all mortality that does occur is due to rupturing of blood vessels in the gills and mouth, not from stress.

Ordering Our Priorities

My final comments on special regulations concern priorities.

It is understandable and quite predictable that many of the most sincere and dedicated trout fishers will embrace the concept of special regulations with great zeal and fervor (typically, no-kill regulations restricted to barbless flies only) and become narrowly focused on the issue to the exclusion of all other aspects of trout conservation. To put the matter in perspective, if 1,000 miles of our best trout streams are managed under special regulations and the regulations work at optimum success to recycle trout again and again, the numbers and pounds of additional trout caught each year would number in the hundreds of thousands. This indeed would be impressive, but would still be a minor gain in comparison to the numbers and pounds of trout and salmon that have been lost due to environmental degradation. Consider the problems of acid rain, logging practices, urbanization, road construction and pollution in the East; recognize that most western salmonid waters and their watersheds are on federal lands where thousands and thousands of miles of coldwater streams have been lost or continually threatened under multiple use management where dominant interest groups have historically called the shots. The protection and restoration of degraded streams and their fish populations hold the prospect of millions more pounds of wild trout that could be fished for and caught annually.

The zeal possessed by many dedicated purists is understandable. Their almost religious belief in fishing regulations to protect – and preferred tackle to catch – trout is a personal credo that will not be readily changed. Truly effective trout conservation, however, is a matter of ordering priorities.

Just as nineteenth century anglers zealously were on guard to protect trout populations from "fish hogs" while whole watersheds were being stripped of cover and destroyed by pollution, modern anglers often fritter away precious energies on controversies about allowable hook types while taxpayer-subsidized cattle herds continue to destroy thousands of miles of formerly excellent trout streams.

After a favorite trout stream is safe from destruction, its habitat restored, then we may divert our concerns to implementation of the best regulations to manage its fishery.

Draft

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February 20, 1995

Mr. John Randolph
Fly Fisherman
2245 Kohn Road
Harrisburg, PA 17105-8200

Dear John:

It has been awhile since we've communicated. The article on hooking mortality by Pat Trotter in the latest issue of Fly Fisherman stimulated me to send some comments on the subject. Pat did a commendable job of reviewing and synthesizing the literature. It's apparent he did his homework.

Overall, I agree with his general conclusions. I would only caution against confusing "science" or "scientific" research with precision when dealing with natural phenomena such as the dynamics of population mortality. Precise data such as 2.5 or 3.2% mortality of trout caught and released on specific types of gear are based on site-specific and time-specific tests. One should not expect complete replication of results if the identical test were conducted on another water or even on the same water with the same fish at another time, simply due to inherent variation in nature. Professional gamblers probably best understand the concept of random variation. When we accept a 95% confidence limit as "statistically significant" we demand to be wrong 5% of the time. For example, a situation where the true frequency of occurrence is 2% as with 100,000 marbles, 98,000 are white and 2,000 are black. To estimate the true frequency of black marbles, several random samples are drawn consisting of various sample sizes of 25, 50, or 100 marbles. The resulting estimates might range from 0 to 10% frequencies of black marbles, depending on sample size and random variation in drawing the sample. This example would be a completely controlled test; there would be no external influences causing nonrandom bias. It is quite different for fish mortality data where different people, different water temperatures, hook sizes, and many other factors can bias the results and superimpose nonrandom variation onto random variation. Also, "grouped" data of mortality from different studies to compare hook types (single vs. treble, barbed vs. barbless) have the apples and oranges comparison problem. One must be aware of the uncertainty involved in the literature dealing with hooking mortality despite the precise figures obtained.

I bring this matter up because a C.S.U. graduate student, George Schisler, is now writing his graduate thesis on hooking mortality. George's study, with the help of the outstanding statistical and mathematical modeling expertise of some of our faculty, is the most comprehensive, detailed, and statistically sound (the most "scientific") study yet on hooking mortality. The study was designed to obtain data on hooking mortality of trout caught on "power bait", a completely artificial, scented bait which presently conforms to the definition of "artificial" for special regulation waters in Colorado. The data base includes trout caught in a small pond, a large reservoir, and in a river. George will publish the results of his study in a fisheries journal. I can't reveal all of the details but will provide some of the highlights. Trout caught on power bait (fished as natural bait) have a mortality comparable to live bait. Water temperature has the greatest external influence on mortality of trout caught-and-released by any method. The higher the temperature, the higher the mortality. Holding a trout out of water can increase mortality after about three to five minutes. One to two minutes out of water causes insignificant increase in mortality. Increasing the time a fish is played (from hooking to landing) from one to five minutes can increase mortality (slightly); this increased mortality is more pronounced with smaller trout (9-10 inches) than with larger (16-18 inches) fish. The increased mortality from time out of water and playing time is strongly related to water temperature. Death is strongly associated with where the fish is hooked -- fish hooked in the stomach or esophagus (common with bait) or gill filaments (causing bleeding) have the highest probability of dying, but cutting the leader and leaving the hook in the fish can reduce this mortality by more than half.

George applied state-of-the-art statistical analysis to produce integrated, three-dimensional graphs which illustrate expected mortality based on gear, water temperature, time out of water, and playing time as they interrelate to each other. When George's study is published, I expect Fly Fisherman will receive letters about this scientific, state-of-the-art study on hooking mortality. I do believe it is the most comprehensive and sound study on hooking mortality to date and the first one which integrates, simultaneously, several factors influencing mortality. I again urge caution, however, in placing great faith in the precision of the graphs. For example, the graph might show that a 12-inch trout caught on a fly, played for three minutes in 55° F water, and held out of water for two minutes has a predicted mortality of 3.2%. It would be a mistake to accept this as a precise and universally true prediction. The data George put into the model is highly variable, due to natural, random variation, and probably also to uncontrolled bias. The statistical method uniformly smooths the data. Without critically analyzing the raw data used in the "idealized" model, and having some understanding of natural variation and statistical probability, one could readily be deceived to claim a degree of precision that is unreal. "Science" cannot remove variation from nature, only try to better understand it.

George and his professor, Dr. Bergersen, wrote a short paper for the Colorado Division of Wildlife on statistical analyses of literature studies on hooking mortality comparing barbed vs. barbless hooks and single vs. treble hooks. I'll enclose a few pages from the report, which concluded no statistically significant differences in mortality between barbed vs. barbless or single vs. treble hooks. I would point out, however, how "lumping" of data can be misleading and the need for critical analysis to avoid apples and oranges comparisons. In the single vs. treble hook comparisons, the overall, "lumped" comparisons do not differ, but note the Michigan study which found significantly higher mortality on trout caught on small spinning lures with treble hooks (about 5 and 10% mortality for trout caught on treble hooks in two studies vs. 2-3% for those caught on the same lures with single hooks). As mentioned, hooking mortality is associated with hooking deep within the mouth. These were relatively large trout which could engulf the small spinning lure (significantly more large trout, over 18 inches, were deeply hooked than smaller fish). The probability of a treble hook causing lethal damage, once the lure is within the mouth, is greater than that of a single hook. This relates to the size of the fish and the voraciousness of strike to engulf the lure during any particular time of fishing. Thus, this Michigan study of large brook trout in a lake could be cited as an example where treble hooks caused higher mortality than single hooks. One should be aware of the complete study, however. What is not depicted on the graph is the results of catching 126 large brook trout during this test on a Rapala lure with large treble hooks. Not a single mortality occurred in the 126 trout caught and released on a Rapala. They simply couldn't get the hooks inside the mouth to cause lethal injury. If the data from these 126 trout were added to the grouped analysis, treble hooks would, overall, show significantly less mortality than single hooks, but apples and oranges are being compared. There are large treble hooks on large lures which rarely get deeply inside the mouth and there are small treble hooks on small lures which are much more likely to be deeply engulfed by larger fish.

The bottom line conclusion is that studies showing survival advantage for a certain hook type are site-specific, time-specific, and condition-specific. They should not be broadly extrapolated to other sites and other conditions at other times. The grouping or "lumping" of numerous studies to obtain overall mean values superimposes nonrandom variation on random variation and will be tainted by apples and oranges comparisons.

Personally, I prefer to fish with barbless flies. Their most practical advantage concerns the hooking and releasing of humans. In waters where single barbless hooks are mandatory, a problem I have is that when action is fast and a fly is lost and a new fly is quickly tied on, I frequently forget to press down the barb and I could be cited as a law-breaker. I would question the credibility of a "barbless hook only" regulation unless it could be clearly demonstrated by factual data on a specific water that such a regulation significantly reduces hooking mortality. Otherwise, I prefer hook type to be the option of the angler. The use of barbless hooks would gain more favor if anglers were convinced that a higher percentage of strikes are hooked on barbless hooks, due to their ease of penetration. Some of your readers might test this hypothesis and send in the results. I would expect, however, that such test results would be contaminated by nonrandom bias.

Sincerely,

Robert Behnke
~~Professor~~

Credibility

Bob Behnke

We all remember taking a test or giving a talk in school. In reviewing a student's performance, it is not difficult for a teacher to assess which students have done their homework; how credible were their written and oral statements.

Every year or so I feel obligated to write something about hooking mortality in relation to hook type (such as single, treble, barbed, or barbless) in response to heated debate on the subject. I realize my attempts at education have all of the power of information penetration as water on a duck's back, but I still feel the obligation.

Thus, I recently wrote to *Fly Fisherman* in response to the ongoing barbed-barbless controversy. I attempted to point out that the desire to settle the matter once and for all by "scientific" study can never be fulfilled. The reason for this concerns an understanding of random chance, nonrandom bias from uncontrolled influences, and the problems of mixing oranges and apples when grouping data from different studies. I also mentioned that George Schisler, a Colorado State University graduate student, is currently completing a thesis on hooking mortality. George's study is the first to simultaneously integrate several factors, such as type of terminal tackle, water temperature, playing time, and time out of water, as they relate to mortality of trout caught and released.

I warned, however, that when George publishes the results of his research and anglers become aware of the most "scientific" study to date on hooking mortality, most will likely be deluded by the sophisticated statistical model which projects three-dimensional graphs, simultaneously interrelating mortality to various factors. Most will not understand that the statistical treatment has smoothed the variation in the raw data to give the illusion of great predictive precision. The precision is an illusion produced by the statistical model. The results of each study on hooking mortality is site-specific, time-specific, and condition-specific. Unless large and consistent differences are apparent among many studies such as comparing mortality between bait and artificial fly or lure-caught fish, no universal conclusions are warranted (for example, between treble vs. single hooks or barbed vs. barbless.)

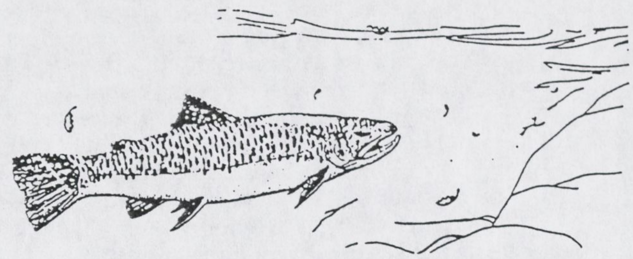
George and his adviser, Dr. Bergersen, compiled information comparing mortality to hook type for the Colorado Division of Wildlife. They compared a great amount of data to demonstrate no statistical difference in mortality of trout caught and released on treble vs. single or barbed vs. barbless hooks. Actually, if they included data from a Michigan study concerning catching and releasing 126 large trout on a Rapala (with large treble hooks), in which not a single trout died, treble hooks would have shown significantly less mortality than single hooks -- but this would be the apples and oranges problem. There are large treble hooks which rarely get inside the mouth to cause lethal damage and there are small treble (and single) hooks which are more likely to be engulfed.

Concerning credibility, if a Trout Unlimited member were to make a plea to the Wildlife Commission to institute a single barbless hook regulation, such a plea should be made in the context of court testimony with all the implications of burden of proof based on factual evidence. The Commission will have a copy of the statistical analysis mentioned above. To counter this evidence with an emotional plea based on a gut feeling that we intuitively know what is true and good, would not likely hold up in court.

For those interested in doing some homework, I will have an article on whirling disease and wild trout in the spring issue of *Trout*. I also published a paper coauthored with three economists on the economics of catchable trout fisheries in the February 1995 issue of the *North American Journal of Fisheries Management* (the true economic cost of catchables is considerably greater than what CDOW claims and we did not include such items as costs now attributable to whirling disease). I can assure you that these subjects concern much more substantial issues than barbed vs. barbless hooks for the future of wild trout.

Thoughts on Barbless Hooks

by Bob Behnke



A few months ago, I served as the "summarizer" for the 1987 Catch-and-Release Symposium held in California. In my symposium paper, to be published in the proceedings, I discussed problems of fish management and people management. An important consideration for broader implementation of special regulations concerns public acceptance of proposed regulations: The broader the base of support, the larger the role that special regulations will play in a state's management program. There are two aspects affecting broad-based public support. The first concerns agency credibility; that is, demonstrating the biological expertise of an agency by carefully selecting waters and trout populations that will most favorably respond to reduced angling mortality—establishing a record of success. The second aspect concerns the proportion of all anglers that may be excluded from special regulation waters because of gear restrictions (the magnitude of the potential opposition to special regulations).

It is clear that for trout fisheries where a high proportion of caught-and-released fish must survive if catch-and-release is to succeed, bait fishing must be banned. Thus, we potentially antagonize a large segment of license buyers and voters and must recognize the potential for a buildup of opposition that can result in a backlash (bills have been introduced into some state legislatures to prohibit all catch-and-release regulations). What other types of angling besides bait fishing should be banned from catch-and-release waters? A recent survey in Colorado determined that about 11% of our licensed anglers are solely or predominantly fly fishers, but only a small fraction of this 11% might be considered no-kill, barbless-hooks-only people. This small group of purists typically generate zealous lobbying for more catch-and-release waters, which is important to spread the word of the vital significance of special regulations for wild trout fisheries. Unfortunately, many of them also have a zealous and unshakable faith that catch-and-release regulations are meaningless without a barbless-flies-only restriction. A barbless-flies-only restriction shrinks the potential base of support for special regulations from about 50% of the licensed anglers (who fish with flies and artificial lures) to less than one percent, which obviously raises the question: Are barbless hooks necessary for high survival of released fish (95% or higher survival)?

In the 1977 Catch-and-Release Symposium, a paper was presented which reviewed all studies on hooking mortality from trout caught and released with single, treble, barbed and barbless hooks under various conditions. The conclusion: "Use of barbless hooks does not significantly reduce mortality and restrictions requiring the use of barbless hooks are not biologically justified." In 1984, the Washington Department of Game had another review made on all hooking mortality studies with the conclusion: "There is no valid technical basis for requiring single barbless hooks." If any disbelievers would like to critically examine all of the studies on which these conclusions are based, I can provide the references, but I doubt that the gut feeling and mind-set of a true believer can be changed by any amount of factual evidence. For example, the winter 1988 issue of *Flyfisher* has an article by Lefty Kreh on releasing fish. Lefty says: "I know about the supposedly scientific studies conducted that claim fish mortality is no different with barbed or barbless hooks. Some scientists also claim that treble hooks make no real difference in harming fish than do single hooks." Of course, Lefty can't believe these "supposedly scientific" studies—common sense and experience tell him otherwise. Although Lefty "knows" of these studies, has he read them and critically examined the evidence to arrive at an informed opinion? The difference between "scientific" and "supposedly scientific" studies evidently is determined by whether the studies agree or disagree with one's beliefs.

What appears to be a common-sense belief that barbless hooks must cause less mortality than barbed hooks, or single hooks less than treble hooks, relates to "handling time" of the released fish. It is virtually impossible to induce lethal stress in a healthy trout existing in good quality waters at low temperatures by catching and releasing. Almost all mortality of released fish is due to rupturing of blood vessels in the gill filaments or in the roof of the mouth (most bleeding fish will die). Barbless hooks have no advantage (actually a disadvantage) for avoiding lethal hooking (hooking causing bleeding).

Factors that increase mortality of released fish include water temperature (when water temperature warms to 60°F and above, mortality of released fish can be expected to significantly increase) and water quality such as low pH and low oxygen (but at levels rarely encountered in waters inhabited by trout). Under these "abnormal" conditions it is likely that trout caught, played to exhaustion and released on light tackle using barbless flies would suffer higher mortality than trout caught and quickly horsed in on a spinning lure.

CONT.

BARB CONT.

In any event, Americans have a general antipathy against state controls hinting of Big Brotherism. Thus, the fewer restrictions placed on special regulation waters, the lesser the probability for a backlash of opposition.

Although the use of barbless flies connotes a proper respect and reverence for trout, the use of barbless hooks should be voluntary and not mandated by law. To increase voluntary use of barbless hooks, articles in the popular media such as the one by Lefty Kreh will help, but if it can be demonstrated that a higher percentage of trout can be landed on barbless hooks than on barbed hooks, then the voluntary use of barbless hooks would greatly increase. A recent paper in California Fish and Game Journal reported that a higher percentage of chinook and coho salmon were landed on barbless hooks in comparison to barbed hooks. If most anglers believe they will land more trout on barbless hooks, they will use them.

To put the issue in perspective, however, one must seriously ask: How important is the controversy over barbed vs. barbless hooks as a genuine conservation issue? In relation to the big issues such as better multiple use management on federal lands with which Trout Unlimited is involved, and where annual increases of millions of pounds of trout and salmon are possible, divisive wrangling over barbed vs. barbless hooks is as if the main concern of an army at war is the type of buttons on the soldiers' shirts. If it were, I wouldn't expect many battles to be won.

Re. violations of special regulations -- keep trout in no-kill zone, keep trout less than min. size, use of barbed hook. use of bait, etc.

Very high compliance except for barbed hooks -ca. 20-30% violation rate. of these, 75% do so by mistake.

- A big law enforcement problem that should be avoided.

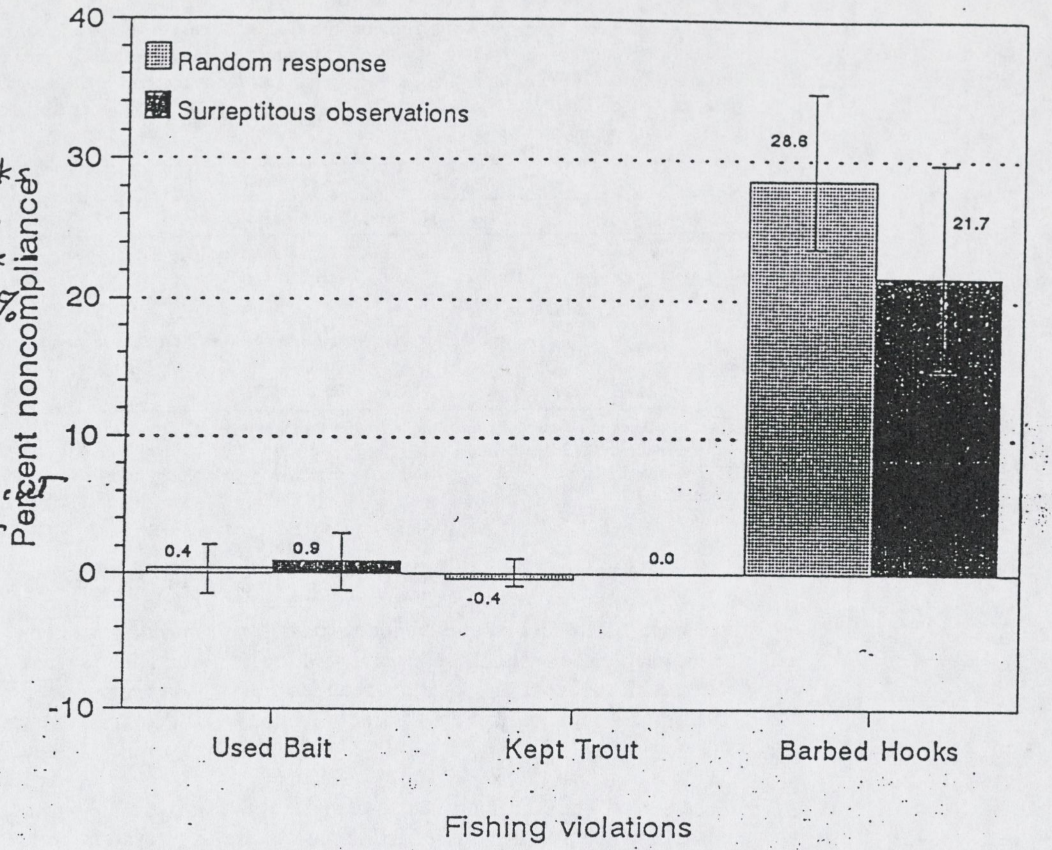


FIGURE 4.—Comparison of noncompliance estimates for the St. Joe River catch-and-release zone from random response interviews and surreptitious observations, May–August 1993. Bars denote 95% confidence limits.

ing the catch-and-release zone violated the barbless regulation each day. The enforcement officer observed that 9.6% of the anglers (11 cases) committed a barbless hook violation. If we include all individuals who quickly cut off their terminal gear as the officer approached, the estimate increases to 21.7%.

TABLE 2.—Regulation awareness for anglers fishing two Idaho special regulation waters, May–August 1993.

Water body regulation	Aware of regulation (%)	Sample size	χ^2 value	P
Coeur d'Alene River				
1 > 356 mm[a]	68	156	24.5	<0.001
Catch and release	91	164		
St. Joe River				
1 > 356 mm[a]	72	148	49.2	<0.001
Catch and release	96	280		

[a] 1 > 356 mm = creel limit of one cutthroat trout longer than 356 mm.

Angler Demographics

Angler awareness of regulations was higher in the catch-and-release zones than in 1>356 zones on both northern Idaho streams. An average of 94% of anglers interviewed in both catch-and-release zones could recite the regulations; 70% could do so in the 1>356 zones. Within both streams, these differences were highly significant (Table 2).

We also observed statistically significant associations between regulation awareness and several demographic categories. Young anglers (<30 years) were less likely to recite the regulations correctly (χ^2 = 29.3, P < 0.001). Bait and lure anglers gave fewer correct responses than fly fishermen (χ^2 = 6.0, P < 0.05). Weekend anglers were less informed than weekday anglers (χ^2 = 5.2, P < 0.024). Local and eastern Washington anglers were not as aware of regulations as other Idaho residents and nonresidents (χ^2 = 7.7, P < 0.05). Only the sex and education variables were not associated with regulation awareness (Table 3).

N. Am. Jour. Fish. Mgt. 1995. 15(4): 721-731.

TABLE 3.—Pooled summary of regulation knowledge (percent able to recite current special regulations) and frequency of individual anglers responding yes to any random response question in four northern Idaho study sections, May through August 1993. Sample size is in parentheses. Only the sex and education variables showed no statistically significant association with awareness of regulations. Responses to random response questions did not differ significantly across demographic groups.

Measurement	Sex		Age (years)						Education[a]			Time of week[b]	
	M	F	14–20	21–30	31–40	41–50	51–60	>60	<13	13–16	>16	WE	WD
					Able to recite regulation								
Percent	82	88	75	80	90	88	96	92	85	87	90	85	91
N	(813)	(108)	(80)	(172)	(229)	(251)	(99)	(104)	(335)	(431)	(167)	(668)	(276)
					Replying yes to any random response question								
Percent	10	9	8	13	9	9	6	12	10	9	10	10	8
N	(817)	(109)	(98)	(197)	(264)	(272)	(110)	(108)	(384)	(485)	(178)	(768)	(290)

[a] Years of education achieved for those anglers more than 20 years old.
[b] WE = weekends; WD = weekdays.
[c] LOC = local anglers; ID = all other Idaho residents; EWA = anglers from the eastern one-third of Washington; Other = all other nonresidents.

We could not categorize likely violators by demographic groups. Within individual zones, no significant differences resulted when responses to random response questions were compared across demographic groups. In addition, none of the pooled data were significantly different (Table 3).

Discussion

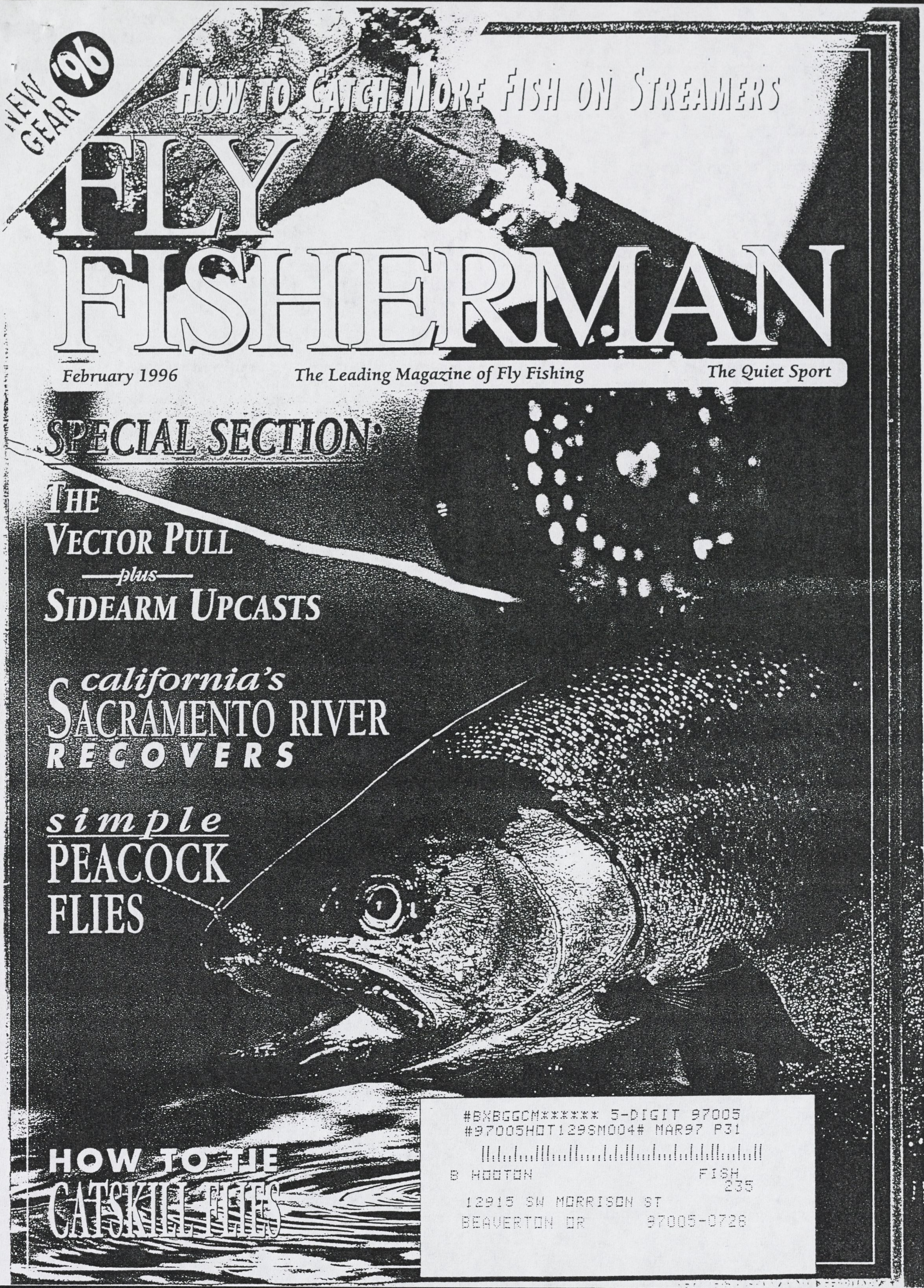
A benefit of inquiring about sensitive topics with random response surveys is a reduction in refusals (Goodstadt and Gruson 1975). Three anglers in 1,061 (0.3%) refused to participate in the random response portion of the interview. Two of these refusals were in the North Fork Coeur d'Alene catch-and-release zone and one on Henrys Lake. The Henrys Lake angler was in obvious violation at the time of the refusal. If we assumed that all anglers refusing to participate were violators, recalculation of noncompliance estimates would have virtually no effect on our results.

Our results for accidental versus intentional violation of barbless hook regulations may have implications for fishery management agencies. Seventy-five percent of the reported barbless hook violations were accidental. Many anglers indicated they typically complied with regulations but sometimes forget to flatten barbs on individual flies and lures for short periods. Despite the recent paper of Taylor and White (1992), most past authors have concluded that hooking mortality does not differ between barbed and barbless hooks (Hunsaker et al. 1970; Falk et al. 1974; Wydoski 1977; Dotson 1982; Mongillo 1984; Titus and Vanicek 1988). If 75% of barbless hook citations are written to anglers attempting to comply with the law and the regulation violated has little or no demonstrated biological value, maintenance of such restrictions may be self-defeating for regulatory agencies. The animosity generated by issuing such citations to largely compliant anglers seems counterproductive.

An important limitation of our validation design is that anglers were observed for only a portion of their angling-day. We could not account for any night angling activity. In addition, only 28% of the anglers ($N = 30$) caught a cutthroat trout during observation periods. Thus, many anglers we observed did not have the opportunity to violate the creel limit. Additional creel violations possibly occurred if unsuccessful anglers moved to other areas on the stream and caught cutthroat trout. Despite the small sample size, none of the successful anglers were observed keeping a trout. This result agrees with our low random response estimate.

Anglers might violate the bait restriction elsewhere during their angler-day and not at the observation site, but this possibility seems remote. Anglers violating regulations because of a lack of awareness would do so all the time. We surreptitiously observed anglers for an average of 39 min and believe anglers intentionally violating bait restrictions would likely do so during that time.

There are several other limitations to our random response methods. We assumed anglers could accurately remember whether they committed violations on their last angling trip. Recall is often not 100% accurate in recreation studies (Hiett and Worrall 1977; Chase and Harada 1984). Accurate recall of barbless hook violations, particularly accidental ones, may be questionable and may be more of an estimate. However, we believe anglers violating the bait, bag, or size restrictions would accurately remember the violations.



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235
12915 SW MORRISON ST
BEAVERTON OR 97005-0728

No Barbless Bait

I am a biologist working on the recovery of the aquatic ecosystem of the upper Sacramento River in northern California following a devastating chemical spill in 1991. I recently read Dr. Patrick Trotter's River Keeper article entitled "Hooking Mortality of Trout" in your March 1995 issue. I commend your magazine for publishing such informative and educational articles.

I am writing to offer some insights, however, on the hooking-mortality figures reported in the article, which compared the use of bait with barbed versus barbless hooks. Dr. Trotter cites a 1992 scientific article by Matthew Taylor and Karl White of Utah State University in which they analyzed several past studies on hooking mortality for nonanadromous trout.

This article provides an excellent starting point for students of hooking mortality of trout, but not all of the information is applicable to all trout fisheries. For example, the authors concluded that the use of bait with barbless hooks resulted in a substantial reduction in hooking mortality (8.4 percent) when compared to the use of bait with barbed hooks (33.5 percent). This type of information could lead fishery managers and fishing organizations to advocate the use of bait with barbless hooks in catch-and-release waters, which I believe could have major negative impacts.

When I first read the Taylor and White article, I was somewhat skeptical of the 8.4 percent hooking-mortality rate for bait with barbless hooks. This figure seemed counterintuitive to all of the hooking-mortality studies I had read in the past.

I contacted Taylor to get some further clarification on the 8.4 percent mortality rate. This low hooking mortality rate for bait with barbless hooks came from a single study published during 1932 on immature brook trout (three to seven inches long).

In that same 1932 study, the author found a maximum hooking mortality rate of only 10.5 percent for the immature brook trout caught and released on bait with barbed hooks. Therefore, the differences for barbed and barbless hooks are much less dramatic when considering only the 1932 study, and these results should only be considered valid for immature brook trout.

In addition, the 33.5 percent hooking mortality rate for bait with barbed hooks reported in Taylor and White is much more reliable and came from a compilation of seven studies on several species of nonanadromous trout.

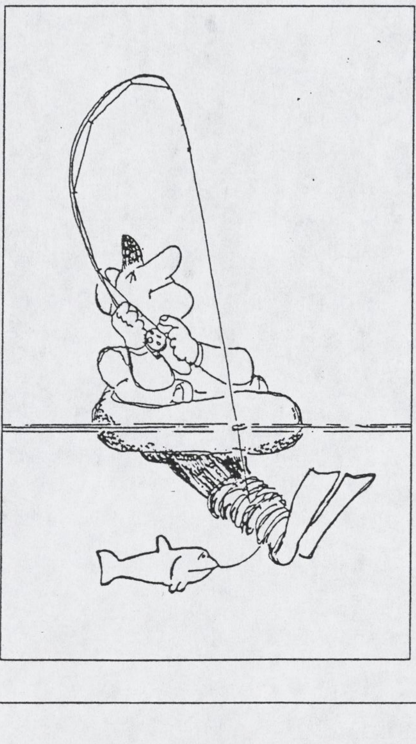
I recently spoke with Dr. Trotter, and we both agree that the low 8.4 percent hooking mortality rate for bait with barbless hooks is very misleading and should not be directly compared to the 33.5 percent mortality rate for bait with barbed hooks reported in Taylor and White. *While the 8.4 percent figure might be useful for consideration in the catch-and-release of immature brook trout, it could be a major mistake to consider the use of bait with barbless hooks in nonanadromous catch-and-release fisheries for either mature trout or for other trout species.*

Immature brook trout would be expected to have a lower mortality rate no matter what type of gear is used, as pointed out by both Dr. Trotter's and Taylor and White's articles. For example, brook trout are less susceptible to hooking mortality than rainbow or cutthroat trout, and hooking mortality increases as the size of the trout increases. This is likely due to the inability of small fish to engulf a baited hook as deeply as larger mature fish.

Please get this information out to your readers. The misuse of the low hooking-mortality rates reported in Dr. Trotter's article and Taylor and White's paper for bait with barbless hooks could have far-reaching negative effects on many of the nation's catch-and-release trout fisheries if these fisheries begin to allow the use of bait.

STEVE TUREK
Redding, California

TIGHT LINES



ROBERT RANDALL ILLUSTRATION

Norway's Sea-runs

As a Norwegian fly fisherman with a bit of sea trout experience under my belt, I would like to comment briefly on the "Connetquot Sea-runs" article in the December 1995 issue.

It seems the Connetquot browns are behaving exactly like their European siblings. And as the German brown trout is the exact same species as the European sea trout (*Salmo Trutta*), one would be glad to report that, for once, all is well with the world.

It is well known in Scandinavia that sea trout stay close to the coast during their stay in salt water. Experience shows that rivers with a large estuary and extended regions of surrounding brackish water produce the largest sea trout. The Morrum River in Sweden is perhaps the best example of this. In general, sea trout mostly forage in the shallows during their stay in salt water.

Therefore, the "laziness" of these fish is a simple product of their genetic make-up. It does, however, raise several interesting issues:

• The saltwater behavior of German browns opens the possibility for focused saltwater fly fishing for the species. Denmark has, for instance, an extended sea-trout saltwater fishery, and it plants large numbers of fish in small streams, expecting most of the fish to be caught by saltwater fly fishers.

• Saltwater sea-trout fishing significantly extends both the season and the capacity of the fishery—not to mention that mixing it up with a four-pound brown in winter and early spring is a nice break from the tying vise. Any flies that imitate local baitfish tend to do the job. Twilight and evening are key periods.

• Protection of estuary and near-coastal habitat is extremely important for the health of both the saltwater and the freshwater fishery. To my knowledge, the problems with recreational netting that exist in Scandinavia are not present in the U.S., so sound management is probably less of a challenge here.

As for fishing techniques for sea-run browns in the river, the following holds in Scandinavia:

• Sea trout tend to congregate at the neck of pools during twilight and darkness.

• Until it is completely dark, floating lines and smaller flies (#6-#10) are used.

• At night larger streamers (#2-#6, often tandem flies) on fast sinking lines are fished close to the bottom.

Finally, one question: Your photographs only showed browns in the typical greenish-brown coloration. Are

Continued on page 8

TO--Bob Behnke
From--Ted Kerasote, phone--307/733-1871, fax--307/733-8505

Dear Bob:

Below please find the section in which I describe some of your thoughts and findings about catch and release fishing and whether fish feel pain. Please feel free to change anything that I misconstrued or that you don't like, and please feel free to make any additions.

Thank-you very much for all the time you've devoted to this.

Sincerely,

Ted

NOT FAR from where John Betts fishes on Colorado's South Platte River another angler, Bob Behnke, Professor of Fishery Biology at Colorado State University, ponders these same questions. In fact, he has been doing research on catch and release fishing for more years than lots of us have been walking up and down streams.

His work, and his popularization of other's research, has put paid to several angling myths. For one, that catch and release fishing can help to increase the size of trout in a stream. -only under ~~[illegible]~~ It can't. "Terminal size and age is determined by environmental conditions and can't be changed by special regulations," he states in no-nonsense sciencese. For another, that barbless hooks are necessary for successful catch and release fishing and that the

size vs. growth

yes: size can increase - but only where environment allow for good growth older age

see figures - Yellowstone

< 5%, - 40%, > 4x.

1974-1984

Gunnison plan 10x in 20-14"

but 3x brown

ST. Joe 10-2-x - 12"

reduce net 75-52%

7-5-6-7 - 5-6 x.

single hook is less injurious than the treble hooks used on spinning lures. No and no again. Behnke cites controlled studies in which mortality did not increase with barbed hooks nor with treble ones. Such evidence infuriates the purists with their hat brims studded with expensive flies. "Among them," says Behnke, "I'm regarded as an evil person."

Ironically, the hate swarms not only from some in the angling community but also from those in the animal rights movement, for Behnke maintains that fish don't experience the sort of pain that a human might

extreme-Trauma (hospital)

experience with a hook in his mouth. "If it ~~was~~ a harsh experience," he says, "you would not likely do it again within a day. Yet you can catch the same fish

in Y. River

every day by dangling a lure in front of it. Yellowstone cutthroats are caught and released about ten times each season. They would learn not to be caught

severe or [illegible] trauma

again if they were experiencing pain."

He does note that cutthroats are notoriously easy to catch as compared to brown trout, with rainbows someplace in between. Do brown trout thus feel more pain than cutthroats? Or are they just smarter? Anglers contend that brownies are the brainiest of trout, but no one knows for sure.

About Stoskopf's' hypothesis that fish feel pain because they display mammalian-like reactions to stress, Behnke counters, "Similarities don't mean that they're feeling the same kind of pain. Fighting a fish for a long time will change the blood chemistry. Eventually you can produce a lethal effect if

overly

the blood becomes acidified. Pain, I'm not sure."

exhaustion (warm water) ✓

Degree of pain - only fish know but circumstancial evidence - no way comparable to humans subjected to same stimulus - resume normal activity - electrofishing - Tagging - hook in gullet - [illegible] cocktail [illegible] gaping wounds - sea lions - sand sharks

Then, like Williams, he points out that whether individual fish actually feel what we know as pain is not really the issue. "Catch and release is a management tool. Without catch and release you wouldn't be able to maintain quality fishing."

Extracting an essay that he wrote for *Trout*, he points out the following data. In 1989 Colorado sold 800,000 angling licences and projects that angling demand will continue to increase. The average angler fishes 10 days per year, which gave the state eight million angler days in 1989. Twenty-nine percent of these angler days are spent on coldwater streams for a total of 2.3 million angler days trout fishing. The Division of Wildlife sets a goal for each angler of 2.8 fish per day, which may not make most anglers ecstatically happy but is designed to send them home sufficiently satisfied. Do the math and you find that Colorado's trout streams have to produce an annual catch of 6.44 million fish, which is about five million more fish than all of the streams in Colorado can yield.

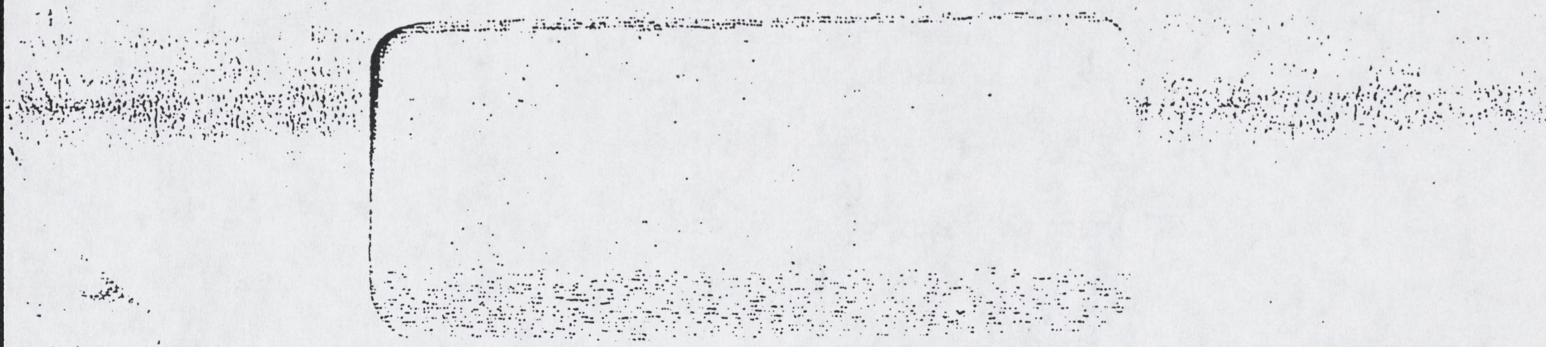
Ah, but there are hatcheries, maintain those enamored of technological fixes for environmental limits. These put-and-take fisheries, goes their argument, can bridge the gap between the supply of wild trout and angler demand. "Not a chance," says Behnke. Colorado hatcheries produce less than five million ~~fish~~ catchable trout, most of them stocked in lakes.

Hence, the need for catch and release. Behnke uses the words, "Recycle trout to maintain acceptable catch rates in heavily fished waters." Lee Wulff, indisputably one of the greatest fly anglers of this century, said the very same thing in 1939 and with a bit less technospeak: "Game fish are too valuable to be caught only once."

From a political and economic standpoint the reasoning of both men is impeccable. Anglers vote and buy fishing licences. They also buy tackle and clothing, stay in motels, and eat in restaurants. There isn't a chamber of commerce in the land that weighs a fish's pain against its community's annual fishing revenues.

You have to seek out a guy like Turner to see the crack in this economic armor. "We're dealing with a group of people," he says, "fishermen, climbers, boaters, whose idea of fun and sport is more important than the good of the environment. I have a great respect for restraint. We could limit access to the resource. Maybe have a lottery like in the Grand Canyon. Raise the cost of licences. We don't have to give everyone unlimited fishing opportunities. Maybe this is something that can't be done everyplace. But it could be done in Yellowstone and Grand Teton parks. Ultimately people have to give."

When I point out to Turner that this would turn America into Europe, where only the wealthy get to fish for trout, he sighs. He has principles, not easy solutions.



Colorado Cooperative Fish & Wildlife Research Unit

Comparisons of Hook Types: A Summary of Past Studies

George Schisler and Eric Bergersen

Colorado Cooperative Fish & Wildlife Research Unit

Comparisons of Hook Types:
A Summary of Past Studies

George Schisler and Eric Bergersen

Colorado Cooperative Fish and Wildlife Research Unit

January 11, 1995

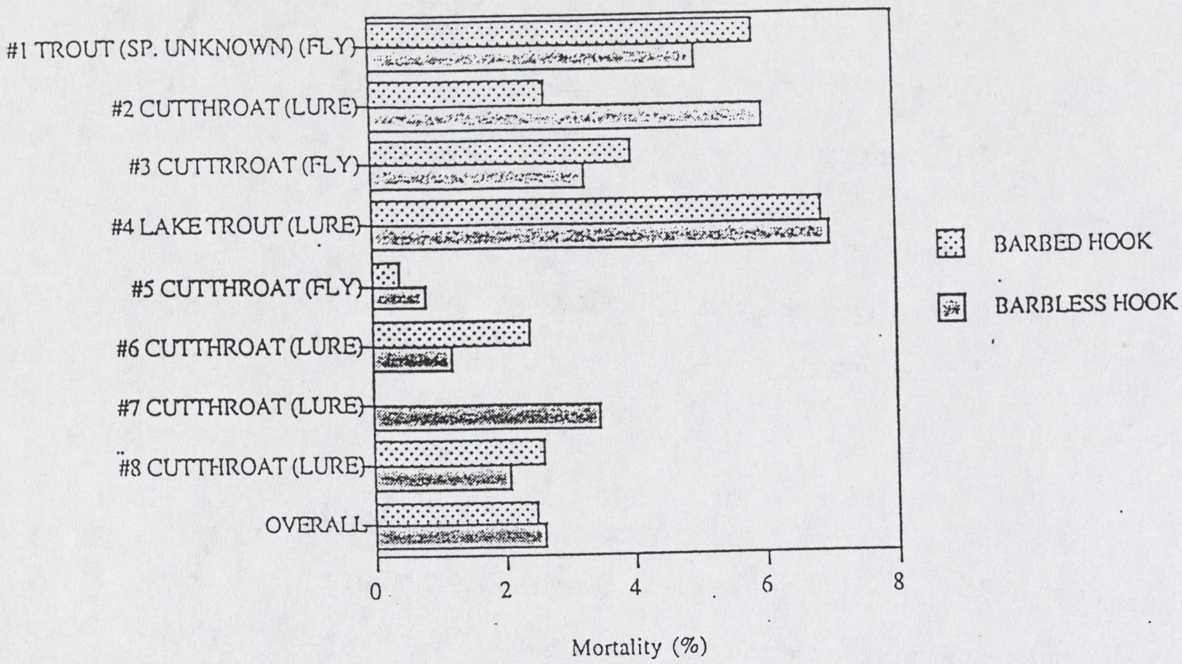
Introduction

Debates over benefits of barbless versus barbed hooks or single versus treble hooks have been going on for decades. Proponents of barbless hooks have argued that they are easier to remove and thus cause less tissue damage to the fish than barbed hooks. Opponents claim barbed hooks cause lower mortalities because the barb prevents the hook from penetrating areas like the roof of the mouth too deeply. Anglers in favor of single hooks make the argument that treble hooks become embedded in more than one location and are harder to remove than single hooks. Others favor treble hooks and maintain that the relatively large size of the treble hook prevents fish from swallowing the hook entirely, which prevents internal organ damage. Intuitive reasoning may give anglers different opinions on these debates depending on individual experiences with different fly and lure types or hook sizes. Many scientific studies have been conducted to evaluate the differences between barbed, barbless, single, and treble hooks. This paper is a summary of past studies that could be found in the literature where direct comparisons of salmonid mortality were made between hook types

Barbed Versus Barbless Hooks

A summary of studies where direct comparisons were made between barbed and barbless hooks is shown in the following graph. Descriptions of the studies shown will follow. Sample sizes, along with numbers of fish that lived and died in each experiment are shown in Table 1. Statistical tests of significance between hook types were evaluated using were two-tailed tests for comparing binomial proportions (Ott 1993) with an alpha level of 0.05.

COMPARISON OF BARBED AND BARBLESS HOOK MORTALITY



Study #1 is the oldest recorded study of this kind found in the literature. It was conducted by Thompson (1946) on an unknown species of trout in New Mexico. Comparisons were made between mortalities of trout caught on barbed and barbless flies. Barbed hook mortalities were 5.9%, and barbless hook mortalities were 5.0%. No significant difference was found between the two hook types (p=.4013).

The second study was conducted by Hunsaker, Marnell, and Sharpe (1970) at Yellowstone Lake, Wyoming. Cutthroat trout (*Oncorhynchus bouvieri*) were captured on lures with barbed and barbless treble hooks. Mortalities were 6.0% for barbless hooks and 2.7% for barbed hooks. The difference was not significant (p=.1131).

Study #3 was also conducted by Hunsaker, Marnell and Sharpe (1970). Again on cutthroat trout in Yellowstone Lake, Wyoming. Comparisons were made between barbed and barbless flies. As with the other studies, no significant differences (p=.4207) were found between barbed (4.0%) and barbless hooks (3.3%).

The fourth study, conducted by Falk, Gillman, and Dahlke (1974) evaluated mortality of lake trout (*Salvelinus namaycush*) with barbed and barbless treble hooks on the Great Slave Lake in Canada. While barbless hooks caused slightly higher mortalities (7.0%) than barbed hooks (6.9%), the results were not significantly different (p=.4920).

Study #5 was conducted by Bjornn (1975), who compared mortalities of barbed and barbless flies on cutthroat trout in the St. Joe River in Idaho. Mortalities were 0.8% for barbless hooks and 0.4% for barbed hooks. The results were not significantly different (p=.2912).

Study #6 was also conducted by Bjornn (1975) on the St. Joe River with cutthroat trout. Mortalities caused by lures with barbed and barbless treble hooks was evaluated. Mortalities for barbless hooks was 1.2%, and mortalities for barbed hooks was 2.4%. These were nonsignificant differences (p=.2005).

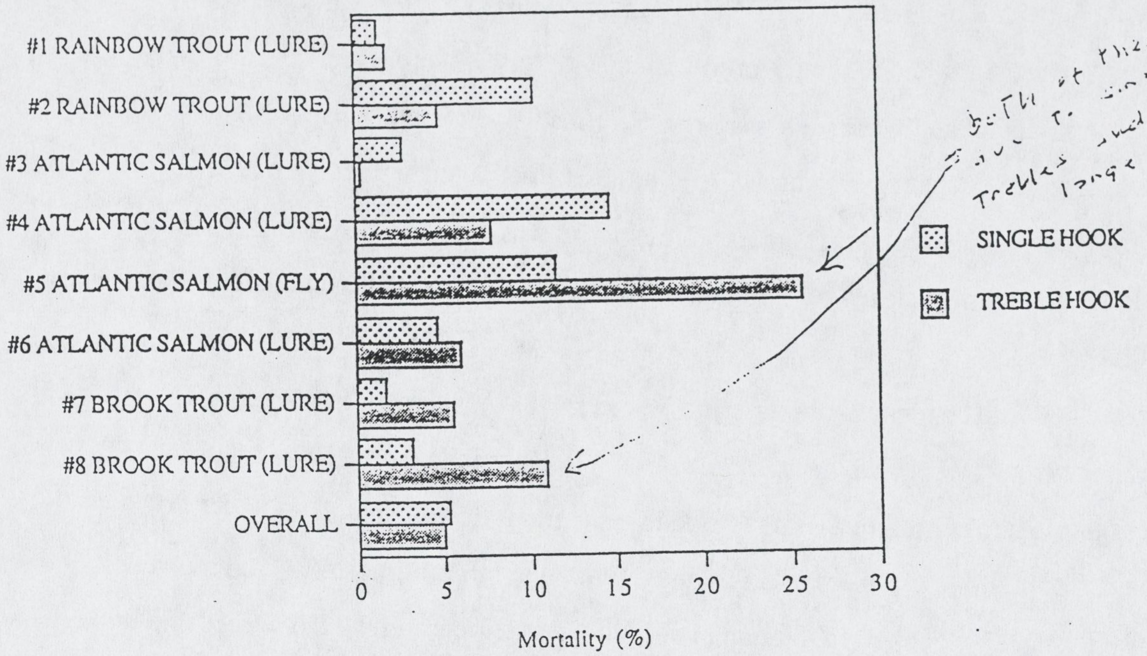
Studies #7 and #8 were conducted by Titus and Vanicek (1988) who evaluated mortalities of lure-caught cutthroat trout (*Oncorhynchus clarki henshawi*) in Heenan lake, California with barbed and barbless treble hooks on lures. Barbed hooks resulted in mortalities of 0% and 2.6%, while barbless hooks resulted in mortalities of 3.5% and 2.1%. One other replicate was conducted at Heenan Lake by Titus and Vanicek in mid-summer at high water temperatures (21 degrees C). Barbed hooks caused mortalities of 48.1% and barbless hooks caused mortalities of 35.3%. Cutthroat trout reach their upper lethal temperature at 21 to 24 degrees C., so the results of that replicate experiment were heavily influenced by the high water temperatures. Because of the confounding effect of high water temperature, we left that replicate out of the data set shown in figure 1. Study #7 resulted in nonsignificant differences between hook types (p=.1660), as did study # 8 (p=.4129).

The overall results include the combined total mortality from barbed and barbless hooks in all of the studies shown in figure 1. These mortality values average 2.5% for barbless hooks and 2.6% for barbed hooks. These values are not significantly different (p=.4247). Mortalities for both barbed and barbless hooks on artificial flies and lures are generally very low. <u>The results of all studies thus far indicate that there is no benefit to using barbed or barbless hooks.</u>

Treble Versus Single Hooks

Mortalities caused by treble and single hooks have been evaluated as extensively as barbed versus barbless hooks. A summary of past studies on treble versus single hooks is shown in the following graph. Descriptions of those studies will follow. Sample sizes and numbers of mortalities are shown in Table 2.

COMPARISONS OF TREBLE AND SINGLE HOOK MORTALITY



both of these are due to small, using trebles and relatively large fish which engulf small lure

Studies #1 and #2 (Klein 1965) compared mortality of rainbow trout (*Oncorhynchus mykiss*) caught and released on lures with single and treble hooks in a rearing pond. Mortalities were 1.3% for trout caught on single hooks, and 1.8% for those caught on treble hooks in the first replicate experiment. Mortalities in the second replicate experiment were 10.3% for fish caught on single hooks, and 4.8% for fish caught on treble hooks. No significant differences were found in study #1 ($p=.3336$), although single hooks caused significantly higher mortalities than treble hooks ($p=.0078$) in study #2.

The third study, conducted by Warner (1976) evaluated mortalities of Atlantic salmon (*Salmo salar*) caught in a hatchery environment on lures with barbed treble and barbed single hooks. Mortalities were 0.3% for treble and 2.7% for single hooks. Mortality from single hooks was significantly higher than mortality for treble hooks in this study ($p=.0057$).

The fourth study was conducted by Warner (1978), and evaluated mortalities of Atlantic salmon caught on lures with treble and single hooks in a lake situation. No significant differences were found between the treble (7.8%) and single (14.7%) hooks ($p=.0526$).

Study #5 was conducted by Warner (1978) on Atlantic Salmon in a lake environment, and compared treble versus single hook flies. Treble hook flies resulted in 25.6% mortality, while single hook flies resulted in 11.5% mortality. Treble hook flies did not cause significantly higher mortality at alpha level of 0.05, but did at alpha level of 0.10 (p=.0401). The author reported that the difference may have been due to the very small size treble hooks used (No. 10), which may have been easily ingested.

Study #6 was also conducted by Warner (1979) on Atlantic Salmon in a hatchery situation. Mortalities from lures with treble hooks were 6.0%, and mortalities from lures with single hooks were 4.6%. These results are not significantly different (p=.2266).

Studies #7 and #8 were conducted simultaneously by Nuhfer and Alexander (1992) on brook trout (*Salvelinus fontinalis*). Treble and single hook mortality was evaluated for two different lure types. These were Cleo spoons (Study #7) and Mepps spinners (Study #8). Treble hooks caused mortalities of 5.6% in study #7 and 10.93% in study #8. Single hooks caused mortalities of 1.61% in study #7, and 3.15% in study #8. Study #7 showed significant differences (p=.0401) between hook types only after the alpha level was lowered to 0.10. Significant differences (p=.0075) were found in study #8 at alpha level of .05.

All studies combined result in overall mortalities of 5.3% for single hooks, and 4.9% for treble hooks. No significant difference between treble and single hooks was found with the combined totals (p=.3483). These data suggest that there is no benefit to using either treble or single hooks.

Summary

Very little evidence has been found to support any particular hook type to reduce catch and release mortality. No consistent patterns can be found in past studies that favor one hook type over another. Individual preference should dictate what hook type an angler uses. We recommend that if anglers want to fine tune their ability to release fish alive, they should try different types of hooks, and depending on the size of the fish being captured, voracity of the fish, fishing location, and other factors, decide for themselves what hook type works the best to minimize mortality.

TABLE 1. Mortality studies of barbed versus barbless hooks.

Author	Species	Hook Type	Caught	Killed	Mortality (%)
Thompson (1946)	UNKNOWN	BARBED	51	3	5.9
		BARBLESS	60	3	5.0
Hunsaker, Marnell, and Sharpe (1970)	CUTTHROAT	BARBED	113	3	2.7
		BARBLESS	100	6	6.0
Hunsaker, Marnell, and Sharpe (1970)	CUTTHROAT	BARBED	75	3	4.0
		BARBLESS	60	2	3.3
Falk, Gillman, and Dahlke (1974)	LAKE TROUT	BARBED	72	5	6.9
		BARBLESS	57	4	7.0
Bjornn (1975)	CUTTHROAT	BARBED	256	1	0.4
		BARBLESS	264	2	0.8
Bjornn (1975)	CUTTHROAT	BARBED	209	5	2.4
		BARBLESS	166	2	1.2
Titus and Vanicek (1988)	CUTTHROAT	BARBED	27	0	0.0
		BARBLESS	29	1	3.5
Titus and Vanicek (1988)	CUTTHROAT	BARBED	77	2	2.6
		BARBLESS	95	2	2.1
OVERALL	MIXED	BARBED	880	22	2.5
		BARBLESS	831	22	2.6

TABLE 2. Mortality studies of single versus treble hooks.

Author	Species	Hook Type	Caught	Killed	Mortality (%)
Klein (1965)	RAINBOW TROUT	SINGLE	233	3	1.3
		TREBLE	224	4	1.8
Klein (1965)	RAINBOW TROUT	SINGLE	272	28	10.3
		TREBLE	271	13	4.8
Warner (1976)	A. SALMON	SINGLE	296	8	2.7
		TREBLE	333	1	0.3
Warner (1978)	A. SALMON	SINGLE	95	14	14.7
		TREBLE	116	9	7.8
Warner (1978)	A. SALMON	SINGLE	52	6	11.5
		TREBLE	39	10	25.6
Warner (1979)	A. SALMON	SINGLE	302	14	4.6
		TREBLE	300	18	6.0
Nuhfer and Alexander (1992)	BROOK TROUT	SINGLE	124	2	1.6
		TREBLE	125	7	5.6
Nuhfer and Alexander (1992)	BROOK TROUT	SINGLE	127	4	3.2
		TREBLE	128	14	10.9
OVERALL	MIXED	SINGLE	1501	79	5.3
		TREBLE	1536	76	4.9

Oregon

DEPARTMENT OF FISH AND WILDLIFE

January 25, 1996

Dr. Bob Behnke
Colorado State University
Dept. Fish & Wildlife Biology
Ft. Collins, CO 80523

Dear Dr Behnke:

Thanks for all the material you loaned me on barbless hooks, hooking mortality, etc. I distributed copies of the articles to all of our field biologists and have asked them for feedback. I will share their response with you. If in fact we back off on the barbless hook issue (I'm convinced), the difficult part will be explaining to the public why we have been jamming this regulation down their throat (no pun intended) for the past ten years. But, better to admit your mistakes and move on with business. Many anglers would applaud the removal of the barbless regulation (they will say "I told you so") and the state police would write a lot less citations. Sounds like a win-win to me.

On to another subject. We reduced the daily trout bag limit in Klamath and Agency lakes about five years ago to 1 per day, 6" minimum length, barbless hooks and an angler must stop fishing after retaining their one fish. The purpose of the one fish bag is conservation. This one fish/barbless regulation has created quite a stir among many of the locals. We continue to receive proposals from the angling public to increase the daily bag to two. Generally, the catch rate in Klamath Lake is fairly low so in reality the daily limit could be 100 trout. On the other hand, there are some days, but not many, when fishing can be "hot" and success is quite good. My question to you is can we increase the daily bag to two per day and still maintain a strong conservation program? If anglers are high grading with a one fish daily limit, are they likely to high grade with a two fish bag also? Or, since the frequency of anglers encountering two fish a day is fairly low, will two fish satisfy even the successful anglers who have "caught their limit"? If we removed the barbless hook regulation and increased the bag from one to two per day we would create goodwill among Klamath Falls area anglers. We do not, however, wish to trade goodwill for conservation. I would appreciate your opinion on this issue.

Look forward to seeing you in March.

Best,

Charlie

P.S. Included a copy of Schill's research from Idaho.

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Oregon

DEPARTMENT OF

FISH AND WILDLIFE

OREGON

Fish & Wildlife

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FAX (503) 229-5602
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STATE OF OREGON
1859

Route Slip

Date 1-23

TO: Name	Division/Section	Initial	Date
1. Bob Behnke			
2.			
3.			
4.			
5.			

as

app

cor detail

cor late

for

Please send this to Behnke w/ rest of his packet

Thanks

FRO e No.

Z5-097677

☐ See Other Side

Route Slip

Date 1-23

TO: Name	Division/Section	Initial	Date
1. Bob Behnke			
2.			
3.			
4.			
5.			

	as requested		investigate		per conversation
	approval		justify		prepare reply
	comment		necessary action		return with more detail
	confer		initial and return		review and circulate
	for your information		note and file		signature

FROM: Bob Hooton	Phone No.

Z5-097677

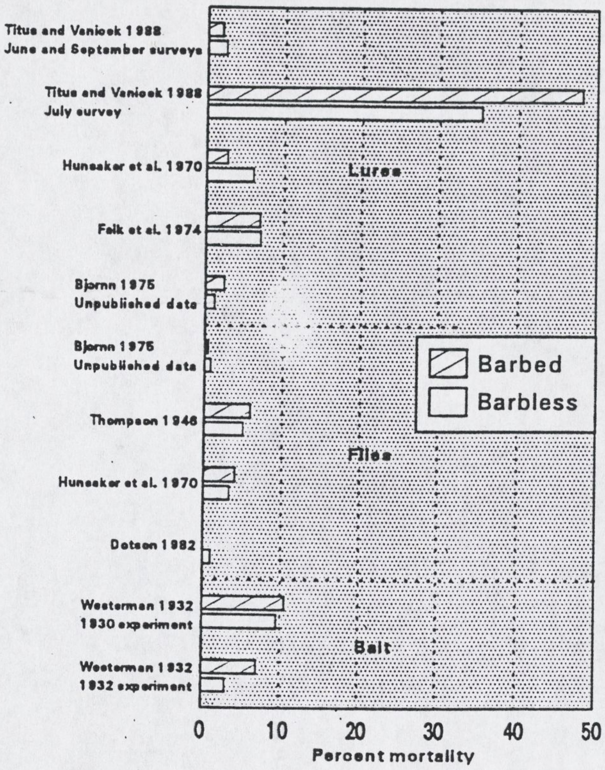
☐ See Other Side

FISHERY RESEARCH

IDAHO FISH & GAME

SPORT FISH RESTORATION

Annual Performance Report
Grant F-73-R-17



PROJECT 4 WILD TROUT REGULATION STUDIES

Subproject 1. Barbless Hook Evaluations

Subproject 2. Regulation Workshop Development

PROJECT 5 ANGLER COMPLIANCE STUDIES

by

D. J. Schill

Principal Research Biologist

R. L. Scarpella

Senior Fishery Technician

IDFG 95-37

October 1995

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ANNUAL PERFORMANCE REPORT

State of: Idaho

Grant No.: F-73-R-17, Fishery Research

Project No.: 4

Title: Wild Trout Regulation Studies

Subproject No.: 1. Barbless Hook Evaluations

Contract Period: April 1, 1994 to March 31, 1995

ABSTRACT

In this study we summarize results of past studies comparing hooking mortality of salmonids caught and released with barbed and barbless hooks. A review of individual studies produced equivocal results with barbed hooks resulting in greater mortality in six studies and less mortality in the remaining five. Only one of these 11 direct comparisons produced significantly different results. Combination of individual studies via meta-analysis yielded non-significant p-values for flies and lures. A significant difference was detected for bait. Calculated effect sizes, expressed as Pearson Product-moment r's for meta-analysis combinations were quite small ranging from -0.001 to 0.060. Thus, the use of barbed or barbless hooks appeared to play little role in determining survival of fish in the past studies. Population simulations suggest the effect of all vulnerable trout being caught from 1 to 5 times annually with artificial barbed or barbless gear exclusively would have little effect on a wide variety of Idaho trout populations in terms of catchable sized trout or large trout available for anglers to catch. We conclude there is no demonstrated biological basis for barbless hook restrictions in artificial flies and lure fisheries for non-anadromous trout based on existing information. Rather, implementation of barbless hook restrictions for such fisheries appears to be a social issue. Managers considering or proposing new special regulation proposals to the angling public should consider possible social costs of implementing a restriction with no demonstrable biological gain. Further, we suggest existing barbless hook requirements should be considered for deletion on waters where socially feasible.

Authors:

D. J. Schill
Principal Research Biologist

R. L. Scarpella
Senior Fishery Technician

INTRODUCTION

Beginning with the first hooking mortality study (Westerman 1932), numerous investigators have questioned whether or not barbless hooks reduce mortality of salmonids caught and released by anglers when compared to releases with barbed hooks. In his pioneering hooking mortality study, Westerman (1932) did not run statistical tests, but concluded that barbless hooks were superior to barbed hooks in reducing hooking losses for rainbow trout *Oncorhynchus mykiss* caught with bait. However, authors of all subsequent field studies of nonanadromous salmonids we are aware of have concluded that no statistically significant differences in hooking mortality exist between barbed and barbless hooks (e.g. Hunsaker et al. 1970; Falk et al. 1974; Titus and Vanicek 1988).

Three reviews of hooking mortality literature have addressed the barbed versus barbless question producing conflicting conclusions. Using results from the above studies and drawing on additional unpublished data sets, Wydoski (1977) concluded that barbless hook use does not reduce hooking mortality significantly and suggests restrictions requiring them cannot be justified biologically. Based on his review of the same data sets, Mongillo (1984) states "there is no valid technical basis for requiring use of barbless hooks." The conclusions of these two qualitative reviews have been called into question by Taylor and White (1992). Based on meta-analysis, these authors concluded that a statistically significant difference in hooking mortality occurs when using the two hook types in nonanadromous salmonid fisheries.

The Taylor and White (1992) findings appear to have renewed interest in regulations requiring barbless hooks. Based primarily on the Taylor and White (1992) article, five Arkansas waters with new regulations enacted in 1994 include a barbless hook restriction (J. Stark, Arkansas Game and Fish Commission, personal communication). In Oregon, a proposal to require barbless hooks for all freshwater fishing including flatwater and streams for all species is being considered (R. Temple, Oregon Department of Fish and Wildlife, personal communication). In Idaho, an additional 700+ km of new barbless hook only regulations were recently adopted for streams.

Increasing use of this management restriction at such a widespread level warrants close scrutiny, especially considering that the preponderance of past authors have not demonstrated any biological advantage to barbless hook use. While reviewing Taylor and White (1992), we realized that several past studies comparing barbed and barbless hooks were not included in their analyses. In addition, our review of their methods generated questions about their overall approach to meta-analysis. As a result, we are uncertain if the significant difference reported between the two hook types by Taylor and White (1992) is accurate.

Regardless of the validity of the Taylor and White (1992) findings, statistically significant results do not necessarily indicate an association is substantively important (Gold 1969). An assessment of the magnitude of the association among variables must still be made in some term other than a statistical test (Cohen 1965). Calculation of effect sizes facilitates such an assessment (Cohen 1988; Rosenthal 1991). We question whether or not the small difference in mortality rates commonly obtained by past authors when comparing barbed and barbless hook-and-release mortality would be meaningful at the population level. Schill (in review) discusses the need to convert hooking mortality rates from samples into population exploitation rates, and to subsequently consider natural mortality rates when developing restrictions for special regulation waters. No analyses we are aware of provide fishery managers with a way to judge such population-level merits of barbless hook regulations.

OBJECTIVES

1. To summarize results of all known studies that directly compare mortality of nonanadromous salmonids caught on barbed and barbless hooks.

2. To combine probability values of all known studies using these hook types using meta-analysis.

3. To use effect size meta-analyses to describe the magnitude of the relationship between barbed/barbless hook use and hooking mortality based on past studies.

4. To evaluate differences in hooking mortality caused by the two hook types at the population level via simulation.

METHODS

Individual Study Summary

We relied on our own literature files from past hooking studies (Schill et al. 1986; Schill, in press) along with the comprehensive reviews of Wydoski (1977), Mongillo (1984), and Taylor and White (1992) as initial sources of past hooking mortality studies for this effort. We reviewed bibliographies in all barbless hook papers found and conducted computerized literature searches to locate newer material. Our intent was to locate all prior field studies of nonanadromous salmonids where barbed and barbless hooking mortality rates, for a given gear type (e.g., flies), were estimated in the same study.

We found seven applicable studies (Westerman 1932; Thompson 1946; Hunsaker et al. 1970; Falk et al. 1974; Bjornn, unpublished data; Dotson 1982; Titus and Vanicek 1988). We combined the results of three trials into two comparisons in the Titus and Vanicek (1988) experiment because of small sample sizes in the spring and fall trials and vastly different hooking mortality estimates for the mid-summer trial. Several studies included barbed/barbless comparisons for both flies and lures, increasing the total number of direct hook comparisons available to eleven.

The typical meta-analysis combines results of statistical tests from previous studies but such tests were not conducted in all past hook comparisons we found. In addition, because of the low mortality associated with both hook types in most past studies, resultant cell frequencies were often too small to legitimately run the chi-square tests several authors employed (Zar 1974). We present chi-square test results of the original authors when available.

However, we developed raw databases in SYSTAT (Wilkinson 1990) for each of the past studies and calculated binomial tests (Zar 1974) for all studies to alleviate small cell frequency concerns. Results were considered significant when $P < 0.05$. For those instances where a significant difference between the hook types was not detected, we calculated statistical power (Peterman 1990) of the individual study to detect a difference given the sample sizes and observed data (Cohen 1988). We estimated power of the binomial tests using the methods and tables of Cohen (1988).

Meta-analysis

We combined Z scores obtained from binomial tests of the 11 direct comparisons using meta-analyses. Rosenthal (1991) and Glass (1976) caution against excluding lower quality studies from meta-analyses because of potential investigator bias in the exclusion of individual studies. Thus, we included the data of Thompson (1946), from New Mexico, despite not knowing the trout species involved. In addition, one of the comparisons of Westerman (1932) involved two different, but similar, hook sizes (number 5 barbed and number 6 barbless), while hook sizes were not provided for the other trial. We included all three of these comparisons despite some concern about their design and evaluated the effects of their "low" quality on the overall meta-analysis results.

Rosenthal (Harvard University, personal communication) suggests using several of the numerous meta-analysis techniques available to examine the consistency of results. Initially, we used the Stouffer method of adding Z scores (Stouffer et al. 1949; Mosteller and Bush 1954; Kirby 1993) using the formula:

$$Z_M = \frac{\sum_{i=1}^{k} Z_i}{\sqrt{k}}$$

where:

Z_M = overall Z score of the meta-analysis
Z_i = Z score of binomial test from individual study
k = number of studies

In this method, Z_i is assigned a positive or negative direction based on the hypothesized outcome of the comparison (Rosenthal 1991). In our analyses, Z scores from studies where barbless hooks resulted in lower hooking mortality were assigned positive values. We subsequently combined results using the Edgington (1972) method of testing mean P using the equivalent but simpler formula of Rosenthal (1991):

$$Z_M = (.50-\bar{p})\,(\sqrt{12k})$$

where:

$\bar{p}$ = average one-tailed probability value of all individual binomial tests, taking note of which tail the outcome p-value falls in, and Z_M and k are as defined above.

Lastly, we employed the Mosteller and Bush (1954) method of adding weighted Z's, considering total study sample size and a subjective quality rating independently as weighting variables with the formula:

$$Z_M = \frac{\sum_{i=1}^{k} w_i Z_i}{\sqrt{\sum_{i=1}^{k} w_i^2}}$$

where:

w_i = study weight being either total sample size or subjective quality rating (2 for high quality or 1 for low quality) from individual study, and Z_M, Z_i, and k were defined above.

Using the above formulae, we combined test statistics for all past studies evaluating bait-, fly-, and lure-caught fish, separately. Since most special regulation waters typically restrict bait and permit the use of both flies and lures, we then combined results of all studies using either of the latter two gear types. Resultant Z_M scores for these combinations were transformed into one-tailed P values using SYSTAT functions (Kirby 1993). Meta-analysis results were considered significant when $P < 0.05$.

To estimate the actual magnitude or strength of the relationship between hook type and hooking mortality detectable from past studies we calculated effect sizes for individual studies using the formula provided by Rosenthal (1991):

$$r_i = \frac{Z_i}{\sqrt{N_i}}$$

where:

r_i = standard Pearson product-moment correlation coefficient from individual study,
N_i = total number of fish in individual study,
and Z_i was previously defined.

For meta-analyses we then used the arc-tangent hyperbolic function of SYSTAT to transform signed r's from individual studies into normalized Fisher's Z_r's (Kirby 1993). We calculated mean Z_r's for the same gear type combinations described above for P value combinations and subsequently calculated weighted mean Z_r's, based on sample sizes of individual studies after Rosenthal (1991):

$$\bar{Z}_r = \frac{\sum_{i=1}^{k} (N_i-3)\, Z_{ri}}{\sum_{i=1}^{k} N_i-3}$$

where:

Z_r = weighted mean Z_r
Z_{ri} = Fisher's Z_r from individual study,
and N_i was previously defined.

A weighted evaluation of study quality effects on effect size was also done by substituting either a 2 or a 1 as a weighting variable instead of N_i-3. Unweighted and weighted mean Z_r's were transformed back to mean Pearson product moment r's using the following formula (Kirby 1993):

$$\bar{r} = \frac{e^{2\bar{Z}_r} - 1}{e^{2\bar{Z}_r} + 1}$$

Resultant effect size estimates, both for individual studies and gear types are evaluated using guidelines of Cohen (1988).

Population Simulations

Differences in trout populations resulting from regulations with and without barbless hook requirements were evaluated with a Beverton-Holt yield-per-recruit model (Ricker 1975). We used MOCPOP, an age-structured population simulation model (Beamesderfer 1991; Beamesderfer and North 1995), to simulate populations having life history parameters within the range observed in Idaho. We independently varied parameters for growth, natural mortality and exploitation to examine the effects of hooking mortality associated with the two hook types on a variety of trout populations.

We simulated populations characterized by low, medium, and fast growth using constant recruitment. Selection of growth data was based on a summary of historical scale analyses from nonanadromous trout stocks residing in Idaho streams (Schill 1991). An index of growth rate, back-calculated length-at-age 4, equaled 200, 358, and 461 mm for low, medium, and high growth populations, respectively. These rates cover the range observed in Idaho stream fisheries. We calculated von Bertalanffy growth coefficients using original data from these stocks using the QWKVON software (Beamesderfer 1991).

A summary of the growth coefficients and additional parameters used in the simulations is presented in Table 1. We assumed fish could survive one year past ages typically reported in scale analyses. Thus, in slow and modest growth populations, maximum age was seven years. We assumed fish in fast growth waters would survive 6 years. Simulations were run for one year past the maximum age. Conditional natural mortality (Ricker 1975) for Idaho trout stocks ranges from 30% to nearly 70% annually for all age classes combined (Schill 1991; Thurow and Schill 1994). We used five possible natural mortality scenarios in simulations for each productivity level to cover a broad spectrum of possibilities. Mortality values used for slow and medium growth stocks are presented in Table 2. Values used in fast growth simulations were identical except that in the three scenarios where mortality varied with fish age, the last change occurred at age 6 rather than age 7.

Exploitation for otherwise identical populations managed with barbed and barbless hook regulations was calculated using weighted mean hooking mortality rates for all past artificial lure and fly studies summarized above in the present study. We did not include Westerman (1932) because few existing special regulations permit the use of bait (Carline et al. 1990). We assumed all fish over 153 mm in length were vulnerable to anglers and initially simulated a population where all catchable-sized trout in the population are captured once. In this case, the population exploitation rate due to catch-and-release angling equaled the weighted mean

Table 1. Parameters used in simulations evaluating population effects of barbless hook regulations in catch-and-release fisheries for Idaho trout stocks. Values in parentheses correspond to exploitation rates when barbless hooks are required.

	Idaho trout growth		
Parameter[a]	Low	Medium	High
R_1	10,000	10,000	10,000
A_{max}	7	7	6
k	.06	.18	.24
t_0	-.12	.12	.52
L_∞	910	702	807
E_1	0.0454 (0.0416)	0.0454 (0.0416)	0.0454 (0.0416)
E_3	0.136 (0.125)	0.136 (0.125)	0.136 (0.125)
E_5	0.227 (0.208)	0.227 (0.208)	0.227 (0.208)

[a] Symbols: R_1 = number of recruits at age 1.
A_{max} = maximum age.
k, t_0, L_∞ = von Bertalanlffy equation slope, intercept, and asymptote.
E_1 to E_5 = Exploitation rate for barbed hook fishery when all fish in population caught and released one, three and five times - based on weighted mean hooking mortality of post studies summarized in this report.

Table 2. Five natural mortality scenarios used for simulating effects of barbless hook regulations in Idaho catch-and-release fisheries for slow and medium growth stocks.

Scenario	Mortality rate Age 1-2	Age 2-6	Age 7
Constant - low	0.3	0.3	0.3
high→ low	0.7	0.5	0.3
low→ high	0.3	0.5	0.7
high→ low → high	0.7	0.4	0.8
constant - high	0.7	0.7	0.7

hooking mortality rate for either hook type. Next, we simulated heavily-fished populations where all catchable-sized trout are captured three and five times by multiplying these average catch frequencies times the weighted mean hooking mortality rates for either hook types. In doing so, we assumed multiple recaptures during a year did not elevate hooking mortality.

One model output, assumed to be an index of overall catch rate by anglers, was numbers of fish in simulated populations larger than 153 mm. We compared this model output for fisheries managed exclusively with barbed or barbless hooks. Since abundance of large fish in populations may be vulnerable to even seemingly low levels of exploitation (Gigliotti and Taylor 1990), we also compared numbers of large trout produced in simulated populations. Absolute numbers in our simulations were strongly influenced by growth rate. To standardize results we converted absolute numbers of catchable or large-sized trout in resultant populations to a percent difference in number of trout present in identical fisheries managed with either hook type, exclusively.

Barbless Hook Survey

To provide perspective on the use of barbless hook restrictions we surveyed all states nationwide. During a phone survey and subsequent examination of printed regulations, we ascertained which states have nonanadromous salmonid fisheries and which currently require barbless hook on special regulation waters all, most, few, or none of the time. Few was defined as less than half of the waters. We subjectively defined a salmonid special regulation as any regulation including or more restrictive than either a 2 fish creel limit alone or a 3 fish limit used in conjunction with a minimum size limit.

RESULTS

Individual Study Summary

A graphical summary of past individual studies comparing barbed to barbless hooking mortality reveals equivocal results (Figure 1). In six studies, use of barbed hooks resulted in greater mortality, while the remaining five studies produced the opposite result. Barbed hooks resulted in lower estimates of hooking mortality in two of four fly comparisons and in three of five lure comparisons. Barbed hook use resulted in higher mortality in both cases where bait was used.

In general, differences in hooking mortality attributable to barbless and barbed hooks were quite small. Based on statistical tests of the authors and our own binomial tests, a single comparison produced results different at the 0.05 significance level (Table 3). This case was the Westerman (1932) bait trial where the 7% barbed hook mortality was significantly greater than the 3% mortality attributable to barbless hook use ($P = 0.02$). All other comparisons proved nonsignificant.

Power analyses of binomial tests revealed that none of the studies with nonsignificant results had a high probability of detecting a difference between observed mortality rates if one

Table 3. Summary of past individual hooking mortality studies directly comparing barbed versus barbless hooks. Sample sizes are in parentheses.

Study	Gear type	Species	Hooking mortality Barbed	Hooking mortality Barbless	Original significance test (χ^2 2-tailed)[a]	Binomial test P (one-tailed)	Power of binomial test	Effect size (r)
Titus and Vanicek 1988 (summer)	treble-hook lures	wild cutthroat trout	48.1 (52)	35.3 (51)	OTG	0.09	0.27	0.13
Hunsaker et al.	treble-hook lures	wild cutthoat trout	2.7 (113)	6.0 (100)	NS	0.11	0.24	0.08
Falk et al. 1974	treble-hook lures	lake trout	6.9 (72)	7.0 (57)	NS	0.49	<0.01	<0.01
Bjornn 1975 (unpublished data)	treble-hook lures	hatchery cutthroat trout	2.4 (209)	1.2 (166)	NT	0.20	0.15	0.04
Bjorn 1975 (unpublished data)	flies	hatchery cutthroat trout	0.4 (256)	0.8 (264)	NT	0.29	0.10	0.02
Thompson 1946 (from Wydoski 1977	flies	unknown	5.9 (51)	5.0 (60)	NT	0.42	0.03	0.02
Hunsaker et al. 1970	flies	wild cutthroat trout	4.0 (75)	3.3 (60)	NS	0.42	0.03	0.02
Dotson 1982	flies	hatchery cutthroat trout	0.0 (105)	1.0 (105)	NS	0.16	0.28	0.07
Westerman 1932 (1930 trial)	bait	rainbow trout	10.5 (200)	9.5 (200)	NT	0.37	0.06	0.02
Westerman 1932 (1932 trial)	bait	rainbow trout	7.0 (200)	3.0 (300)	NT	0.02[b]	- -	0.09

[a] NT = Not tested statistically by original author.
OTG = Original author test included other test groups, no test statistic available for barbed versus barbles only.
[b] Denotes statistical significance.

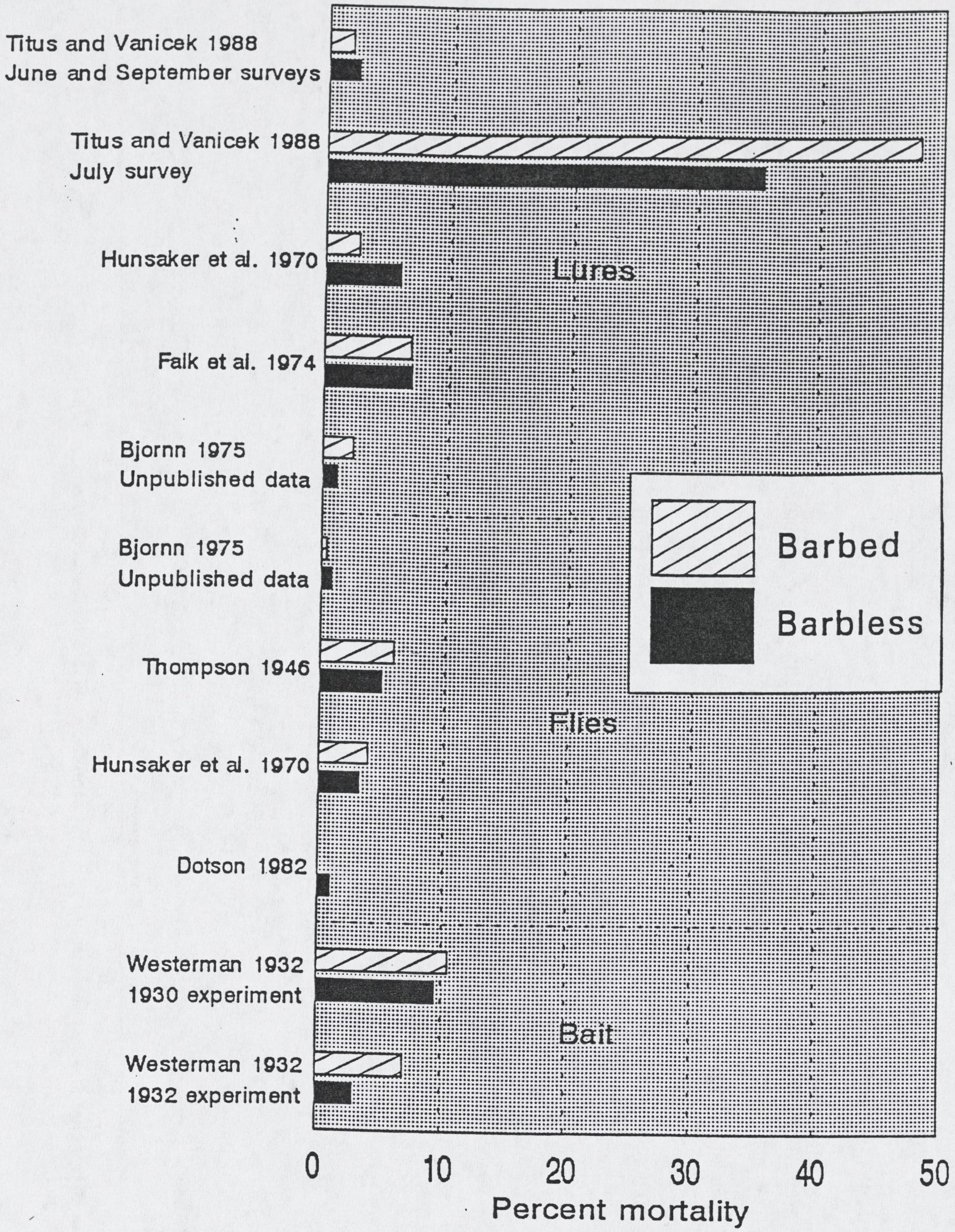

Figure 1. Summary of all past study trials directly comparing hooking mortality from catching and releasing nonanadromous trout with barbed versus barbless hooks.

was actually present. The highest observed power value was 28% (Table 3), well below the standard 80% guideline often used in the literature (Peterman 1990). We also calculated power for the chi-square tests ran in some cases by the original authors. Power of these tests was nearly identical to the ones we calculated for binomial tests.

Meta-analysis

Combination of studies among gear types using four different methods produced consistent results. Comparison of barbed and barbless hooking mortality for studies combined by gear type yielded nonsignificant P values ranging from 0.22 to 0.28 for flies and 0.37 to 0.40 for lures (Table 4). Combination of all fly and lure studies was also nonsignificant. In contrast, trout caught on barbless bait hooks experienced lower mortality rates than those caught on barbed bait hooks with meta-analysis P values ranging from 0.03 to 0.04. Weighting the studies by quality did not effect results.

Effect sizes, expressed as Pearson product-moment r's, for the various gear type combinations were low ranging from -0.001 to 0.060 (Table 5). None of these values approached the subjective 0.30 figure suggested by Cohen (1988) as evidence for a weak relationship between two variables. Thus, the use of barbed or barbless hooks appeared to play little role in determining survival of fish in the past studies. Assignment of quality ratings produced minimal change in resultant effect sizes.

Population Simulations

Based on data from past hooking mortality studies, the effect of all vulnerable trout being caught from 1 to 5 times with barbed or barbless flies or lures had little effect on simulated populations. The percent difference in numbers of catchable-sized trout available for anglers to catch in simulated populations subjected to barbless hooks versus barbed hooks was small, regardless of natural mortality or growth rates (Figure 2). Even when all fish in the populations were caught five times and natural mortality was low, the difference in population numbers was less than 3%.

The number of large-sized trout surviving in simulated populations was more sensitive to the differences in hooking mortality we assigned to the two hook types. However, the percent difference in large-sized trout was less than 5% in most instances with maximum of a 6.6% difference in the medium growth population when fish were all caught 5 times (Figure 1).

Barbless Hook Survey

Graphical summary of this survey indicates that barbless hook only restrictions are applied with some apparent regionalization (Figure 3). East coast states tended to utilize barbless hook restrictions on a minority of their special regulation waters while most midwestern states had none. Midwest states that did have them had limited numbers of special

Table 4. Comparison of p-values obtained via four meta-analysis techniques that combined past barbed versus barbless hooking mortality studies by gear type. Statistical significance denoted by *.

Gear	N	Method of Combination			
		Stouffer	Mean p	Weighted (N)	Weighted (quality)
Lures	5	0.38	0.37	0.40	[a]
Flies	4	0.28	0.25	0.22	0.24
Bait	2	0.04*	[b]	0.03*	[a]
Flies/lures	9	0.44	0.42	0.34	0.42

[a] Not tested - no difference in quality ratings within the group being tested.
[b] Test not appropriate given sample size of 2.

Table 5. Comparison of mean effect sizes (r) obtained via three meta-analysis methods that combined past barbed versus barbless hooking mortality studies by gear type.

Gear	N	Combined effect sizes: Mean r	Weighted mean r (N-3)	Weighted (quality)
Lures	5	0.015	0.008	0.015
Flies	4	-0.014	-0.023	-0.019
Bait	2	0.055	0.060	0.055
Flies/lures	9	0.002	-0.007	-0.001

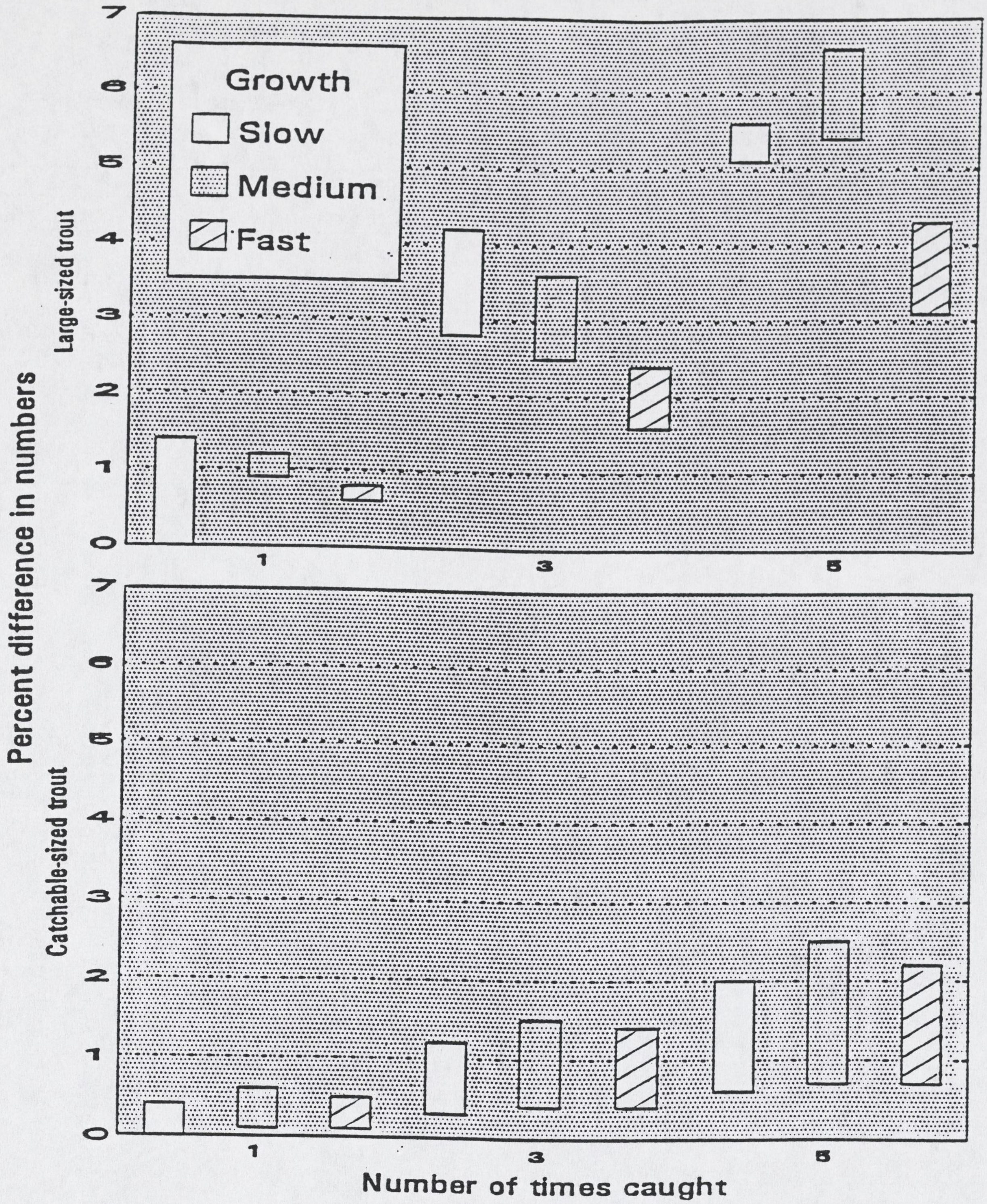

Figure 2. Percent difference in numbers of catchable-sized (> 153 mm) and large trout (> 254 or 305 mm) available to anglers in hypothetical fisheries of varying growth when all vulnerable fish in the populations are caught one, three, or five times with either barbed or barbless hooks. Bars denote range of differences under five possible natural mortality scenarios.

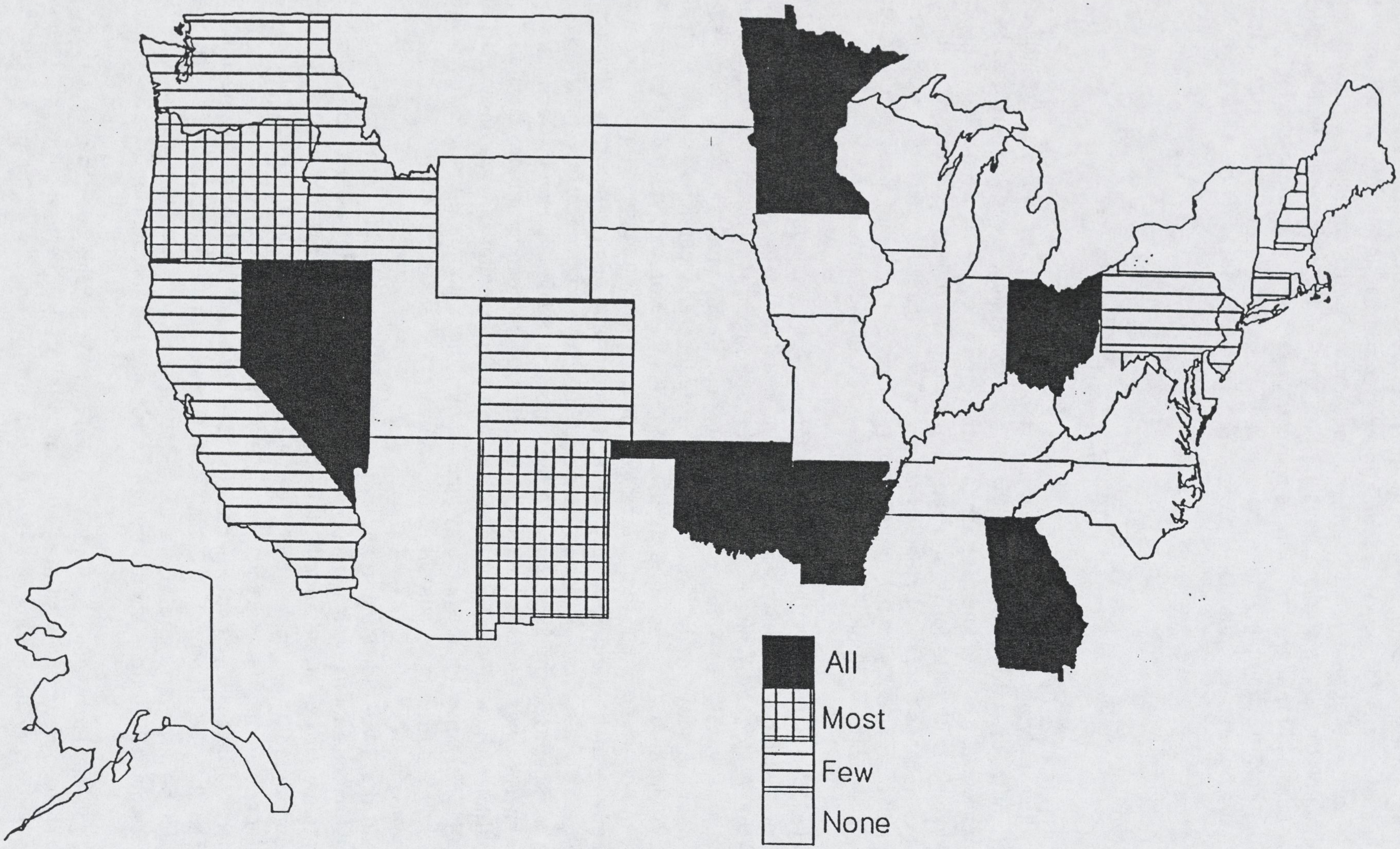

Figure 3. Prevalence of barbless hook requirements in special regulation fisheries for resident trout in U.S. streams. States missing from the map do not have resident trout stream fisheries with special regulations meeting our definition.

regulation streams in general and imposed barbless regulations in all cases. The five states of Arkansas, Georgia, Minnesota, Ohio, and Oklahoma reported a total of 18 stream segments meeting our subjective criteria for a special regulation water and barbless hooks were required in all of them. Widespread application of barbless hook requirements appear to be a western phenomenon. Although the states of Idaho, Washington, and California are identified in Figure 3 as having few barbless hook waters, a large number of stream km in these states have a barbless regulation. For example, Idaho has over 3,700 stream km of barbless hook regulations, but has an even larger number of special regulation stream km where they are not required.

DISCUSSION

Results of this study agree with the qualitative literature reviews of Wydoski (1977) and Mongillo (1984), both of whom concluded there is no biological basis to barbless hook restrictions where artificial flies and lures are concerned. In terms of individual studies, the fact that barbed hooking mortality rates for fly and lure comparisons were less than that of barbless hooks in five of nine cases (Figure 1) clearly supports this conclusion. Results of the meta-analyses, in terms of both effect size measurement and P value combination, also demonstrated no biological basis for barbless hook restrictions with artificial flies and lures.

This conclusion is in direct conflict with the meta-analytic findings of Taylor and White (1992). However, we have difficulty accepting their conclusions because of their general analytical approach. Taylor and White (1992) utilized raw hooking mortality proportions from individual studies in analyses of covariance noting that these data needed no conversion since they were already in the same metric. Rosenthal (1990) repeatedly cautions against such an approach unless a blocking design can be used, citing examples of early meta-analyses with flawed findings. Further, in a manner that seems to us like comparing apples and oranges, the authors compared mean hooking mortality rates from barbed hook studies in numerous locations to the mean rate from a limited subset of barbless trials in a few of the same locations. Since its inception a half century ago by statisticians such as Fisher, Cochran, and Snedecor, meta-analysis has typically involved a process of combining actual test statistics from individual studies (Rosenthal 1990). No such approach appears to have been used by Taylor and White (1992) either for the barbed versus barbless hook comparisons or other facets of their analyses, such as treble versus single hooks etc.

Results of the two individual trials examining barbless hooks with bait and our subsequent P value combinations both suggest possible merit for use of barbless hooks by bait anglers releasing trout. However, additional study on this topic should be done since the only two trials were conducted at the same hatchery in 1932. We did not incorporate bait results in our simulations because few special regulations permit the use of this gear type. Nonetheless, reports of bait-allowed catch-and-release fisheries are beginning to appear in the literature (Carline et al. 1990; Thurow and Schill 1994; Orciari and Leonard 1990) so additional work on the topic appears warranted. Depending on the outcome of additional experiments, effects of barbless bait restrictions should then be scrutinized at the population level.

Meta-analysis has been widely applied in medical and social fields but has received scant attention in the fishery literature prior to the Taylor and White (1992) article. It may be useful in summarizing other fishery literature where reviewers are often faced with numerous studies, often with conflicting results. The approach provides investigators with the ability to decrease the rate of Type II error and increase the power of individual studies to detect statistical differences (Rosenthal 1991; Miller and Pollock 1994).

Such a characteristic would seem appropriate for hooking mortality literature in general. In the case of the past studies we summarized, none even approached an even chance of detecting a difference in the data being analyzed, if one actually existed. Reasons for this include small sample size and small differences in mortality rates. With the exception of major gear comparisons where effect sizes are large, e.g. fly versus bait, most past hooking mortality studies probably have similar low power values. Not surprisingly, past investigators have rarely found statistically significant differences for most comparisons, such as treble versus single hooks, hook sizes, etc. (Hunsaker et al. 1970; Wydoski 1977; Dotson 1982; Titus and Vanicek 1988). Given the small differences in hooking mortality typically obtained in past individual studies, large increases in sample size above those commonly used are probably necessary to detect statistical differences, if they actually exist.

Calculation of power for meta-analyses is extremely complex and we were unable to find any guidelines in the case of combined binomial tests. However, power of meta-analyses using several of the P value combination methods we employed have been shown to be quite powerful for several other statistical tests (Becker 1985). Thus, while we have no way of approximating power for our meta-analyses, they likely reflect a big increase over past individual studies in ability to examine small mortality differences often reported between barbed and barbless hooks.

Having the power to detect a given difference is only relevant if the difference being tested statistically is meaningful at a biological level. For artificial lures and flies combined, weighted mean hooking mortality rates for the nine barbed versus barbless trials summarized in this study were quite similar at 4.54% and 4.16%, respectively. Such small differences in hooking mortality resulted in minimal differences in population exploitation rates in modeling exercises, even when fish in the simulated populations were all caught five times.

There are limitations to the simulation methods we used. Our simulations assumed hooking mortality remained constant for up to five capture events annually for each individual fish. A direct examination of multiple recapture effects on hooking mortality has yet to be done, but Schill et al. (1986) reported a hooking mortality rate per capture of less than 1% for fish recaptured an average of 9.7 times. We also restricted our analyses to five possible natural mortality scenarios that obviously do not include all possibilities. We did not consider the effects of stock-recruitment relationships which are poorly understood for stream trout populations (Rieman 1989). We also assumed recruitment was constant but do not believe this limits the utility of our conclusions. Simulations based on constant recruitment reflect the average response of a population to exploitation, in this case hooking mortality, over an extended period of time (Beamesderfer and North 1995).

Despite a summary of individual study results (Figure 1) and meta-analyses that are nonsignificant where artificial flies and lures are concerned, we conducted population simulations assuming the small observed difference in weighted mean mortality attributable to the two hook types was real. For simplicity, we considered the specialized case of a total catch-and-release fishery with no legal harvest but results would likely be similar for fisheries with size and bag limits, etc. We observed differences in simulated populations from use of the two different hook types that would be indiscernible to the angling public.

It seems probable that the small differences we observed in simulated populations may themselves be exaggerated for several reasons. First, the simulations were conducted assuming no anglers would use barbless hooks in the "barbed fishery" even though many would do so voluntarily in the real world. Thus, assuming a small advantage to use of barbless hooks, as we did in the simulations, differences at the population level would be even smaller in an actual fishery. With the exception of the unusual fishery on the Yellowstone River and an urban fishery in central Pennsylvania, individuals in few wild trout populations are probably caught an average of five times (Carline et al. 1990). Thus, the worst-case differences reported in Figure 2 do not apply to many existing fisheries. In addition, our modeling assumes all trout in past studies died of hooking mortality. Numerous authors suggest that elevated stress associated with holding pens or cages could result in inflated hooking mortality estimates (Wright 1970; Schill et al. 1986; Muoneke 1990; Taylor and White 1992). In only two studies that we are aware of where hooking mortality for wild trout has been estimated without confining fish in small test pens (Schill et al. 1986; Schill, in review), mortality rates were well below mean values from other past studies for the same gear type. If hooking mortality rates for uncaged fish released by actual anglers are lower than those we used in calculating exploitation for our simulations, then the minimal differences we report in Figure 2 for barbed and barbless fisheries are exaggerated.

Many anglers and some fishery managers may have difficulty accepting our results. In the first hooking mortality study, Westerman (1932) states that barbless hooks are "the most sportsmanlike and humane manner of taking trout, one which should have real appeal to the practical yankee as an economic proposition in abating waste". This attitude remains firmly entrenched in the minds of some fishery managers who dispute results of the past hooking studies we summarized. They argue that, from a common sense perspective, barbless hooks are easier to remove from trout and should reduce mortality. However, even if our meta-analyses are incorrect and a slightly larger difference in survival exists between the two hook types than we used in modeling exercises, population benefits of a barbless hook restriction large enough for anglers to detect would seem unlikely. This seems especially true, given that several factors described above (e.g., volunteer use of barbless hooks in barbed fisheries) probably inflated the small differences observed in our simulations when compared to a real fishery.

There seems to be a tendency for salmonid biologists, in particular, to err on the "side of the fish" when biological support for a regulation at the population level is lacking, but there are some contradictions with this management approach. First, given our simulation results and assuming a small difference between the hook types actually exists, for barbless hooks to be justifiable, a management objective for the fishery in question would have to be to save as many fish as possible from hooking mortality. Such a goal is typically not expressed in management plans. Instead, management goals are usually stated differently (e.g., maintain a diversity of opportunity, or maintain a quality or trophy trout population). The imposition of a barbless hook requirement is obviously not needed for a fishery to meet such a goal. To avoid the loss of agency credibility, unnecessary angling regulations should be avoided (Behnke 1987).

A second drawback is that the manager or agency implementing a barbless hook regulation without biological justification assumes there is no cost to the agency for enacting such regulations, but this may not be the case. Schill and Kline (in press) estimate that 75% of barbless hook violations on two Idaho waters with barbless hook requirements were made by individuals who usually comply with the regulations, but occasionally forget to flatten their barbs down. If barbless hooks do not reduce hooking mortality significantly and citations are written to largely honest anglers, the animosity generated by such enforcement may be counterproductive to fishery agencies (Schill and Kline 1995). In Idaho, 20% of all angling violations or 534 tickets and warnings were written for barbless hooks violations in 1994 (T. McArthur, Idaho Fish and Game, unpublished data). The potential to generate unnecessary hostility from anglers is real, especially if it spreads to other family members, neighbors, and friends as a result of a ticket. Social and financial costs to management agencies could become important over time.

Quantitative results of this study aside, the graphical summary of our barbless hook survey calls into question the need for barbless restrictions. Crossing boundaries from one state with barbless restrictions to one that has none, does not appear to translate into appreciable differences in fish populations. For example, driving from Idaho, where many special regulation waters include a barbless restriction, into Wyoming or Montana, where there are no barbless hook restrictions, anglers would be hard pressed to note any reduction in angling quality. In addition, the fact that an angler on a transcontinental fishing trip across America could easily experience a change in barbless hook policies 10 or more times suggests to us that barbless hook restrictions are largely a social issue.

Although existing data suggest little biological basis for use of barbless hooks, there are several additional reasons why anglers may want to use them. It is easier to remove barbless hooks from trout and angler ears, making the process less stressful on anglers in both cases and making it possible to resume fishing more quickly. This explains some angler preferences for barbless hooks. Also, some biologists and anglers believe that use of barbless hooks should be required for aesthetic reasons; the assumption being that barbed hooks produce greater injury and incidence of torn maxillaries, etc. than barbless hooks. Such an hypothesis could easily be tested but has not been to date. However, despite the presence of torn maxillaries on appreciable numbers of cutthroat trout subjected to repeated recapture, Yellowstone River angler use has continued to rise steadily and angler satisfaction with this fishery is at the highest level believed attainable in Yellowstone National Park (Varley 1984). Whether or not a relationship between elevated jaw injury and use of barbed hooks exists may be irrelevant if the angling public is satisfied with such a fishery.

We did not include a number of saltwater salmonid studies comparing barbed and barbless hooks in our analysis because of different holding procedures, duration of the observation period, as well as obvious life history and physiological differences. However, our review of that literature reveals results similar to the nonanadromous studies we summarized with small differences in mortality typically being reported between the two hook types. Again, studies suggesting slightly lower hooking losses attributable to barbless hooks have been offset by other studies with conflicting results. Thus, while we have not conducted an exhaustive review or meta-analysis of this literature, it seems reasonable to suspect that benefits of barbless hooks are minor or negligible in these instances as well.

Based on present evidence, we conclude that barbless hooks are not justified for nonanadromous salmonid fisheries from a biological basis. Managers considering or proposing new special regulations to the angling public should consider possible social costs of implementing a restriction with no demonstrable biological gains.

While eventual elimination of barbless hook requirements may be warranted, rapid removal of such restrictions could also create social and political problems for management agencies. As Jackson (1989) observed, trout anglers can become almost evangelical in their support for various trout regulations. Barbless hook restrictions are certainly perceived as crucial for the development of quality trout angling by a segment of the angling community. Such fervent support is not likely to be abruptly altered by results of a single hooking mortality study. A first step in the process of eliminating barbless hook restrictions on existing waters should begin with efforts to inform and educate the public about the lack of biological support for barbless hook restrictions based on existing information.

RECOMMENDATIONS

1. Inform anglers of the lack of biological justification for barbless hook regulations.
2. Discontinue practice of requiring barbless hooks on new special regulation waters in Idaho.
3. Consider deletion of barbless hook requirements on Idaho waters where socially feasible.

ACKNOWLEDGEMENTS

Dr. Robert Rosenthal provided invaluable assistance and advice on the meta-analysis portion of this study.

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ANNUAL PERFORMANCE REPORT

State of: Idaho

Grant No.: F-73-R-17, Fishery Research

Project No.: 4

Title: Wild Trout Regulation Studies

Subproject No.: 2. Regulation Workshop Development

Contract Period: April 1, 1994 to March 31, 1995

ABSTRACT

During the past year I developed a workshop for presentation to anglers with the goal of assisting them in understanding wild trout management. This workshop developed into three distinct segments. The first segment involved a discussion of the basic factors affecting wild trout populations including recruitment, growth, natural mortality, and angling mortality or exploitation.

Sample data from a variety of statewide waters were presented for these parameters to give anglers perspective. A second portion of the workshop included a discussion of hooking mortality based on a summary of past information. The third segment involved computer simulation of various regulation options for a local fishery that was typically the subject of some regulation controversy. The purpose of the first two segments of the workshop was to enable workshop participants to understand the meaning of the numbers used in the population simulations. The entire simulation process was displayed visually on a large screen and regulation suggestions submitted by anglers were considered in the modeling. A total of three workshops were conducted and an unedited video of the workshop was produced.

Author:

D.J. Schill
Principal Research Biologist

ANNUAL PERFORMANCE REPORT

State of: Idaho

Grant No.: F-73-R-17, Fishery Research

Project No.: 5

Title: Angler Compliance Studies

Subproject No.: 1

Contract Period: April 1, 1994 to March 31, 1995

ABSTRACT

During the past year I evaluated the quality of existing data from sources outside Idaho Fish and Game that would enable me to assess the biological significance of angler non-compliance on the St. Joe and Coeur d'Alene Rivers in northern Idaho. Project personnel recalculated estimates of angler use and harvest for both waters from data provided by University studies. The accuracy of snorkeling population estimates currently available for these waters was evaluated via field comparison to electrofishing by project personnel in conjunction with Region 1 management staff. Results suggest historical methods of snorkeling for trend counts in the St. Joe and Coeur d'Alene Rivers significantly underestimate total numbers of cutthroat trout in the stream. Cutthroat trout abundance data were kept by Region 1 staff for use in management efforts. I conclude that existing data on angler catch and estimates of cutthroat trout abundance are of insufficient quality to adequately evaluate effects of non-compliance on these fisheries. Additional data will need to be collected before poaching estimates obtained via this project in the recent past can be evaluated at the population level.

Author:

D.J. Schill
Principal Research Biologist

Submitted by:

D.J. Schill
Principal Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Steven M. Huffaker, Chief
Bureau of Fisheries

Allan R. Van Vooren
Fisheries Research Manager

[1996]

TIGHT LINES

No Barbless Bait

I am a biologist working on the recovery of the aquatic ecosystem of the upper Sacramento River in northern California following a devastating chemical spill in 1991. I recently read Dr. Patrick Trotter's River Keeper article entitled "Hooking Mortality of Trout" in your March 1995 issue. I commend your magazine for publishing such informative and educational articles.

I am writing to offer some insights, however, on the hooking-mortality figures reported in the article, which compared the use of bait with barbed versus barbless hooks. Dr. Trotter cites a 1992 scientific article by Matthew Taylor and Karl White of Utah State University in which they analyzed several past studies on hooking mortality for nonanadromous trout.

This article provides an excellent starting point for students of hooking mortality of trout, but not all of the information is applicable to all trout fisheries. For example, the authors concluded that the use of bait with barbless hooks resulted in a substantial reduction in hooking mortality (8.4 percent) when compared to the use of bait with barbed hooks (33.5 percent). This type of information could lead fishery managers and fishing organizations to advocate the use of bait with barbless hooks in catch-and-release waters, which I believe could have major negative impacts.

When I first read the Taylor and White article, I was somewhat skeptical of the 8.4 percent hooking-mortality rate for bait with barbless hooks. This figure seemed counterintuitive to all of the hooking-mortality studies I had read in the past.

I contacted Taylor to get some further clarification on the 8.4 percent mortality rate. This low hooking mortality rate for bait with barbless hooks came from a single study published during 1932 on immature brook trout (three to seven inches long).

In that same 1932 study, the author found a maximum hooking mortality rate of only 10.5 percent for the immature brook trout caught and released on bait with barbed hooks. Therefore, the differences for barbed and barbless hooks are much less dramatic when considering only the 1932 study, and these results should only be considered valid for immature brook trout.

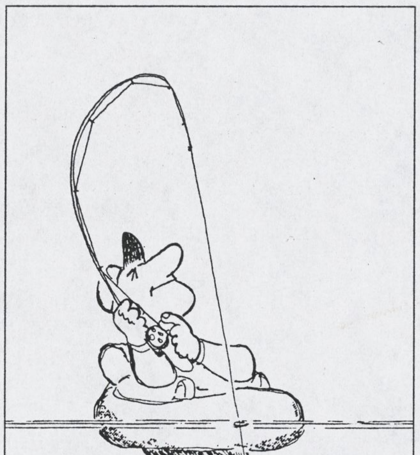
In addition, the 33.5 percent hooking mortality rate for bait with barbed hooks reported in Taylor and White is much more reliable and came from a compilation of seven studies on several species of nonanadromous trout.

I recently spoke with Dr. Trotter, and we both agree that the low 8.4 percent hooking mortality rate for bait with barbless hooks is very misleading and should not be directly compared to the 33.5 percent mortality rate for bait with barbed hooks reported in Taylor and White. *While the 8.4 percent figure might be useful for consideration in the catch-and-release of immature brook trout, it could be a major mistake to consider the use of bait with barbless hooks in nonanadromous catch-and-release fisheries for either mature trout or for other trout species.*

Immature brook trout would be expected to have a lower mortality rate no matter what type of gear is used, as pointed out by both Dr. Trotter's and Taylor and White's articles. For example, brook trout are less susceptible to hooking mortality than rainbow or cutthroat trout, and hooking mortality increases as the size of the trout increases. This is likely due to the inability of small fish to engulf a baited hook as deeply as larger mature fish.

Please get this information out to your readers. The misuse of the low hooking-mortality rates reported in Dr. Trotter's article and Taylor and White's paper for bait with barbless hooks could have far-reaching negative effects on many of the nation's catch-and-release trout fisheries if these fisheries begin to allow the use of bait.

STEVE TUREK
Redding, California



ROBERT RANDALL ILLUSTRATION

Norway's Sea-runs

As a Norwegian fly fisherman with a bit of sea trout experience under my belt, I would like to comment briefly on the "Connetquot Sea-runs" article in the December 1995 issue.

It seems the Connetquot browns are behaving exactly like their European siblings. And as the German brown trout is the exact same species as the European sea trout (*Salmo Trutta*), one would be glad to report that, for once, all is well with the world.

It is well known in Scandinavia that sea trout stay close to the coast during their stay in salt water. Experience shows that rivers with a large estuary and extended regions of surrounding brackish water produce the largest sea trout. The Morrum River in Sweden is perhaps the best example of this. In general, sea trout mostly forage in the shallows during their stay in salt water.

Therefore, the "laziness" of these fish is a simple product of their genetic make-up. It does, however, raise several interesting issues:

• The saltwater behavior of German browns opens the possibility for focused saltwater fly fishing for the species. Denmark has, for instance, an extended sea-trout saltwater fishery, and it plants large numbers of fish in small streams, expecting most of the fish to be caught by saltwater fly fishers.

• Saltwater sea-trout fishing significantly extends both the season and the capacity of the fishery—not to mention that mixing it up with a four-pound brown in winter and early spring is a nice break from the tying vise. Any flies that imitate local baitfish tend to do the job. Twilight and evening are key periods.

• Protection of estuary and near-coastal habitat is extremely important for the health of both the saltwater and the freshwater fishery. To my knowledge, the problems with recreational netting that exist in Scandinavia are not present in the U.S., so sound management is probably less of a challenge here.

As for fishing techniques for sea-run browns in the river, the following holds in Scandinavia:

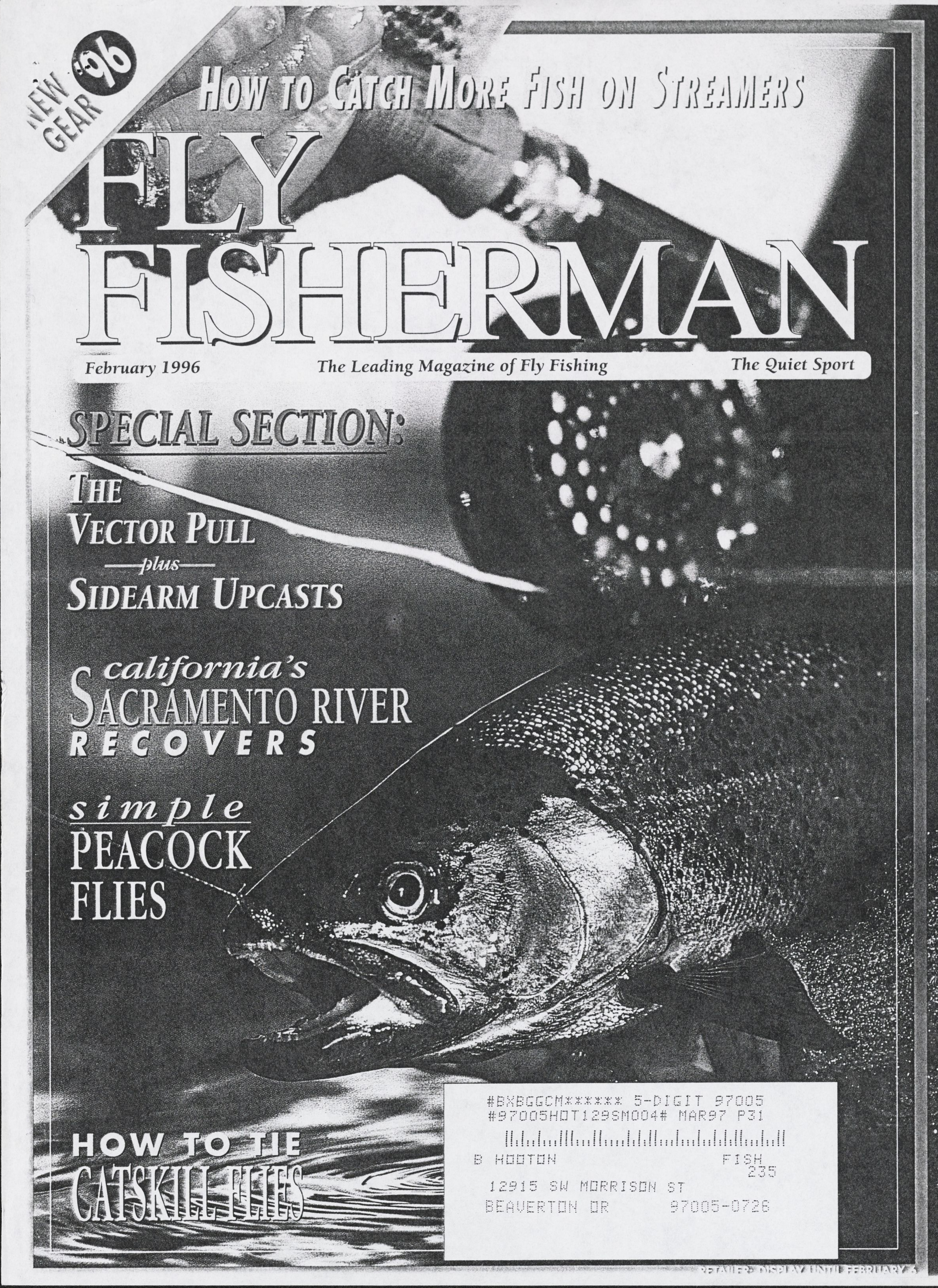
• Sea trout tend to congregate at the neck of pools during twilight and darkness.

• Until it is completely dark, floating lines and smaller flies (#6-#10) are used.

• At night larger streamers (#2-#6, often tandem flies) on fast sinking lines are fished close to the bottom.

Finally, one question: Your photographs only showed browns in the typical greenish-brown coloration. Are

Continued on page 8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DEPARTMENT OF FISH AND WILDLIFE

FISH DIVISION

January 7, 1997

Dr. Bob Behnke
Colorado State University
Dept. Fish & Wildlife Biology
Ft. Collins, CO 80523

Dear Dr Behnke:

Good to see you over the holidays, I always enjoy our visits.

Enclosed are two articles on the Miramichi, both from *Wild Steelhead and Atlantic Salmon*. Hope they help.

Also enclosed a copy of our new fishing regs. Note that we dropped all barbless hook requirements (see page 5). Our fan mail to date is from anglers (mostly fly anglers) that are shocked and amazed that we have betrayed the civilized world by allowing anglers to make their own choice. Next thing you know we will require all first born sons to fish with worms!!

Take care and let me know if you plan on visiting the area again soon.

Cheers!!

Charlie

John A. Kitzhaber
Governor

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Handle  With Care

Catch And Release Is Catching On

When you catch and release fish, you are preserving a valuable resource for other anglers to enjoy in the future. But if you aren't careful, the fish you release may simply die. If you keep fishing, you could kill more fish than a person who catches his or her limit and goes home. Here are some tips to help your released fish survive.

OREGON Fish & Wildlife

Suggested Tackle

- **Barbless hooks strongly advised!** Use pliers to pinch barbs down.
- Use strong line to bring your catch in gently but quickly.
- Fish caught with flies or lures survive more often than fish caught with bait.
- Overly large hooks can damage mouth parts and eyes.
- Small hooks may be taken deeply by fish.

Landing Your Catch

- Land your fish as carefully and quickly as possible.
- Avoid removing the fish from the water. If your "trophy" is a photo, have the camera ready and gently cradle the fish at water level while someone else snaps the picture.
- Avoid using a net which can damage the fish's skin. If you must, use a soft cotton net, not nylon.
- Don't touch the eyes or gills and don't squeeze the fish.

Removing Your Hook

- Remove the hook quickly and gently, keeping the fish under water.
- Use long-nosed pliers or a hemostat to back the hook out.
- When fish is hooked deeply, cut the line near the hook (hook will dissolve).
- Use steel hooks that will quickly rust out. Avoid using stainless steel hooks.
- Cut your line rather than injure an active fish.

Reviving Your Catch

- Point your fish into a slow current or gently move it back and forth until its gills are working and it maintains its balance.
- When the fish recovers and attempts to swim out of your hands, let it go.
- Large fish may take some time to revive.

Keeping your catch? Here are a few tips

If you choose to keep your fish, follow these suggestions:

- For salmon, steelhead, sturgeon or halibut, record the correct information on your tag immediately
- Fish flesh deteriorates rapidly if not properly handled. Do not keep the fish on a stringer in the water - if alive, the stressed fish will produce chemicals altering the meat's flavor.
- A sharp blow to the head will kill the fish quickly. Break or cut through the gills allowing the blood to be pumped from the body.
- Clean and ice your fish in the field, removing kidneys and blood from the backbone and rib cage.
- Store fish on ice, preferably so they are not touching each other or resting in water, which may flavor the meat.
- Don't store fish in a plastic bag - the slime produced can ruin your catch.

Statewide Regulations

Description:

Statewide Regulations generally apply to all fishing zones and, combined with the regulations listed under each zone, comprise the regulations an angler must follow when sport fishing in Oregon. Statewide Regulations have the following categories:

I. Licenses, Tags and Permits
II. Catch and Possession Limits
III. Definitions
IV. Gear, Bait and General Restrictions
V. Harvest Methods, Hours and Restrictions

Instructions:

1. Read the ***Statewide Regulations,*** which apply to all zones. Then;
2. Read the ***General Regulations*** for the zone in which you will be fishing. Then;
3. Read the ***Special Regulations*** for the lake or stream (alphabetically listed) that you intend to fish. If the water is not listed, the ***General Regulations*** for that zone apply.

I. Licenses, Tags and Permits:

All persons 14 years or older must have an Oregon angling license to take any fish for personal use, **except:**

- No license is required when taking *smelt* or *shellfish*;
- Oregon resident landowners and members of their immediate family, may angle on land they own and reside upon without angling licenses;
- When angling in the Pacific Ocean within 3 miles of shore between Cape Falcon, Oregon and Leadbetter Point, Washington either a Washington (for Washington residents only) or an Oregon license is valid. Persons other than Washington residents must have a valid Oregon license to land fish in Oregon which were caught in the ocean.

Licenses, Permits and Tags	Fee	Qualifications
Resident Annual Licenses:		
Angling License	$17.50	• Must have resided in Oregon for at least 6 consecutive months immediately before applying for a license. • Must have an Oregon driver's license or State Non-driver's ID card, ***OR*** • Three of the following (one must show name and current address): utility/rent receipt, passport, birth certificate, social security card, voter registration card, military ID card, or marriage certificate.
Combination Angling and Hunting License	$29.50	
Juvenile Angling License (14 through 17 years of age)	$ 6.25	
Duplicate License	$ 6.00	
Non-Resident Annual License:		
Angling License	$40.50	• No residency requirements.
Daily Licenses:		
1-Day Angling License	$ 6.75	• **Salmon-Steelhead, Sturgeon and Halibut Tags** are included with daily licenses, and fish must be recorded.
7-Day Angling License	$30.50	• The same fees apply to both residents and non-residents and there are no residency requirements.
Annual Salmon-Steelhead, Sturgeon, or Halibut Tags:		• The same tag fees apply to both residents and non-residents, and there are no residency requirements. • Anglers may purchase only one of each fishing tag per year. • It is ***unlawful*** to alter entries on tags or licenses and to possess an altered tag or license. • Adult *salmon* or *steelhead*, legal size *sturgeon* and *Pacific halibut* must be recorded on the appropriate tags immediately upon removal from the water and fish must be recorded in the order caught. The information to be recorded is: code of species caught; code for the stream, lake or ocean port; the month and day fish are caught; *sturgeon* length in inches.
Salmon-Steelhead Tag	$10.50	• Required in addition to a fishing license (except daily licenses) when angling for *salmon* and/or *steelhead*.

1997

Oregon Sport Fishing Regulations

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Southwest -	4192 N Umpqua Hwy. Roseburg, OR 97470	(541) 440-3353
Central/ - Southeast	61374 Parrell Road Bend, OR 97702	(541) 388-6363
Northeast -	107 20th Street LaGrande, OR 97850	(541) 963-2138
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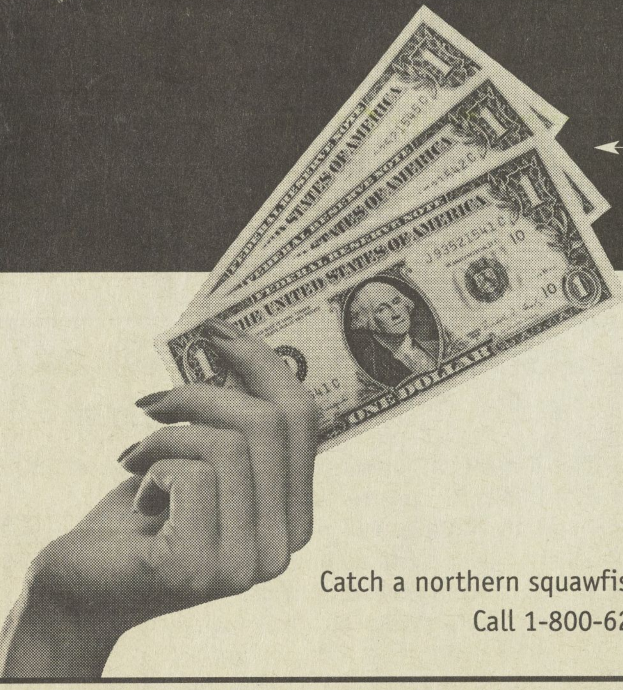

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Barbed Hook Restrictions in Catch-and-Release Trout Fisheries: a Social Issue

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Abstract.-We summarized results of past studies that directly compared hooking mortality of resident trout caught and released with barbed or barbless hooks. Barbed hook use resulted in lower estimates of hooking mortality in two of four fly comparisons and in three of five lure comparisons. Only one of 11 comparisons resulted in statistically significant differences in hooking mortality. In this instance, use of barbless bait hooks caused significantly less mortality but design concerns limit the utility of this finding. Mean hooking mortality rates from past lure studies were slightly higher for barbed hooks than barbless ones, but the opposite was true for flies. For flies and lures combined, mean hooking mortality was 4.5% for barbed hooks and 4.2% for barbless hooks. Combination of test statistics from individual studies by gear type via meta-analysis yielded nonsignificant results for barbed versus barbless flies, lures, or flies and lures combined. We conclude the use of barbed or barbless flies or lures plays virtually no role in subsequent mortality of trout caught and released by anglers. Because natural mortality rates for wild trout in streams commonly range from 30-65% annually, a 0.3% mean difference in hooking mortality for the two hook types is irrelevant at the population level, even when fish are subjected to repeated capture. Based on existing mortality studies, there is no biological basis for barbed hook restrictions in artificial flies and lure fisheries for resident trout. Restricting barbed hooks appears to be a social issue. Managers proposing new special regulations to the

angling public should consider the social costs of implementing barbed hook restrictions that produce no demonstrable biological gain (end of abstract).

Numerous investigators have questioned whether or not use of barbless hooks results in fewer post-release mortalities than barbed ones. In his pioneering study of hooking mortality, Westerman (1932) did not use statistical tests, but concluded that barbless hooks were superior to barbed hooks in reducing hooking losses for brook trout *Salvelinus fontinalis* caught with worms. However, authors of all subsequent field studies on resident (nonanadromous) trout, have found no significant differences in hooking mortality between barbed and barbless hooks (e.g. Hunsaker et al. 1970; Falk et al. 1974; Titus and Vanicek 1988).

Four past reviews of hooking mortality literature have addressed the barbed versus barbless question producing conflicting conclusions. In two separate qualitative reviews using results from the above studies and additional unpublished data sets, Wydoski (1977) and Mongillo (1984) concluded that use of barbless hooks does not reduce hooking mortality and that restrictions prohibiting barbed hooks cannot be justified biologically.

More recently however, Taylor and White (1992) evaluated most of the same data sets using a quantitative review technique known as meta-analysis. In meta-analysis, test statistics (e.g. *t* values) from multiple studies, often with conflicting results, can be combined mathematically in a quantitative review (Jarvinen 1991; VanderWerf 1992). This review approach decreases the rate of type II error and increases the power to detect statistical differences (Rosenthal 1991; Miller and Pollock 1994). Taylor and White (1992) concluded that a statistically significant difference in hooking mortality occurs when using the two hook types to catch resident trout. A more recent qualitative review (Muoneke and Childress 1994) also concluded that use of barbless hooks reduces hooking mortality but much of their discussion focused on adult anadromous salmonids in ocean troll fisheries.

There appears to be renewed interest in regulations prohibiting use of barbed hooks. In Oregon, a proposal to require barbless hooks for all stream fishing, regardless of species sought, was recently considered but subsequently abandoned (R. Temple, Oregon Department of Fish and Wildlife, personal communication). In Idaho, over 700 km of barbed hook restrictions were recently adopted for new catch-and-release fisheries in 1996. Based primarily on Taylor and White (1992), five Arkansas waters with new regulations enacted in 1994 include a barbed hook restriction (J. Stark, Arkansas Game and Fish Commission, personal communication).

Increasing use of this management restriction at such a widespread level warrants close scrutiny, especially given the differences in conclusions of past reviews. While reading Taylor and White (1992), we realized that several past studies comparing barbed and barbless hooks were not included in their analyses. In addition, our review of their methods generated questions about their general approach to meta-analysis. As a result, we questioned whether or not the significant difference reported between the two hook types by Taylor and White (1992) was supported by the data.

Regardless of the validity of the Taylor and White (1992) findings, statistically significant results do not necessarily imply real-world significance (Gold 1969). An assessment of the magnitude of association among variables, and hence, it's true importance, must still be made in some term other than a statistical test (Cohen 1965). Taylor and White (1992) note that despite their statistically significant results, differences between average barbed and barbless mortality rates in past studies were small and must be put in biological context by fishery managers. Schill (1996) discusses the need to convert mortality rates from typical hooking studies into population exploitation rates, and to subsequently consider natural mortality rates when developing restrictions for special regulation waters. We are aware of no such study that discusses the merits of barbed hook restrictions at the population level.

This study summarizes results of all past efforts where hooking mortality rates of resident trout caught on barbed and barbless hooks were compared in side-by-side trials. We then combine test statistics of these studies using meta-analysis in a quantitative review. The strength of the relation between barbed versus barbless hook use and hooking mortality is subsequently examined by calculating effect sizes (Cohen 1988; Rosenthal 1991). Last, we consider the biological significance of barbed hook restrictions at the population level.

Methods

Individual Study Summary

References cited in past hooking study reviews (Wydoski 1977; Mongillo 1984; Taylor and White 1992; Muoneke and Childress 1994) were used as initial reference sources. We reviewed references in all relevant papers, and conducted computerized literature searches to identify newer material. Our intent was to locate all prior studies of resident trout where barbed and barbless hooking mortality rates, for a given gear type (e.g., flies), were estimated in the same study.

Seven applicable studies were located (Westerman 1932; Thompson 1946; Hunsaker et al. 1970; Falk et al. 1974; Bjornn, unpublished data; Dotson 1982; Titus and Vanicek 1988). The Titus and Vanicek (1988) experiments consisted of three separate trials (June, July and September) where the two hook types were compared. Hooking mortality in the July trial was thought by the authors to be strongly influenced by elevated water temperatures and these fish experienced a five-fold increase in mortality above those in both June and September trials. Therefore the July trial was evaluated separately. Thus two comparisons of hook types were made from the single Titus and Vanicek (1988) study. In addition, several of the above studies included barbed/barbless comparisons for both flies and lures increasing the total number of direct hook comparisons available to eleven.

Meta-analysis combines test statistics from previous studies, but statistical tests were not conducted in all 11 past hook comparisons. In addition, the low mortality associated with both hook types in most past studies and resultant cell frequencies were often too small to meet assumptions of chi-square analysis (Zar 1974). We developed raw data bases for each individual comparison and analyzed the data in SYSTAT (Wilkinson 1990) using binomial tests (Zar 1974). Results were considered significant at $P < 0.05$. For those trials where a significant difference between the hook types was not detected, statistical power of individual studies to detect a difference given the sample sizes and observed data was estimated using the methods and tables of Cohen (1988).

Meta-analysis

Test Statistic Combinations

The test statistics (Z-scores) obtained from binomial tests of the 11 direct comparisons were combined using meta-analysis. Several meta-analysis techniques were compared to examine the consistency of results (R. Rosenthal, Harvard University, personal communication). First, the Stouffer method of adding Z scores was used (Kirby 1993):

$$Z_M = \frac{\sum_{i=1}^{k} Z_i}{\sqrt{k}}$$

where:

Z_M = overall Z score of the meta-analysis

Z_i = Z score of binomial test for study I

k = number of studies

In this method, Z_i is assigned a positive or negative direction based on the hypothesized outcome of the comparison (Rosenthal 1991). In our analyses, Z scores from studies where barbless hooks resulted in lower hooking mortality were assigned positive values.

The second approach used to combine the studies was the Edgington (1972) method of testing mean P. We used the equivalent but simpler formula of Rosenthal (1991):

$$Z_M = (.50-\overline{p})(\sqrt{12k})$$

where:

P = average one-tailed probability value of all individual binomial tests, taking note of which tail the outcome P-value falls in,

and Z_M and k are as defined above.

Rosenthal (1991) and Glass (1976) cautioned against excluding lower quality studies from meta-analyses because of potential investigator bias in excluding studies that conflict with their expectations. Thus, the data of Thompson (1946) were included although the trout species was not identified. In addition, one of the comparisons by Westerman (1932) involved two slightly different hook sizes (number 5 barbed and number 6 barbless)and hook sizes were not provided for the other trial. All three of these comparisons were included in the analyses despite some concern about their design.

Possible effects of these design concerns on findings was evaluated in a third meta-analytic approach using the weighted-Z method. We assigned half as much weight to the Westerman (1932) and Thompson (1946) studies and compared meta-analysis results to those where all studies were assigned equal weight (Rosenthal 1991). This method was also used to examine the influence of sample size on meta-analysis results. The formula of Mosteller and Bush (1954) was used to add weighted Z's, considering total study sample sizes and a subjective quality rating independently as weighting variables. Thus separate test statistics were calculated for the two weighting approaches using:

$$Z_M = \frac{\sum_{i=1}^{k} w_i Z_i}{\sqrt{\sum_{i=1}^{k} w_i^2}}$$

where:

$\underline{W}_i$ = either total sample size or subjective quality rating (2 for high quality or 1 for low quality) as the weight for study $\underline{I}$,

and $\underline{Z}_M$, $\underline{Z}_i$, and $\underline{k}$ were as defined above.

Using the above formulae, test statistics were combined for all past studies evaluating bait-, fly-, and lure-caught fish, separately. Because most special regulation waters typically restrict bait and permit the use of both flies and lures, results of all studies using either of the latter two gear types were also combined. Resultant $\underline{Z}_M$ scores for these combinations were evaluated for significance using one-tailed $\underline{P}$ values (Rosenthal 1991). Meta-analysis results were considered significant at $\underline{P} < 0.05$.

Effect Size Calculations

To estimate the actual magnitude or strength of the relation between hook type and hooking mortality found in past studies, effect sizes for individual studies were calculated using the formula of Rosenthal (1991):

$$r_i = \frac{Z_i}{\sqrt{N_i}}$$

where:

$\underline{r}_i$ = standard Pearson product-moment correlation coefficient for study $\underline{I}$,

$\underline{N}_i$ = number of fish in study $\underline{I}$,

and $\underline{Z}_i$ as previously defined.

SYSTAT was used to transform signed $\underline{r}$'s from individual studies into normalized Fisher's $\underline{Z}_r$'s (Kirby 1993). We calculated mean $\underline{Z}_r$'s for the same gear types described above for the test statistic combinations (bait, lure, fly, fly and lure) and subsequently calculated weighted mean $\underline{Z}_r$'s, based on sample sizes of individual studies (Rosenthal 1991):

$$\overline{Z}_r = \frac{\sum_{i=1}^{k} (N_i - 3) Z_{ri}}{\sum_{i=1}^{k} N_i - 3}$$

where:

$\underline{Z}_r$ = weighted mean Z_r

$\underline{Z}_{ri}$ = Fisher's Z_r for study I,

and N_i as previously defined.

A weighted evaluation of study quality on effect size was also obtained by substituting either a 2 or a 1 as a weighting variable instead of $\underline{N}_i$-3. Unweighted and weighted mean $\underline{Z}_r$'s were transformed back to mean Pearson product-moment $\underline{r}$'s using the following formula (Kirby 1993):

Calculated effect sizes, expressed as standard Pearson product-moment correlation coefficients (r), were low (Table 1). Only one of these values slightly exceeded 0.10, a lower guideline bound suggested by Cohen (1988) as evidence for a small association among variables.

The graphical summary of past studies comparing barbed to barbless hooking mortality revealed equivocal results (Figure 1). In six comparisons, use of barbed hooks resulted in greater mortality, while barbless hooks resulted higher mortality in the remaining five. Barbed hook use resulted in lower estimates of hooking mortality in two of four fly comparisons and in three of five lure comparisons. Use of barbed hooks resulted in higher mortality in both cases where bait was used.

Calculation of weighted mean mortality rates obtained from past studies directly comparing the two hook types also reveals equivocal results. Mean hooking mortality rates for lure studies were slightly higher for barbed hooks; the opposite was true of flies (Table 2). For flies and lures combined, mean hooking mortality was 4.5 % for barbed hooks and 4.2% for barbless hooks.

Meta-analysis

Combination of individual study data via four meta-analysis approaches did not change the above results. Comparison of barbed and barbless hooking mortality for studies combined by gear type yielded nonsignificant Z-scores with P-values ranging from 0.22- 0.28 for flies and 0.37-0.40 for lures (Table 3).

Differences due to hook type in fly and lure studies combined were also nonsignificant (P = 0.34-0.44). Trout caught on barbless bait hooks experienced statistically lower mortality rates than those caught on barbed bait hooks (P = 0.03-0.04) but discrepancy in size of barbed and barbless hooks compared limits the utility of this finding. Weighting the studies by quality or sample size did not affect calculated P-values appreciably (Table 3), further strengthening meta-analytic conclusions.

Based on correlation coefficients, the use of barbed or barbless hooks appeared to play virtually no role in determining mortality of fish in the past studies. Effect sizes (correlation coefficients) for the various gear type meta-analyses were quite low; always less than 0.03 for fly and lure combinations (Table 4). None of these values approached the 0.10 guideline value of Cohen (1988) as evidence for a small relationship. Weighting by study quality or sample size produced minimal change in resultant effect size estimates, again strengthening this conclusion.

Discussion

Our results agree with the qualitative literature reviews of Wydoski (1977) and Mongillo (1984), both of whom concluded that there is no biological basis for barbed hook restrictions on artificial flies and lures. In five out of nine individual trials, hooking mortality rates for barbed flies or lures were less than rates for barbless hooks, clearly supporting this conclusion. This finding conflicts with the conclusions of

Taylor and White (1992) but we have difficulty accepting their conclusions for several reasons. Taylor and White (1992) utilized raw data (proportions) from individual studies in their analysis. Rosenthal (1991) repeatedly cautions against this approach, citing past examples of flawed studies with paradoxical findings. Meta-analysis normally involves a process of combining summary test statistics from individual studies (e.g. Jarvinen 1991). Taylor and White (1992) did not use this approach, either for the barbed versus barbless hook comparisons or other facets of their analyses, e.g. treble versus single hooks.

More importantly, we are concerned that Taylor and White (1992) compared results from the various trials inappropriately in a biological sense. For example, in their bait analyses they summarized data from 23 baited hook trials nationwide and compared those data to results from 2 trials in a single Michigan hatchery (Westerman 1932). They report a wide disparity in mean hooking mortality from barbed (34%) vs barbless bait hooks (8.4%). However, the authors do not report that the Westerman (1932) trials compared barbed to barbless hooks for the same species directly at the same site and found much smaller differences in mortality (Table 1). Barbless hooks were not investigated in any of the remaining 21 barbed trials at other locations nationwide. The same approach was used in their other barbed versus barbless gear comparisons. Sixty-nine estimates of barbed hooking mortality for artificials were compared to estimates for only 8 barbless trials in a few of the same locations. Meta-analysis is not intended to overcome such spatial and temporal differences. In our study we only summarized past studies where both hook types were compared directly in trials at the same location.

Results from the two individual trials examining barbless hooks with bait and the subsequent test statistic combination via meta-analysis both suggest possible merit to use of barbless hooks by bait anglers releasing trout. However, the use of different sized barbed and barbless hooks in that work is problematic, as well as the fact that the only two trials were conducted at the same hatchery over 60 years ago. In addition, test fish were small and hooks used in this study large relative to most hooking studies, perhaps explaining the unusually low mortality rate observed in the two trials, regardless of hook type. Additional studies with baited hooks should be conducted; existing data are insufficient for any firm recommendations regarding barbless hooks and bait.

All of the past individual studies we summarized exhibited poor statistical power. None approached a 50% chance of detecting a significant difference in the data being analyzed if one actually existed. Small sample sizes and small differences in mortality rates in individual studies contributed to the lack of power. With the exception of major gear comparisons where effect sizes are large, (e.g. fly versus bait), most past hooking mortality studies probably have similar low power values.

Calculation of power for meta-analysis is extremely complex and we could not find any formulae in the case of combined binomial tests. However, power of meta-analyses using several of the combination methods we employed has been shown to be quite adequate for several other statistical tests (Becker 1985). Thus, although we could not approximate power for the meta-analyses in this study, we believe the approach increased the probability of detecting potential mortality differences between barbed and barbless hooks relative to past studies.

Having sufficient power to detect a statistical difference is only relevant if a difference is large enough to be meaningful at a practical level (Gold 1969; Cohen 1965). Weighted mean hooking mortality rates for the nine barbed versus barbless trials involving artificial flies or lures were quite similar at 4.5% and 4.2%, respectively. We questioned whether reducing hooking mortality by this amount (0.3%) could possibly be important in wild trout populations given that annual natural mortality rates in trout streams typically range from 30 to 65% (Schill 1991; Schill 1996).

To address this question Schill and Scarpella (1995) used the MOCPOP population simulation program (Beamesderfer 1991; Beamesderfer and North 1995) to examine differences in a variety of hypothetical salmonid populations in which all trout large enough to be captured by anglers are caught one, three, and five times annually using either of the two hook types. The modeling approach considered a wide range of growth rates and natural mortality scenarios typical for wild trout stocks in streams, along with the mean hooking mortality rates for barbed and barbless artificials reported above. Even when all individual fish were caught 5 times annually, a barbed hook restriction had little effect on populations. Numbers of trout in the simulated populations fished with barbless hooks exclusively, averaged only about 1.5% higher for catchable-sized trout (>154mm) and 5 % for quality-sized trout (>305mm) than when all trout were caught with barbed hooks.

There is some potential for misinterpreting these simulation results. Our meta-analytic findings indicate the 0.3% difference in barbed versus barbless artificials is not statistically significant, i.e. they are not "real", or in any event, not large enough to be detectable. The completion of subsequent studies could easily result in a combined fly and lure average where barbless hooks produce slightly greater average mortality. This is currently the case in past fly-only comparisons where mean barbless hook mortality is greater than that for barbed (Table 2). Readers are reminded that the simulation results reported above are only an exercise assuming a statistical difference actually exists where one presently does not. In this hypothetical exercise, results indicate that the benefits from barbed hook restrictions would be so small as to clearly be undetectable by the angling public, even in the most heavily-fished scenarios. Given these modeling observations and results of the meta-analysis and individual studies summarized above, we view barbed hook restrictions as a social issue.

Many anglers and some fishery managers may have difficulty accepting this perspective. In the first hooking mortality study, Westerman (1932) states that barbless hooks are "the most sportsmanlike and humane manner of taking trout, one which should have real appeal to the practical Yankee as an economic proposition in abating waste." This attitude remains firmly entrenched in the minds of some fishery managers who dispute results of the past hooking studies. They believe that, from a common sense perspective, barbless hooks are easier to remove from trout and therefore should reduce mortality.

However, implementing a barbed hook restriction without biological justification assumes there is no cost to the agency for enacting such regulations. This may not be the case. Schill and Kline (1995) estimate that 75% of barbed hook violations on two Idaho waters with such restrictions were made by individuals who usually comply with the regulations, but occasionally forget to flatten their barbs down. If barbless hooks do not reduce hooking mortality significantly and citations are written to largely honest anglers, the animosity generated by such enforcement may be counterproductive to fishery agencies (Schill and Kline 1995). In Idaho, 20% of all angling violations (534 citations and warnings) were written for barbed hook violations in 1994 (T. McArthur, Idaho Department of Fish and Game, unpublished data). The potential to generate unnecessary hostility from a sizeable group of anglers is real, especially if it spreads to other family members, neighbors, and friends as a result of a citation. Social and financial costs to management agencies could become important over time.

A geographical inventory of special regulations also calls into question the biological necessity for barbed hook restrictions. Schill and Scarpella (1995) conducted a nationwide telephone survey of state agencies managing trout populations to determine the consistency of barbed hook restrictions. Results indicated that these restrictions were applied with some apparent regionalization but inconsistencies were common. For example, the heavily-fished Yellowstone National Park and western Montana fisheries, where barbed hooks are permitted, are widely regarded by many anglers as the finest trout fishing in the world. Clearly, barbed hook restrictions are not needed for high quality trout angling.

Conclusions

We conclude that barbed hook restrictions are not justified for resident salmonid fisheries based on existing biological data. Managers considering or proposing new special regulations to the angling public should consider possible social costs of implementing a restriction with no demonstrable biological gains. Further, we suggest existing barbed hook restrictions be considered for deletion on waters where socially feasible. As Behnke (1987) suggests, unnecessary angling regulations should be eliminated to avoid the loss of agency credibility. Anglers who fervently support the use of barbless hooks should be encouraged to do so voluntarily.

Whereas elimination of barbed hook restrictions may be warranted, rapid removal of them could create social and political problems for agencies in some situations. Many trout anglers are almost evangelistic in their support for various regulations (Jackson 1989) and barbed hook restrictions are certainly perceived as crucial for quality trout angling by a segment of the angling community. Such fervent support is not likely to be abruptly altered by results of this study. It often takes 20 years for new research results to be filtered through fishery managers and become common sense to anglers (Loftus 1987). Those anglers who currently view barbed hook restrictions as a requirement for good fishing will require time and perhaps additional studies to change their perception. The first step in the process of eliminating unnecessary barbed hook restrictions on existing waters should begin with efforts to inform and educate the public (including proponents and detractors of barbless hooks) about the lack of biological support for them based on existing information.

Acknowledgments

R. Rosenthal provided invaluable advice on the meta-analysis portion of this study. T. Bjornn provided unpublished data for analysis and T. Schill assisted with database construction. B. Hunt, R. Gresswell, A. VanVooren, M. Mitro, A. Nuhfrer and two anonymous reviewers provided constructive comments on the manuscript. This project was fully supported financially by the Sport Fish Restoration Act, Project F-73-R-17.

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Table 1. Summary of past hooking mortality studies directly comparing barbed versus barbless hooks. Sample sizes are in parentheses, statistical significance ($P < 0.05$) denoted by an asterisk.

Study	Gear type	Species	Hooking mortality		Original significance test (χ^2 2-tailed)[a]	Binomial test P (one-tailed)	Power of binomial test	Effect size[b] (r)
			Barbed	Barbless				
Titus and Vanicek 1988 (July)	treble-hook lures	wild cutthroat trout	48.1 (52)	35.3 (51)	OTG	0.09	0.27	0.13
Titus and Vanicek 1988 (June/Sept)	treble-hook lures	wild cutthroat trout	1.9 (104)	2.4 (124)	OTG	0.40	0.04	0.02
Hunsaker et al.	treble-hook lures	wild cutthoat trout	2.7 (113)	6.0 (100)	NS	0.11	0.24	0.08
Falk et al. 1974	treble-hook lures	wild lake trout	6.9 (72)	7.0 (57)	NS	0.49	<0.01	<0.01
Bjornn 1975 (unpublished data)	treble-hook lures	hatchery cutthroat trout	2.4 (209)	1.2 (166)	NT	0.20	0.15	0.04

Bjorn 1975 (unpublished data)	flies	hatchery cutthroat trout	0.4 (256)	0.8 (264)	NT	0.29	0.10	0.02
Thompson 1946 (from Wydoski 1977)	flies	unknown	5.9 (51)	5.0 (60)	NT	0.42	0.03	0.02
Hunsaker et al. 1970	flies	wild cutthroat trout	4.0 (75)	3.3 (60)	NS	0.42	0.03	0.02
Dotson 1982	flies	hatchery cutthroat trout	0.0 (105)	1.0 (105)	NS	0.16	0.28	0.07
Westerman 1932 (1930 trial)	bait	hatchery brook trout	10.5 (200)	9.5 (200)	NT	0.37	0.06	0.02
Westerman 1932 (1932 trial)	bait	hatchery brook trout	7.0 (200)	3.0 (300)	NT	0.02		0.09

[a] OTG = Original author test included other test groups, no test statistic available for barbed versus barbles only.

NS = Not significant.

NT = Not tested statistically by original author.

[b] Standard Pearson product-moment correlation.

Table 2. Weighted mean rates of hooking mortaily for barbed versus barbless hooks based on past studies, number of studies in parentheses.

	Mortality (%)	
Gear	Barbed	Barbless
Lures (5)	7.3	6.6
Flies (4)	1.4	1.7
Flies or Lures (9)	4.5	4.2
Barb (2)	8.8	5.6

Table 3. Comparison of p-values obtained via four meta-analysis techniques that combined past barbed versus barbless hooking mortality studies by gear type. Statistical significance ($\underline{P}<0.05$) denoted by an asterisk.

		Method of Combination			
Gear	N	Stouffer	Mean P	Weighted (N)	Weighted (quality)
Lures	5	0.38	0.37	0.40	[a]
Flies	4	0.28	0.25	0.22	0.24
Bait	2	0.04*	[b]	0.03*	[a]
Flies or lures	9	0.44	0.42	0.34	0.42

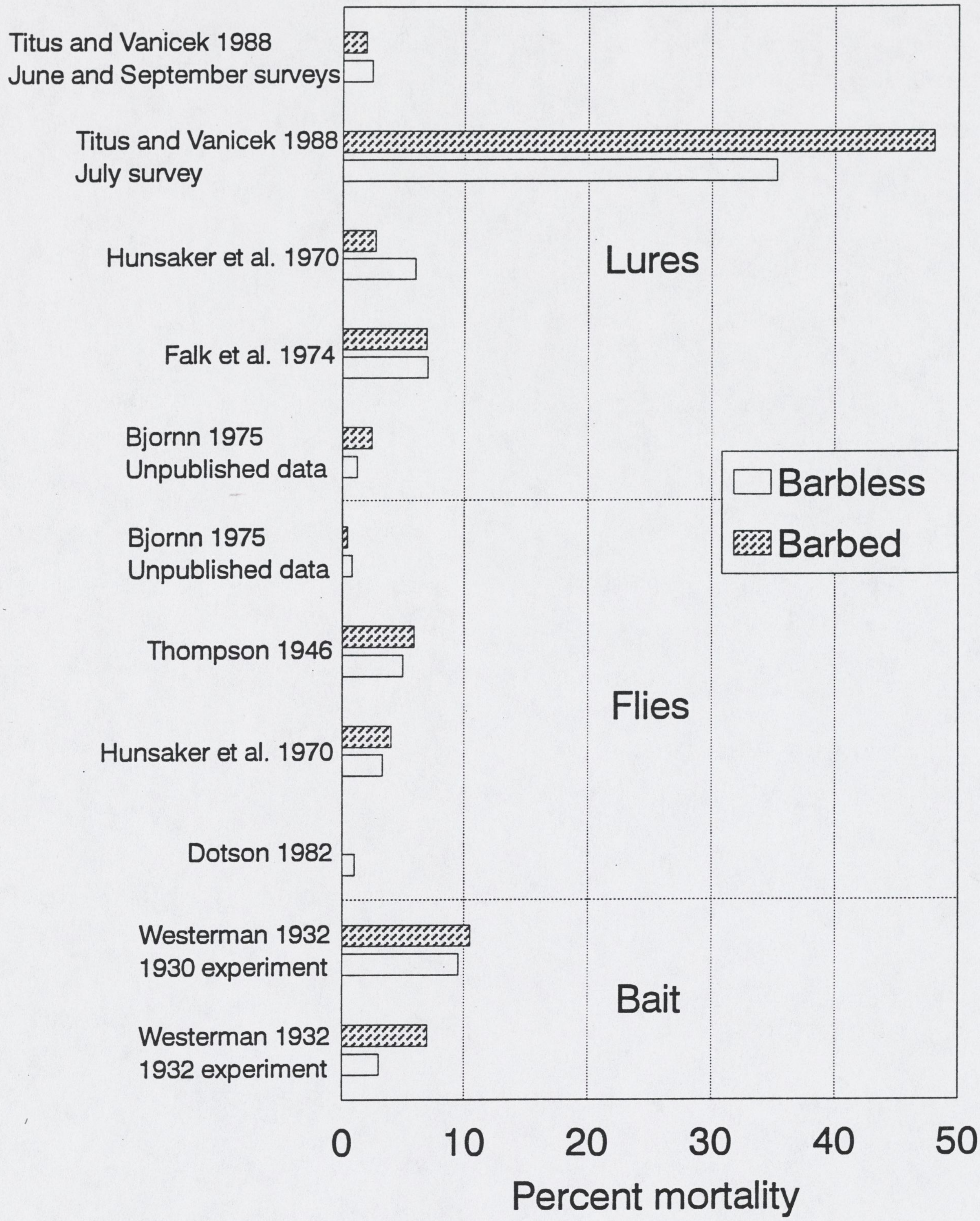
[a] Not tested - no difference in quality ratings within the group being tested.

[b] Test not appropriate given sample size of 2.

Table 4. Comparison of mean effect sizes or correlation coefficients (r) obtained via three meta-analysis methods that combined past barbed versus barbless hooking mortality studies by gear type.

		Combined effect sizes		
Gear	N	Mean r	Weighted mean r (N-3)	Weighted (quality)
Lures	5	0.015	0.008	0.015
Flies	4	-0.014	-0.023	-0.019
Bait	2	0.055	0.060	0.055
Flies or lures	9	0.002	-0.007	-0.001

Figure 1.-Summary of all past study trials directly comparing hooking mortality from catching and releasing resident trout with barbed versus barbless hooks.


Titus and Vanicek 1988
June and September surveys
Titus and Vanicek 1988
July survey
Hunsaker et al. 1970
Falk et al. 1974
Bjornn 1975
Unpublished data
Bjornn 1975
Unpublished data
Thompson 1946
Hunsaker et al. 1970
Dotson 1982
Westerman 1932
1930 experiment
Westerman 1932
1932 experiment
Lures
Flies
Bait
Barbless
Barbed
0
10
20
30
40
50
Percent mortality

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North American Journal of Fisheries Management 17:873–881, 1997

Barbed Hook Restrictions in Catch-and-Release Trout Fisheries: A Social Issue

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Abstract.—We summarized results of past studies that directly compared hooking mortality of resident (nonanadromous) salmonids caught and released with barbed or barbless hooks. Barbed hooks produced lower hooking mortality in two of four comparisons with flies and in three of five comparisons with lures. Only 1 of 11 comparisons resulted in statistically significant differences in hooking mortality. In that instance, barbless baited hooks caused significantly less mortality than barbed hooks, but experimented design concerns limited the utility of this finding. Mean hooking mortality rates from past lure studies were slightly higher for barbed hooks than barbless ones, but the opposite was true for flies. For flies and lures combined, mean hooking mortality was 4.5% for barbed hooks and 4.2% for barbless hooks. Combination of test statistics from individual studies by gear type via meta-analysis yielded nonsignificant results for barbed versus barbless flies, lures, or flies and lures combined. We conclude that the use of barbed or barbless flies or lures plays no role in subsequent mortality of trout caught and released by anglers. Because natural mortality rates for wild trout in streams commonly range from 30% to 65% annually, a 0.3% mean difference in hooking mortality for the two hook types is irrelevant at the population level, even when fish are subjected to repeated capture. Based on existing mortality studies, there is no biological basis for barbed hook restrictions in artificial fly and lure fisheries for resident trout. Restricting barbed hooks appears to be a social issue. Managers proposing new special regulations to the angling public should consider the social costs of implementing barbed hook restrictions that produce no demonstrable biological gain.

Numerous investigators have questioned whether the use of barbless hooks results in fewer post-release mortalities than barbed hooks. In his pioneering study of hooking mortality, Westerman (1932) did not use statistical tests but concluded that barbless hooks were superior to barbed hooks in reducing hooking losses for brook trout *Salvelinus fontinalis*. However, authors of all subsequent field studies on resident (nonanadromous) salmonids (hereafter referred to as trout) have found no significant differences in hooking mortality between barbed and barbless hooks (e.g., Hunsaker et al. 1970; Falk et al. 1974; Titus and Vanicek 1988).

Four past reviews of hooking mortality literature have addressed the barbed versus barbless question and produced conflicting conclusions. In two separate qualitative reviews with results from the above studies and additional unpublished data sets, Wydoski (1977) and Mongillo (1984) concluded that the use of barbless hooks does not reduce hooking mortality and that restrictions prohibiting barbed hooks cannot be justified biologically.

More recently however, Taylor and White (1992) summarized most of the same data sets using analysis of covariance in a quantitative procedure they called meta-analysis. Typically, in meta-analysis, test statistics (e.g., *t*-values) from multiple studies, often with conflicting results, can be combined mathematically in a quantitative review (Jarvinen 1991; VanderWerf 1992). Meta-analysis decreases the rate of type II error and increases the power to detect statistical differences (Rosenthal 1991; Miller and Pollock 1994). Using a different approach, Taylor and White (1992) concluded that a statistically significant difference in hooking mortality occurs when the two hook types are used to catch resident trout. A more recent qualitative review (Muoneke and Childress 1994) also concluded that the use of barbless hooks reduces hooking mortality, but much of their discussion focused on adult anadromous salmonids in ocean troll fisheries.

There appears to be renewed interest in regulations prohibiting use of barbed hooks. In Oregon, a proposal to require barbless hooks for all stream fishing, regardless of species sought, was recently considered but subsequently abandoned (R. Temple, Oregon Department of Fish and Wildlife, personal communication). In Idaho, barbed hook restrictions were adopted in 1996 for new catch-and-release fisheries in 700 additional stream kilometers, and more are being considered for 1998. Based primarily on Taylor and White (1992), five Arkansas waters with new regulations enacted in 1994 include a barbed hook restriction (J. Stark, Arkansas Game and Fish Commission, personal communication).

The increasing use of this management restriction at such a widespread level warrants close scrutiny, especially given the differences in conclusions of past reviews. While reading Taylor and White (1992), we realized that several past studies comparing barbed and barbless hooks were not included in their analyses. In addition, our review of their methods generated questions about their over-all approach to meta-analysis. As a result, we rexamined the barbed versus barbless hook question by using the more common approach to meta-analysis described above.

Regardless of the data set analyzed, statistically significant results do not necessarily imply real-world significance (Gold 1969). An assessment of the magnitude of association among variables, and hence, its true importance, must still be made in some manner besides a statistical test (Cohen 1965). Taylor and White (1992) note that despite their finding of statistical significance, the differences between average barbed and barbless mortality rates in past studies were small and must be put in biological context by fishery managers. Schill (1996) discusses the need to convert mortality rates from typical hooking studies into population exploitation rates and to consider natural mortality rates when developing restrictions for special regulation waters. We are aware of no study that discusses the merits of barbed hook restrictions at the population level.

We summarize results of all past efforts in which hooking mortality rates of resident trout caught on barbed and barbless hooks were compared in side-by-side trials. We then combine test statistics of these studies using meta-analysis in a quantitative review. We subsequently examine the strength of the relation between barbed versus barbless hook use and hooking mortality by calculating effect sizes (Cohen 1988; Rosenthal 1991). Last, we consider the biological significance of barbed hook restrictions at the population level.

Methods

Individual Study Summary

References cited in past hooking study reviews (Wydoski 1977; Mongillo 1984; Taylor and White 1992; Muoneke and Childress 1994) were used as initial reference sources. We reviewed references in all relevant papers, and conducted computerized literature searches to identify newer material. Our intent was to locate all prior studies of resident trout in which barbed and barbless hooking mortality rates for a given gear type (e.g., flies) were estimated in the same study.

Seven applicable studies were located (Westerman 1932; Thompson 1946; Hunsaker et al. 1970; Falk et al. 1974; Dotson 1982; Titus and Vanicek 1988; T. Bjornn, University of Idaho, personal communication). The Titus and Vanicek (1988) experiments consisted of three separate trials (June, July, and September) in which the two hook types were compared. Hooking mortality in the July trial was thought by the authors to be strongly influenced by elevated water temperatures, and these fish experienced a fivefold increase in mortality above the rates recorded for both June and September trials. Therefore, the July trial was evaluated separately. Thus, two comparisons of hook types were made from the single Titus and Vanicek (1988) study. Also, several of the above studies included barbed and barbless comparisons for both flies and lures, increasing the total number of direct hook comparisons available to 11.

Meta-analysis combines test statistics from previous studies, but statistical tests were not conducted in all 11 hook comparisons. In addition, the low mortality associated with both hook types in most past studies and resultant cell frequencies were often too small to meet assumptions of chi-square analysis (Zar 1974). We developed raw databases for each individual comparison and analyzed the data in SYSTAT (Wilkinson 1990) using binomial tests (Zar 1974). Results were considered significant at $P < 0.05$.

Meta-analysis

Test statistic combinations.—The test statistics (Z-scores) obtained from binomial tests of the 11 direct comparisons were combined by meta-analysis. Several meta-analytic techniques were compared to examine the consistency of results (R. Rosenthal, Harvard University, personal communication). First, the Stouffer method of adding Z-scores was used (Kirby 1993):

$$Z_M = \frac{\sum_{i=1}^{k} Z_i}{\sqrt{k}},$$

where Z_M = overall Z-score of the meta-analysis, Z_i = Z-score of binomial test for study i, and k = number of studies. In this method, Z_i is assigned a positive or negative direction based on the hypothesized outcome of the comparison (Rosenthal 1991). In our analyses, Z-scores from studies in which barbless hooks resulted in lower hooking mortality were assigned positive values.

The second approach used to combine the studies was the Edgington (1972) method of testing mean P. We used the equivalent but simpler formula of Rosenthal (1991):

$$Z_M = (0.50 - \bar{P})(\sqrt{12k}),$$

where $\bar{P}$ = average one-tailed probability value of all individual binomial tests, taking note of which tail the outcome P-value falls in, and Z_M and k are as defined above.

Rosenthal (1991) and Glass (1976) cautioned against excluding lower-quality studies from meta-analyses because of potential investigator bias in excluding studies that conflict with their expectations. Thus, the data of Thompson (1946) were included although the trout species was not identified. In addition, one of the comparisons by Westerman (1932) involved two slightly different hook sizes (number 5, barbed, and number 6, barbless), and hook sizes were not provided for the other trial. All three of these comparisons were included in the analyses despite some concern about their design.

Possible effects of these design concerns on our conclusions was evaluated in a third meta-analytic approach that used the weighted-Z method. We assigned half as much weight to the Westerman (1932) and Thompson (1946) studies and compared meta-analysis results to those in which all studies were assigned equal weight (Rosenthal 1991). This method was also used to examine the influence of sample size on meta-analysis results. The formula of Mosteller and Bush (1954) was used to add weighted Zs; total study sample sizes and a subjective quality rating were considered independently as weighting variables. Thus, separate test statistics were calculated for the two weighting approaches with the equation

$$Z_M = \frac{\sum_{i=1}^{k} w_i Z_i}{\sqrt{\sum_{i=1}^{k} w_i^2}},$$

where w_i = either the total sample size or the subjective quality rating (2 for high quality or 1 for low quality) as the weight for study i, and Z_M, Z_i, and k are as defined above.

With the above formulae, test statistics were combined for all past studies evaluating bait-, fly-, and lure-caught fish, separately. Because most special regulation waters typically restrict bait and permit the use of both flies and lures, results of all studies that used either of the latter two gear types were also combined. Resultant Z_M-scores for these combinations were evaluated for significance by using one-tailed P-values (Rosenthal 1991). Meta-analysis results were considered significant at $P < 0.05$.

Effect size calculations.—To estimate the magnitude or strength of the relation between hook type and hooking mortality found in past studies, effect sizes for individual studies were calculated by using the formula of Rosenthal (1991):

$$r_i = \frac{Z_i}{\sqrt{N_i}},$$

where r_i = standard Pearson product-moment correlation coefficient for study i, N_i = number of fish in study i, and Z_i is as previously defined.

SYSTAT was used to transform signed rs from individual studies into normalized Fisher's Z_rs (Kirby 1993). We calculated mean Z_rs for the same gear types described above for the test statistic combinations (bait, lure, fly, fly and lure) and subsequently calculated weighted mean Z_rs, based on sample sizes of individual studies (Rosenthal 1991):

$$\bar{Z}_r = \frac{\sum_{i=1}^{k} (N_i - 3) Z_{ri}}{\sum_{i=1}^{k} N_i - 3},$$

where $\bar{Z}_r$ = weighted mean Z_r, Z_{ri} = Fisher's Z_r for study i, and N_i is as previously defined.

A weighted evaluation of study quality on effect size was also obtained by substituting either a 2 or a 1 as a weighting variable instead of $N_i - 3$. Unweighted and weighted mean Z_rs were transformed back to mean Pearson product-moment ($\bar{r}$) with the following formula (Kirby 1993):

$$\bar{r} = \frac{e^{2\bar{Z}_r} - 1}{e^{2\bar{Z}_r} + 1}.$$

Resultant effect size estimates, both for individual studies and gear types, were evaluated with the guidelines of Cohen (1988).

Results

Individual Study Summary

In general, differences in hooking mortality attributable to use of barbless or barbed hooks were quite small in individual studies. Based on statistical tests made by the original authors and our

TABLE 1.—Summary of past hooking mortality studies directly comparing barbed versus barbless hooks. Sample sizes are in parentheses; statistical significance ($P < 0.05$) is denoted by an asterisk.

Study and trial	Gear type[a]	Species[b]	Source	Percent hooking mortality (N) for: Barbed hooks	Barbless hooks	Original significance test ($\chi2$, 2-tailed)[c]	Binomial test, P (one-tailed)	Effect size[d] (r)
Titus and Vanicek (1988)								
Jun, Sep trials	Lures	Cutthroat trout	Wild	1.9 (104)	2.4 (124)	OTG	0.40	0.02
Jul trial	Lures	Cutthroat trout	Wild	48.1 (52)	35.3 (51)	OTG	0.09	0.13
Hunsaker et al. (1970)	Lures	Cutthroat trout	Wild	2.7 (113)	6.0 (100)	NS	0.11	0.08
	Flies	Cutthroat trout	Wild	4.0 (75)	3.3 (60)	NS	0.42	0.02
Falk et al. (1974)	Lures	Lake trout	Wild	6.9 (72)	7.0 (57)	NS	0.49	<0.01
Bjornn (1975)[e]	Lures	Cutthroat trout	Hatchery	2.4 (209)	1.2 (166)	NT	0.20	0.04
	Flies	Cutthroat trout	Hatchery	0.4 (256)	0.8 (264)	NT	0.29	0.02
Thompson (1946)	Flies	Unknown		5.9 (51)	5.0 (60)	NT	0.42	0.02
Dotson (1982)	Flies	Cutthroat trout	Hatchery	0.0 (105)	1.0 (105)	NS	0.16	0.07
Westerman (1932)								
1930 trial	Bait	Brook trout	Hatchery	10.5 (200)	9.5 (200)	NT	0.37	0.02
1932 trial	Bait	Brook trout	Hatchery	7.0 (200)	3.0 (300)	NT	0.02*	0.09

[a] All lures had treble hooks.
[b] Cutthroat trout *Oncorhynchus clarki*; lake trout *Salvelinus namaycush*.
[c] OTG = original author test included other test groups, no test statistic available for barbed versus barbless only; NS = not significant; NT = not tested statistically by original author.
[d] Standard Pearson product-moment correlation.
[e] T. C. Bjornn, University of Idaho, unpublished data.

own binomial tests, only one comparison was statistically significant (Table 1). In a bait trial (Westerman 1932), mortality associated with barbed hooks was significantly greater than mortality attributable to barbless hooks ($P = 0.02$).

The strength of the relationship between barbed or barbless hook use and mortality was weak in individual studies. Calculated effect sizes, expressed as standard Pearson product-moment correlation coefficients (r), were low (Table 1). Only one of these values slightly exceeded 0.10, a lower guideline bound suggested by Cohen (1988) as evidence for a small association among variables.

The graphical summary of past studies comparing barbed to barbless hooking mortality revealed equivocal results (Figure 1). In six comparisons, use of barbed hooks resulted in greater mortality, whereas barbless hooks resulted in higher mortality in the remaining five. Barbed hook use resulted in lower estimates of hooking mortality in two of four fly comparisons and in three of five lure comparisons. Use of barbed hooks resulted in higher mortality in both cases in which bait was used.

Calculation of weighted mean mortality rates obtained from studies that compared the two hook types directly also revealed equivocal results. Mean hooking mortality rates for lure studies were slightly higher for barbed hooks; the opposite was true of flies (Table 2). For flies and lures combined, mean hooking mortality was 4.5% for barbed hooks and 4.2% for barbless hooks.

Meta-analysis

Combination of individual study statistics by four meta-analysis approaches did not change the above results. Comparison of barbed and barbless hooking mortality for studies combined by gear type yielded nonsignificant Z-scores with P-values ranging from 0.22 to 0.28 for flies and from 0.37 to 0.40 for lures (Table 3). Differences due to hook type in fly and lure studies combined were also nonsignificant ($P = 0.34$–0.44). Trout caught on barbless bait hooks experienced statistically lower mortality rates than those caught on barbed bait hooks ($P = 0.03$–0.04), but the discrepancy in sizes of the barbed and barbless hooks that were compared limits the utility of this finding. In addition, weighting the studies by quality or sample size did not affect calculated P-values appreciably (Table 3).

Based on correlation coefficients, the use of barbed or barbless hooks appeared to play virtually no role in determining mortality of fish. Effect sizes (correlation coefficients) for the various gear type meta-analyses were quite low for fly and lure combinations (Table 4). None of these values ap-

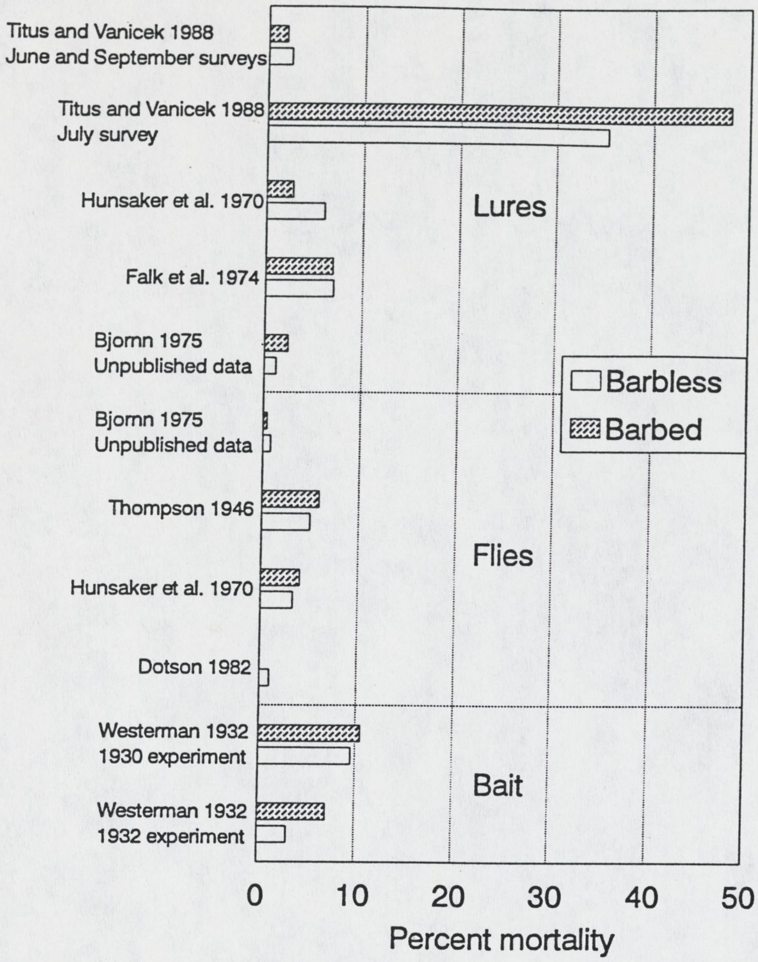

FIGURE 1.—Summary of all past trials comparing hooking mortality of resident trout caught with barbed versus barbless hooks.

proached the 0.10 guideline value of Cohen (1988) as evidence for a small relationship. Weighting by study quality or sample size produced minimal change in resultant effect size estimates.

Discussion

Our results agree with the qualitative literature reviews of Wydoski (1977) and Mongillo (1984), both of whom concluded that there is no biological basis for barbed hook restrictions on artificial flies and lures. In five out of nine individual trials, hooking mortality rates for barbed flies or lures were less than rates for barbless hooks.

This finding conflicts with the conclusions of Taylor and White (1992), but we have difficulty accepting their conclusions. These authors used raw data (proportions) from individual studies in their analysis. Rosenthal (1991) cautions against this approach, citing past examples of flawed meta-analyses with paradoxical findings. Meta-analysis normally involves a process of combining summary test statistics from individual studies (e.g., Jarvinen 1991). Taylor and White (1992) did not use this approach, either for the barbed versus barbless hook comparisons or for other facets of their analyses (e.g., treble versus single hooks).

TABLE 2.—Weighted mean rates of hooking mortality for barbed versus barbless hooks based on past trials.

Gear	Number of trials	Hooking mortality (%) for: Barbed	Barbless
Lures	5	7.3	6.6
Flies	4	1.4	1.7
Bait	2	8.8	5.6
Flies or lures	9	4.5	4.2

TABLE 3.—Comparison of P-values obtained by four meta-analysis techniques that combined barbed versus barbless hooking mortality trials by gear type. Statistical significance ($P < 0.05$) is denoted by an asterisk. See text for descriptions of combination methods.

Gear	N	Method of combination: Stouffer	Mean P	Weighted (N)	Weighted (quality)
Lures	5	0.38	0.37	0.40	[a]
Flies	4	0.28	0.25	0.22	0.24
Bait	2	0.04*	[b]	0.03*	[a]
Flies or lures	9	0.44	0.42	0.34	0.42

[a] Not tested; no difference in quality ratings within the group being tested.

[b] Test not appropriate given $N = 2$.

TABLE 4.—Comparison of mean effect sizes or correlation coefficients (r) obtained by three meta-analysis methods that combined barbed versus barbless hooking mortality trials by gear type.

Gear	N	Combined effect sizes: Mean r	Weighted mean r (N-3)	Weighted (quality)
Lures	5	0.015	0.008	0.015
Flies	4	−0.014	−0.023	−0.019
Bait	2	0.055	0.060	0.055
Flies or lures	9	0.002	−0.007	−0.001

More importantly, we are concerned about the basic biological approach used by Taylor and White (1992) to compare results from the various trials. In their bait analyses, they summarized data from 23 barbed baited hook trials nationwide and compared those data to results from only 2 barbless bait trials at a single Michigan hatchery (Westerman 1932). They report a wide disparity in mean hooking mortality between barbed (33.5%) and barbless bait hooks (8.4%). However, the authors ignore that Westerman (1932) compared barbed to barbless hooks for the same species directly at the same site and found much smaller differences in mortality (Table 1). Barbless hooks were not investigated in any of the remaining 21 bait trials at other locations nationwide. Thus, other factors frequently shown to affect hooking mortality, such as varying water temperatures, species, etc., could easily have confounded their analysis. For a more detailed discussion of these concerns, see Turek and Brett (1997).

The same limitation is present in the other barbed versus barbless gear comparisons of Taylor and White (1992). Sixty-nine estimates of barbed hooking mortality for fly or lure trials were compared to estimates for only 8 barbless trials in a few of the same locations. Meta-analysis is not intended to overcome such spatial and temporal differences. In our review, we only summarized past trials in which both hook types were compared directly in trials at the same locations and times.

Results from the only two trials comparing barbless and barbed hooks with bait (Westerman 1932) and our subsequent test statistic combination via meta-analysis both suggest possible merit to the use of barbless hooks by bait anglers releasing trout. However, the use of different-sized barbed and barbless hooks in that work is problematic, as well as is the fact that the only two trials were conducted at the same hatchery. In addition, test fish were small and hooks used in this study were large relative to most hooking studies, perhaps explaining the unusually low mortality rate observed in the two trials, regardless of hook type. Additional studies with baited hooks should be conducted; existing data are insufficient for any firm recommendations regarding barbless hooks and bait.

In the individual studies we reviewed, statistical power (Peterman 1990) to detect significant differences in mortality was likely low given sample sizes and observed mortality differences. However, having sufficient power to detect a statistical difference is only relevant if a difference is large enough to be meaningful at a practical level (Cohen 1965; Gold 1969). Weighted mean hooking mortality rates for the nine barbed versus barbless trials involving artificial flies or lures were quite similar at 4.5% and 4.2%, respectively. We questioned whether reducing hooking mortality by 0.3% could possibly be important in wild trout populations given that annual natural mortality rates in trout streams typically range from 30% to 65% (Schill 1996; D. J. Schill, unpublished data).

To address this question Schill and Scarpella (1995) used the MOCPOP population simulation program (Beamesderfer 1991; Beamesderfer and North 1995). We examined differences in a variety of hypothetical salmonid populations in which all trout large enough to be captured by anglers are caught one, three, and five times annually with either of the two hook types. The modeling approach considered a wide range of growth rates and natural mortality scenarios typical for wild trout stocks in streams, along with the mean hooking mortality rates for barbed and barbless artificials reported above. Even when all individual fish were caught five times annually, a barbed hook restriction had little effect on populations. Numbers of trout in the simulated populations fished exclusively with barbless hooks averaged only about 1.5% higher for catchable-sized trout (>154 mm total length, TL) and 5% higher for quality-sized trout (>305 mm TL) than when all trout were caught with barbed hooks.

There is some potential for misinterpreting these simulation results. Our meta-analytic findings indicate the 0.3% difference in barbed versus barbless artificials is not statistically significant, i.e., they are not "real," or in any event, not large enough to be detectable. The completion of subsequent studies could easily result in a combined fly and lure average where barbless hooks produce slightly greater average mortality. This is currently the case in past fly-only comparisons in which mean barbless hook mortality is greater than that for barbed (Table 2). The simulation results reported above are only an exercise assuming a statistical difference actually exists where one presently does not. In this hypothetical exercise, results indicate that the benefits from barbed hook restrictions would be so small as to clearly be undetectable by the angling public, even in the most heavily fished scenarios. Given these modeling observations, results of the meta-analysis, and individual studies summarized above, we view barbed hook restrictions as a social issue.

Many anglers and some fishery managers may have difficulty accepting this perspective. In the first hooking mortality study, Westerman (1932) stated that barbless hooks are "the most sportsmanlike and humane manner of taking trout, one which should have real appeal to the practical Yankee as an economic proposition in abating waste." This attitude remains firmly entrenched in the minds of some fishery managers who dispute the results of the past hooking studies. They believe that, from a common sense perspective, barbless hooks are easier to remove from trout and, therefore, should reduce mortality.

However, implementing a barbed hook restriction without biological justification assumes there is no cost to the agency for enacting such regulations. This may not be the case. Schill and Kline (1995) estimated that 75% of barbed hook violations on two Idaho waters with such restrictions were made by individuals who usually comply with the regulations but occasionally forget to flatten their barbs down. If barbless hooks do not reduce hooking mortality significantly and citations are written to largely honest anglers, the animosity generated by such enforcement may be counterproductive to fishery agencies (Schill and Kline 1995). In Idaho during 1994, 20% of all angling violations (534 citations and warnings) were written for barbed hook violations (T. McArthur, Idaho Department of Fish and Game, unpublished data). The potential to generate unnecessary hostility from a sizeable group of anglers is real, especially if it spreads to family members, neighbors, and friends as a result of a citation. Social and financial costs to management agencies could become important over time.

A geographical inventory of special regulations also calls into question the biological necessity for barbed hook restrictions. Schill and Scarpella (1995) conducted a nationwide telephone survey of state agencies managing trout populations to determine the consistency of barbed hook restrictions. Of 37 states with special regulation trout waters, 22 (59%) reported having no barbed hook restrictions. Results also indicated that these restrictions were applied with some apparent regionalization, but inconsistencies were common. For example, fisheries in Yellowstone National Park and western Montana are widely regarded by many anglers as the finest trout fishing in the world, yet barbed hook restrictions have never been implemented on waters in these two geographic areas (D. Vincent, Montana Divisions of Fish, Wildlife and Parks and R. Gresswell, U.S. Forest Service, personal communications). Clearly, barbed hook restrictions are not needed for high-quality trout angling.

Conclusions

We conclude that, based on existing biological data, barbed hook restrictions are not justified for resident salmonid fisheries. Managers considering or proposing new special regulations to the angling public should consider the possible social costs of implementing a restriction that produces no demonstrable biological gains. Further, we suggest that existing barbed hook restrictions be reconsidered and that the restrictions be removed where anglers support such change. As Behnke (1987) suggested, unnecessary angling regulations should be eliminated to avoid the loss of agency credibility. Anglers who support the use of barbless hooks can do so voluntarily. Although existing data suggest little biological basis for use of barbless hooks, there are several reasons why anglers may want to use them. For example, barbless hooks can be removed from trout mouths and angler ears more easily, making the process less stressful to anglers in both instances and making it possible for them to resume fishing more quickly.

Whereas elimination of barbed hook restrictions may be warranted, rapid removal of the restrictions could create social and political problems for agencies. Many trout anglers are almost evangelistic in their support for various regulations (Jackson 1989), and barbed hook restrictions are certainly perceived as crucial for quality trout angling by a segment of the angling community. Such fervent support is not likely to be abruptly altered by the results of our study. It often takes 20 years for new research results to be filtered through fishery managers and to become common sense to anglers (Loftus 1987). Those anglers who currently view barbed hook restrictions as a requirement for good fishing will need time and perhaps additional studies before they will be convinced to change their perception. The first step in the process of eliminating unnecessary barbed hook restrictions on existing waters should begin with efforts to inform and educate the public (including proponents and detractors of barbless hooks) about the lack of biological support for them based on existing information.

Acknowledgments

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[1997]

North American Journal of Fisheries Management 17:477–481, 1997

Short-Term Hooking Mortality of Weakfish Caught on Single-Barb Hooks

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Abstract.—Weakfish *Cynoscion regalis* support an important recreational fishery in the mid-Atlantic region of the United States. Several state fishery management agencies have imposed size and creel limits in an attempt to reduce weakfish fishing mortality. Despite these management measures, few data are available for the estimation of angling mortality following the catch and release of sublegal fish. We used sport-fishing tackle to capture 90 weakfish (300–453 mm total length) in Great South Bay, New York, during August–September 1995. All animals were caught with single barbed hooks (size 1/0) on either natural baits or artificial lures. We recorded bait type (natural or artificial) for each capture event. Mean short-term mortality was estimated at 2.6%, with a 95% confidence interval of 0.6–7.0%. Mortality did not differ significantly between fish caught on natural baits and those caught on artificial lures. The results suggest that inadvertent angling mortality of weakfish is quite low and unlikely to inhibit stock rebuilding efforts in the mid-Atlantic region.

Weakfish *Cynoscion regalis* are currently subject to high rates of exploitation along much of the east coast of the United States. Overfishing of this resource resulted in a spawning-stock biomass decline in excess of 90% from 1979 to 1991. (Lockhart et al. 1996). Despite these reductions, weakfish continue to support important commercial and recreational fisheries from New York to North Carolina. In New York, recreational anglers pursue the species primarily by drift fishing from boats or casting from shore. Typical gear consists of spinning tackle outfitted with 12–15-lb. (4.5–5.6-kg) test line attached to single hooks (E. Kopack, Warren's Tackle Center, personal communication). Hook sizes in the recreational fishery range from 1/0 to 5/0, with 2/0 being the most common (J. Albanese, Captree Bait and Tackle, personal communication). Popular natural baits in this fishery include squid strips and the sandworm *Nereis virens*. Artificial lures commonly include bucktails or lead-head jigs equipped with plastic worms. Gear and techniques in the New York fishery are typical of those used throughout the weakfish's range, although natural baits vary considerably with geographic location (Manooch 1984).

Weakfish management is currently governed by Amendment III of the Atlantic States Marine Fisheries Commission's Weakfish Plan (Lockhart et al. 1996). Among the management measures mandated by this amendment is a 304 mm total length (TL) minimum size limit from Massachusetts to Florida, although some states have elected to implement even larger minimum size limits.

Previous workers have provided estimates of short-term hooking mortality for members of the family Sciaenidae (Matlock et al. 1993; Murphy et al. 1995; Swihart et al. 1995). Although one of these reports was on weakfish, it dealt exclusively with the use of natural baits fished on relatively small hooks (Swihart et al. 1995). Many anglers believe that mortality levels are higher for fish caught on bait versus those caught on artificial lures. Although no such data are available for weakfish, investigations based on other members of the family Sciaenidae do not support this conclusion (Matlock et al. 1993; Murphy et al. 1995).

In 1991, anglers in the five-state mid-Atlantic region caught an estimated 2.1 million weakfish and released alive an estimated 653,000 fish (Van Voorhees et al. 1992). Despite the number of fish released, relatively little is known about the fate of weakfish following catch and release. If management efforts aimed at rebuilding weakfish stocks are to be successful, it is necessary to incorporate accurate estimates of angling mortality (including inadvertent angling mortality) in stock assessment models.

Our objectives were to provide additional estimates of short-term (72-h) mortality following catch-and-release angling. We also sought to identify those variables most likely to affect mortality estimates. We especially sought to test the hy-

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Phil Batt / Governor
Jerry M. Conley / Director

Dr. Robert Behnke
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CO state University
Fort Collins, CO 80523

Dear Bob

You reviewed a paper of mine several years ago on random response. I recall you wanted a stronger statement against barbed hook restrictions. I noted at the time that a stronger statement against them was in the works. Well, it's finished, sort of. This is a revised draft for the NAJFM that I thought you would be interested in. Please don't cite as it's not completely through the review process but this is the revision and likely to sail through since I pretty much met a horde of reviewers requests.

I am aware of the trials and problems you had in TROUT and elsewhere on the barbless issue. The "religious" right is already descending on me for this work. I have submitted this paper for wild trout VI and already members of FFF on the paper selection committee are writing me in protest and demanding I present their views!!!!! Oh well, this is what happens when you question peoples gods :).

Anyway, hope this paper satisfies your preference for a stronger statement against barbed hook restrictions. You are cited in the conclusions.

Good fishing
Daniel J. Schill
Daniel J. Schill
Principal Research Biologist

OFFICE MEMO

TO: Dave Anderson **Date**

FROM: Bob Behnke

SUBJECT:

REMARKS: This is paper about meta-analysis controversy.
I would appreciate your opinion. When Taylor and White
(physiologist and psychologist at Utah St.) published paper in 1992
claiming "meta-analysis" showed lower mortality for barbless
hooks than barbed hooks (with live bait, not flies, lures). I
critiqued their paper, pointing out, in my assessment,
they had too many apples and oranges mixed for a
meta-analysis. Also, the only "valid" data of equally
paired tests -- Westerman 1930, 1932 -- actually is not valid
in that Westerman simply had outcome fit preconceived
opinion by allowing barbed hooks to be taken by fish

for longer period (resulting in deeper hooking).

This controversy has been going on for years and is truly a tiny molehill type issue, blown into mountain of problems for F&G agencies. I've written about matter several times, emphasizing the matter of hook type is a non issue. George Sisler & Eric Bergersen also prepared summary for DOW Commission on the subject, but the proponents of barbless hooks have great zeal, comparable to anti hunting sentiment in Wildlf. Mgt. When the Taylor and White meta-analysis paper came out, it fueled the flames again -- magazine articles, internet repts., etc. claiming "scientific proof" (the meta-analysis) that barbless hooks kill fewer fish in catch-and-release fisheries. Would you agree that this paper adequately demolishes the "meta-analysis" results of Taylor and White?

Bob:

3/3/98

I have looked at the paper by Schill and Scarpella and your note to me. I have a few comments:

1. The paper is good, but not great. My overall conclusion is that there is no difference, but their methodology leaves some to be desired.

2. They have far too much emphasis on testing.

3. Very poor citations to the meta-analysis literature. This makes one think they do not know much about the subject of meta-analysis.

4. Relatively little emphasis on what studies should have been included in the meta-analysis in the first place. This is step 1 in meta-analysis procedure. When this is done poorly, then controversy rages.

5. Fig. 1 is interesting and gets to the point (I felt).

6. The focus should have been properly on effect size and its standard error. They do not do this. For example, in Table 1 there is no measure of precision for the percentages given. There is no measure of precision for the differences in the percentages. They do not even include a standard error for their measure of effect size (r). This is simply poor.

7. The use of a correlation coefficient for "effect size" seems strained.

I hope these comments will be of interest.

David

Oct 25, 1998

Bob Behnke
Colorado State University
Fort Collins, CO 80523-1474

Dear Bob,

Thanks for the letter. As usual, your comments bring up even more questions. Regarding Stone char: I talked to a fellow on the plane to PK who is an author for "Outside" magazine. He was on his way over to work on an article about Kamchatka. He said that he had caught a "black" melanistic char on a past trip. I gave him a card and asked if he would send a photo. I have yet to receive it. In Ron Greer's book "Ferrox Trout" Swan Hill Press 1995, page 44 he talks about boganid char but provides a photo from Fred Kircheis labeled "stone charr-USSR. Anyway, I am sure Fred did not take the photo, but that it was provided by him. The point here is that the fish in the photo is very likely a stone char. In his presentation to the ISACF at Raduga, Glubokovsky showed a very similar photo which he called stone char....not "albus" which he referred to as "white char". I don't think that there is confusion between the two, however, stone char still is, as you put it, a "mystery fish". I do not understand the connection between S. kronocius and stone char. If it (S. kronocius) was designated as S. albus and is not S. albus, why should it be derived from stone char? Since S. albus (likely only an form of Dolly Varden) is not stone char, how does it follow that S. kronocius is a stone char?? Savvaitova (1993, Arctic chars: The Structure of population systems and prospects for economic use) talks about stone char as solitary predator in the Kamchatka River basin. She also talks about three groups from L. Kronostskoye, a long-nosed char, a long-headed char and white char. Nowhere does she suggest that stone char is one of the three. Based on what she says, it seems that stone char occurs in the Kamchatka river and some tributaries, is very dark or black at spawning, and is different from the basic malma (or albus) in the system. I'd still like to see one! From what I saw, albus is very close to malma. If I had seen the same fish in Norton Sound, I would think it within the normal variation for malma. Chereshnev, however, thought that there were significant differences between albus and malma. I am not a taxonomist! However, the question of stone char is still very interesting.

Alv pred. if alpine - malma

Nothing new on Norton Sound char yet. Both Jim Reist and Ruth Phillips have samples. As far as I know, Ruth has not compared these to known northern form fish from the Kotzebue area.

As far as the hook and release mortality on Dolly Varden, we conducted the experiment with Department personnel (I know the possible bias for handling) and tried to mimic the way folks in the Nome area fish. Because all the fishing is in flowing waters, detection of a bite is fairly immediate. If this had been a lake situation where fish could swallow the baits easier, I would guess that we would have had higher mortality with baited hooks. The other thing to consider is that the water temp was quite cold. Again this is normal for the time that malma are available. All I can say is that the results suggest that there is low mortality with all methods of angling. I fully expected that we would have higher mortality with salmon eggs, but that was not the case. I'll enclose a copy of the original report on this study.

Your and Chereshnev's observations about Arctic grayling being cropped off by sport fishing squares with my observations. In the Nome area, grayling grow quickly until reaching sexual maturity at around 7 yrs. They then put most of their energy into reproduction and shift to very slow growth. Because they can live for more than 20 years, some attain a large size. We commonly catch 3 pound plus grayling in some streams. The Nome River has been overexploited and has been closed to sport fishing for the past 6 years. The population has not recovered in that time. Other rivers like the Niukluk (Fish River Tributary) had not been as severely depressed, and its grayling population has responded favorably to a reduced bag limit since 1986. The "normal" situation for some unexploited streams is for the mean size to be large with few small fish and low recruitment. This is a stable situation that can be easily upset by exploitation. Our background bag limit in the Nome area is 5 grayling per day with only one over 15 inches. In many streams, one seldom catches a grayling under 15 inches, so it is an effective daily bag of one fish. This seems to be working for the time being. However, most Nome residents do not target grayling. A few visitors do, but the effort directed at grayling is quite low overall. People favor coho and pink salmon fishing.

map
letter Dorofeyeva

I talked extensively with James Prosek. He mentioned Thymallus brevirostris to me. Where in Mongolia does this critter inhabit? I have a friend headed there next fall and I'll see if he can travel to the area where they occur.

I really enjoyed Kamchatka and would like to return sometime, hopefully with more time for fishing. You talked about the Camka River as a good resident rainbow stream. Where else have you fished over there?

Sedanka

Best Wishes,
Fred DeCicco

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Dr. Robert Behnke — no dif. artificial w. salmon eggs
Dept. of Fishery + Wildlife Biology
Colorado State University
Fort Collins, CO 80523-1474

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FISHERY DATA SERIES NO. 94-47

MORTALITY OF ANADROMOUS DOLLY VARDEN CAPTURED AND RELEASED ON SPORT FISHING GEAR[1]

By

Alfred L. DeCicco

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

November 1994

1 This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-9, Job No. R-3-3-(b).

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

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INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) sometimes imposes restrictive sport fishing regulations to protect stocks from over-harvest. However, as fishing regulations become more restrictive, anglers may release a larger portion of their catch. Further, some anglers prefer to release sport caught fish regardless of the regulation structure. In 1990, anglers in Alaska caught almost 440,000 Arctic char *Salvelinus alpinus* and Dolly Varden *S. malma* and released over 306,000 (70% of the catch); during 1991, 461,000 were caught and almost 319,000 (69%) were released; and during 1992, 378,950 were caught and almost 302,000 (80%) were released (Mills 1991, 1992, 1993). Dolly Varden occur in coastal drainages throughout Alaska, while Arctic char occur in lakes in Southcentral and Southwestern Alaska and Alaska's North Slope. ADF&G does not differentiate between Arctic char and Dolly Varden for record keeping, however, given the relative distribution of these two species, it is probable that the majority of fish caught in the "Arctic char/Dolly Varden" category are Dolly Varden. ADF&G realizes that a portion of the released fish may die as a result of being hooked and handled but it has been assumed that the rate of mortality is low.

McKinley (1993) found that Arctic char caught from a hatchery raceway suffered a low overall mortality rate (0.033), and that all mortalities occurred with baited hooks. For a broad spectrum of species Wydoski (1977) reported overall mean mortality rates of 25% for fish caught with bait on barbed hooks and 6.1% for fish caught on artificial lures with barbed treble hooks. Retrieved, baited lures tended to cause mortality rates in salmonids similar to those of baited hooks that were still fished (Mongillo 1984). Fishing with barbless hooks has not been shown to reduce mortality significantly, but it may reduce handling time (Mongillo 1984). Vincent-Lang et al. (1993) found that the mortality rate of coho salmon *Oncorhynchus kisutch* caught and released in tidal areas was significantly higher than for fish captured and released in upstream freshwater areas. They concluded that anadromous salmon undergoing the osmoregulatory stress of returning to freshwater were more susceptible to the additional stress of being hooked than those already adapted to the freshwater environment. Pauley and Thomas (1993) found that mortality of anadromous coastal cutthroat trout *O. clarki* taken above and below tidal influence in Puget Sound, Washington was higher with worm baited hooks (39.5 - 58.1%) than for three different spinner treatments (10.5 - 23.8%). Another study dealing with cutthroat trout in the Yellowstone River found an overall hooking mortality rate of 0.3%, however it was estimated that each fish was caught 9.7 times resulting in a hook related mortality of 3% of the population (Schill et al. 1986).

Hook placement was the primary factor, and resultant bleeding the primary cause affecting mortality rates in captured fish (Mongillo 1984). Fish hooked in the gill arches or esophagus had much higher mortality rates than those hooked in the jaws or mouth (Mongillo 1984). McKinley (1993) found that 56% of Arctic char hooked in the gill arches died. Loftus et al.(1988) reported 71.4% mortality in lake trout *S. namaycush* hooked internally and 6.9% mortality when hooked externally. Pauley and Thomas (1993) found that the probability of death was greater for coastal cutthroat trout hooked in the gill, tongue, esophagus or eye and was significantly higher than for those hooked in other locations.

This study is the first attempt to quantify the mortality rates due to catch and release of Dolly Varden. Since catches of Dolly Varden in Alaska are large, a high hook and release mortality would have significant management implications.

Field work for this study was conducted over two seasons, in the Nome area during 1993 and in the Kotzebue area during 1994. Four gear types were investigated: treble hook lure (1/2 or 3/8 oz. Hot Rod), single hook lure (1/8 oz. rubber skirted jig), single hook (no. 10) - baited, treble hook (no. 12) - baited. These terminal gears represent the present range of legal terminal gears used by anglers to catch Dolly Varden in the Arctic-Yukon-Kuskokwim region. Quantified mortality rates of Dolly Varden caught with these four terminal gears may substantiate the efficacy of catch-and-release regulations for controlling sport fisheries for Dolly Varden.

The Nome area was initially selected for this study because streams with Dolly Varden are easily accessible, and fish in this area are typically in the same size range as Dolly Varden that occur in most areas of Alaska. During 1993, three treatment groups were completed, and a fourth was begun. Dolly Varden did not return to Nome area streams in their usual numbers by early October, and the study was not completed. To ensure that fish were available, the remainder of the study was conducted on the Wulik River (Kotzebue area) in 1994. Nome area treatment groups included: a) single hook lure, 60 fish; b) single hook bait, 59 fish; treble hook lure, 14 fish; and c) single hook lure (early group fresh from the sea). Kotzebue area treatment groups included a) Treble hook lure, 46 fish; b) Treble hook baited with salmon eggs, 60 fish; and, c) a control of 60 fish caught with a seine.

The project objectives were:

1. to test the hypothesis that there is no significant mortality suffered by Dolly Varden caught once with the different gear types; and,

2. to test the hypothesis that there is no significant difference in the mortality rate of sport caught and released Dolly Varden which have recently entered fresh water (the early group), and the mortality rate of caught and released Dolly Varden which have been residing in freshwater for more than one week (all other Dolly Varden caught in regards to objective 1). The alternative hypothesis was that the hooking mortality rate is greater for caught and released Dolly Varden that have recently entered fresh water.

METHODS

Sampling Gear and Techniques

All fish were captured using a medium weight spinning rod and reel equipped with 8-lb or 10-lb monofilament line. Each person fishing used a variety of the selected gear types and fished in a normal manner to approximate methods used by anglers typically fishing for Dolly Varden in northwestern Alaska. Fish were "played" for a minimum of approximately 30 s before being brought to land. Other than the use of a hemostat or needlenosed pliers to remove the hook, special handling procedures were not followed. Each Dolly Varden captured was measured to the nearest millimeter in fork length (FL), tagged with an individually numbered Floy FD-67 internal anchor tag, and placed in a holding pen. The location of the hook and the amount of bleeding were noted for each fish. Hook placement was noted as in Figure 1, and the amount of bleeding was rated on a four point scale (adapted from Falk and Gillman 1975): 0) none, no evidence of external bleeding; 1) slight, a small amount of bleeding generally localized near the point of hook entry; 2) moderate, a greater amount of external bleeding generally localized around the point of hook entry; 3) severe, copious amounts of blood, staining the water in the holding bucket and generally surrounding and obscuring the point of hook entry. The time of day was also noted for all captures.

If a fish was hooked deep in the esophagus, the line was cut. For all other hook placements, the hook was removed. All captured fish were placed in 1.2m X 1.2m X 1.2m, or 0.9m X 1.4m X 0.9m holding pens with a maximum of 60 fish per pen. Dead fish were removed from the pens when they were observed (time and tag number noted). Pens were checked for mortalities as additional fish were added, each morning, and several times each day that fish were held after pens were filled. Each pen was monitored for 48 h after the last fish was released into it; all fish were then released. Only fish that died within 48 hours of capture were considered mortalities from fishing. The mortality rate for each gear type was calculated as follows:

$$\hat{m}_i = \frac{X_i}{n_i} \qquad (1)$$

where:

$\hat{m}_i$ = the mortality rate of fish caught with gear i

n_i = the number of fish that were caught with gear i; and,

X_i = the number of fish caught with gear i that died.

The standard error of this rate was estimated by (Zar 1984):

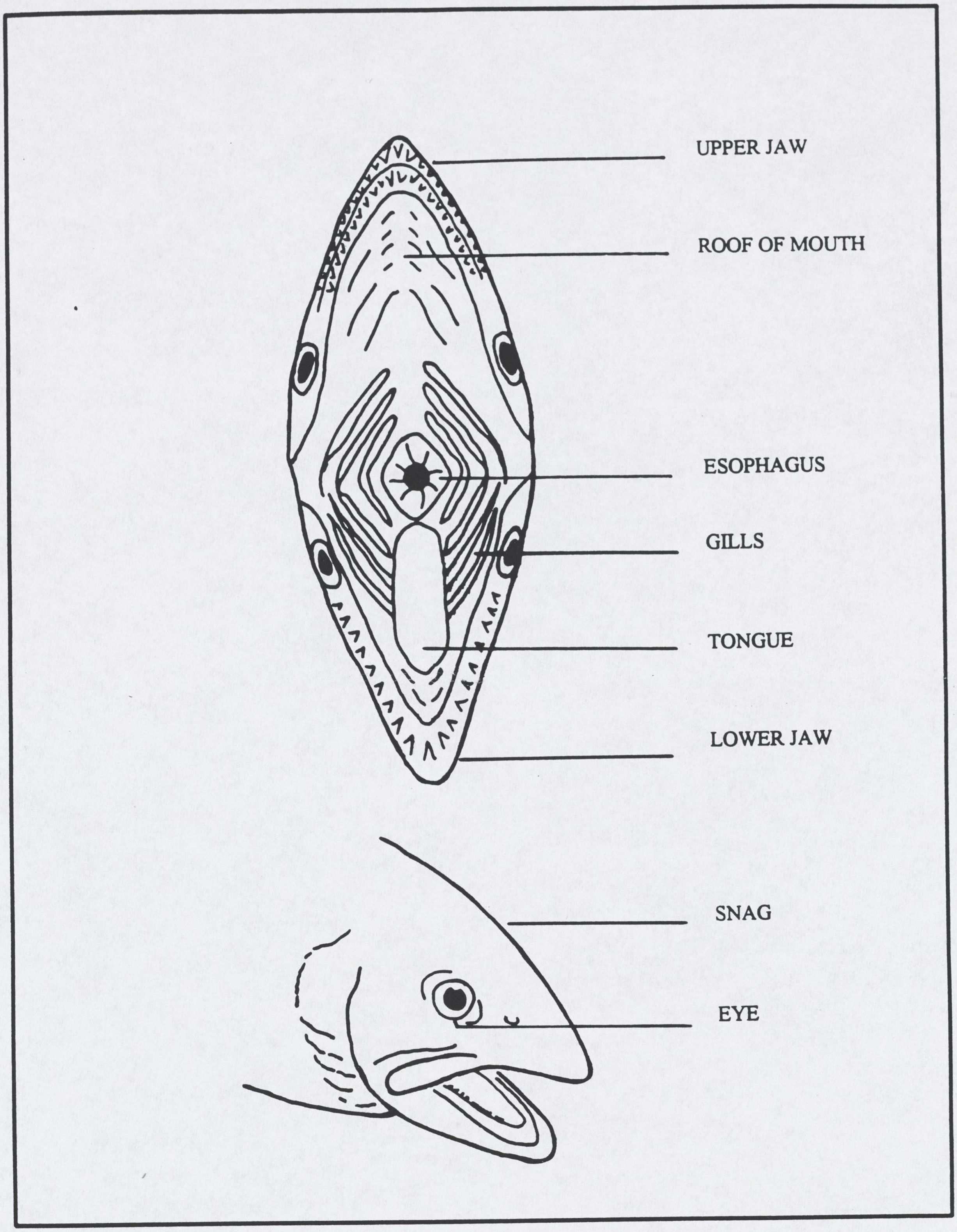

Figure 1. Description of hook placement.

$$SE[\hat{m}_i] = \left[\frac{\hat{m}_i (1 - \hat{m}_i)}{(n_i - 1)} \right]^{1/2} \quad (2)$$

A one-tailed binomial test was performed to determine if the mortality rate for any one gear type is significantly greater than the control. Confidence intervals were used to compare mortality among gear types. Confidence intervals are calculated as (Zar 1984):

$$LCI_i = \frac{X_i}{X_i + (n_i - X_i + 1)F_{\gamma 1, \gamma 2}} \quad (3)$$

and,

$$UCI_i = \frac{(X_i + 1)F_{\gamma 1, \gamma 2}}{n_i - X_i + (X_i + 1)F_{\gamma 1', \gamma 2'}} \quad (4)$$

where:

LCI_i = lower 90% confidence interval for the mortality rate of gear i;

UCI_i = upper 90% confidence interval for the mortality rate of gear i;

F_{γ_1, γ_2} = probability from the F distribution with γ_1, γ_2 degrees of freedom

where:

$\gamma_1 = 2(n_i - X_i + 1)$;
$\gamma_2 = 2X_i$;

$F_{\gamma_1', \gamma_2'}$ = probability from the F distribution with γ_1, γ_2 degrees of freedom where:

$\gamma_{1'} = 2(X_i + 1)$;
$\gamma_{2'} = 2(n_i - X_i)$;

To retain an overall level of significance of 10%, the alpha level for each test between gears was set at 0.02.

A similar one-tailed binomial test was performed to determine if the mortality rate for the single gear type used on fish recently entering fresh water (the early group) is significantly greater than the mortality rate for that same gear type used on fish which have been resident in fresh water for more than one week. Confidence intervals were constructed in the same manner as described above for this second objective (no alpha level adjustment needed).

Data on hook placement and level of bleeding were collapsed into generalized categories and compared using contingency tables. If the hypothesis of independence of hook placement and level of bleeding failed to be rejected ($P > 0.10$), then the hook placement categories were pooled.

The length distributions of control fish and fish caught with each gear type were compared using the Anderson-Darling k-sample test (Scholz and Stephens 1987).

A control group of 60 fish was seined and distributed in the holding pens. Control fish were captured in 1994 the day after the last two gear type samples were taken.

RESULTS

Of 359 Dolly Varden captured and held in this experiment, only six (1.7%) died during the monitoring period. Three died within 30 min, two within 6 h, and one within 12 h of capture. The mortality rates did not vary significantly among the treatment groups and the control. The mortality rate of all Dolly Varden caught with single hook gear types was 0.017 (SE < 0.001), virtually identical to that of all fish caught on treble hook gear types, 0.017 (SE < 0.001). Mortality from baited gears (0.025, SE < 0.001) was only slightly higher than, but not significantly different from that for all unbaited gears (0.011, SE < 0.001)(Table 1).

The Early Group:

The first Dolly Varden observed in the Nome area during 1993 were found in the Snake River during late August. Of the 60 fish captured using single hook lures, two (mortality = 0.033, SE = 0.023) died during the holding period, both within 30 min of capture. Both mortalities were hooked in the eye, bleeding was noted as ''moderate'' in one case and ''slight'' in the other (Appendix A). Although mortality in this group was higher than that of the later single-hook lure group (no mortalities) it was not significantly different (Table 1).

Mortality By Gear Type

No deaths occurred during the monitoring period in the 60 fish sample caught from the Nome River using unbaited single hook lures. Likewise, there were no deaths recorded in the 60 fish sample caught on unbaited treble hook lures. Fish in this sample were taken from the Snake, Nome and Wulik rivers.

Only one fish died of 59 caught from the Nome River using single hooks baited with salmon eggs (mortality = 0.017, SE < 0.001). This fish was hooked in the tongue and was bleeding heavily. Of 60 Dolly Varden caught from the Wulik River with treble hooks baited with salmon eggs, only two died (mortality = 0.033, SE = 0.023). One of the dead fish was hooked in the eye and was bleeding ''heavily'' while the other was hooked in the lower jaw and was experiencing ''moderate'' bleeding.

Table 1. Estimates of mortality rate, standard error, and 90% confidence intervals for Dolly Varden caught by gear types.

Gear Type	n	x	m	SE	LCI	UCI
Single Hook Lure (Early Group)	60	2	0.033	0.023	0.003	0.120
Single Hook Lure	60	0	0		0	0.064
Treble Hook Lure	60	0	0		0	0.064
Single Hook Bait	59	1	0.017	<0.001	<0.001	0.092
Treble Hook Bait	60	2	0.033	0.023	0.003	0.120
All Baited Hooks	119	3	0.025	<0.001	0.009	0.056
All Unbaited Hooks	180	2	0.011	<0.001	0.003	0.030
All Single Hooks	179	3	0.017	<0.001	0.006	0.037
All Treble Hooks	120	2	0.017	<0.001	0.004	0.044
Control Group (beach seine)	62	1	0.016	<0.001	<0.001	0.088

Bleeding, Hooking Location and Size of Fish

The numbers of fish experiencing varying degrees of bleeding were compared by the location of hook placement using contingency tables. The distribution of bleeding severity from fish hooked in the jaw was found not different from those snagged (hooked somewhere other than in the eye or mouth area) (χ^2 = 3.69, DF = 2, P < 0.001). These groups were then pooled and compared with fish hooked in the eye, tongue, gill or roof of mouth. The distribution of bleeding severity between these groups was found to be different (χ^2 = 64.17, DF = 3, P < 0.001). More fish hooked in the eye, tongue, gill or roof of mouth experienced moderate or severe bleeding than those snagged or hooked in the jaw (Figure 2).

The length distributions of samples by gear type (Figure 3) were compared using the Anderson Darling K-sample test and found to be different (Takn = 42.68, P < 0.001). Since significant differences in mortality by gear type were not found, none could be directly attributed to differences in fish length.

DISCUSSION

Overall mortality related to hooking and handling Dolly Varden in this experiment was found to be very low. Significant differences were not found in mortality among different gear types and the control group. Hook and release fishing may therefore be regarded as a reasonable management option for Dolly Varden populations in northern Alaska. It is probable that southern-form Dolly Varden react similarly to hook and release fishing; if so, this management option may be applicable statewide.

One of 62 seine caught control fish died. This fish was a spent male which became entangled in the netting of the holding pen by its type. When the water level dropped during the night, the fish was left suspended out of the water. Even though no fish from any of the treatment groups experienced this fate, the fish was considered a holding mortality. If this fish were not considered a mortality, the results of this experiment would have been left essentially unchanged. Mortalities from treatment groups would have still not been significantly different from the control group.

Although no size-based differences in hooking mortality were shown in this experiment, the length distribution fish varied significantly among treatment groups. Dolly Varden captured from the Wulik River (46 fish in the treble hook lure treatment group, the treble hook bait group and the control group) were larger than fish caught in the Nome area (other groups). Observed mortality may have been different had smaller fish been captured in the treble hook groups, or had larger fish been captured in the single hook groups.

Mortality rates have been found to be similar between hook types in most studies (Dotson 1982, Falk and Gillman 1975, Mongillo 1984). Klein (1965) found higher mortalities in rainbow trout *O. mykiss* caught with single hooks

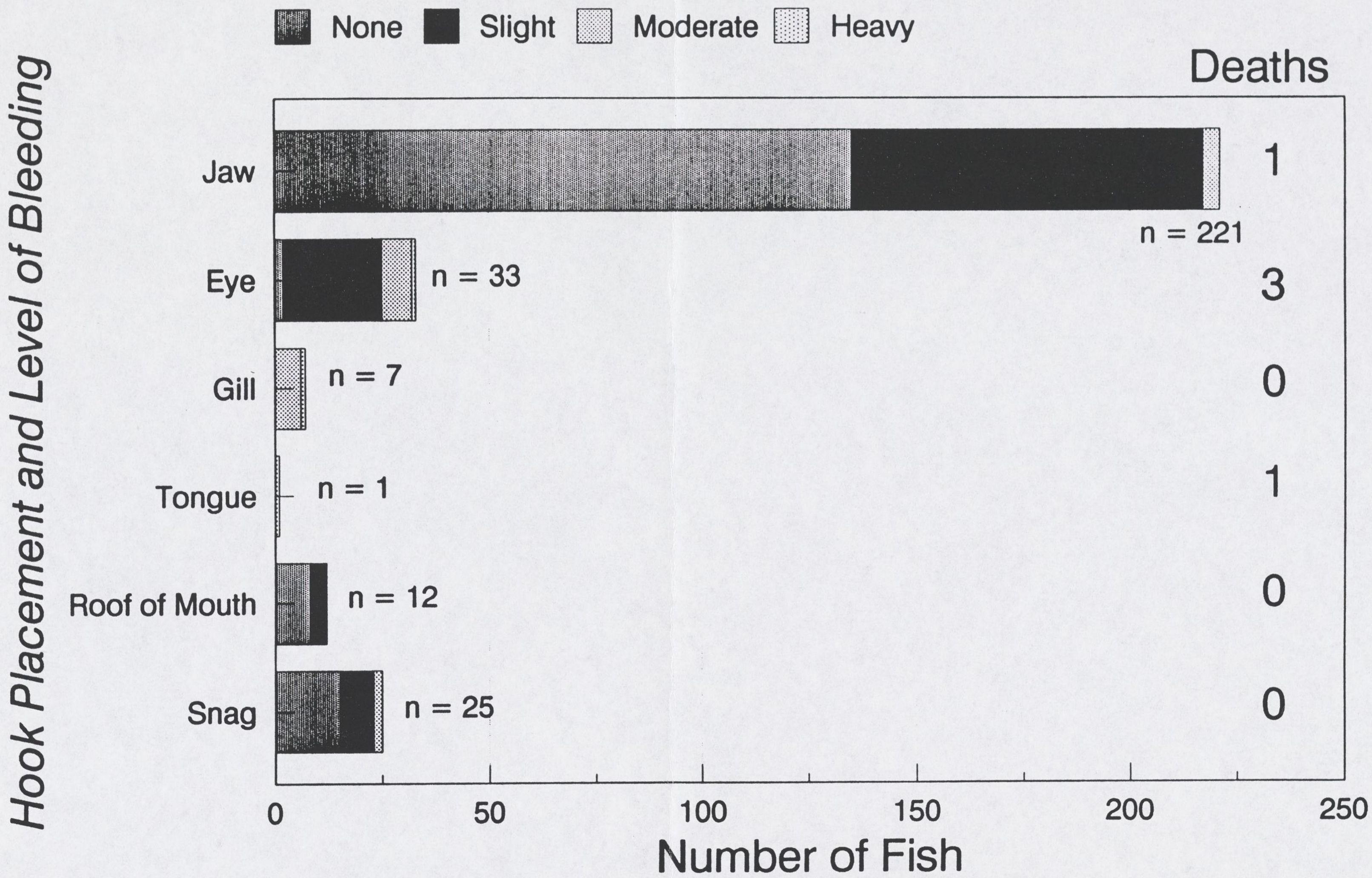

Figure 2. Mortality and level of bleeding by hooking location of Dolly Varden caught on sport fishing tackle, gear types pooled.

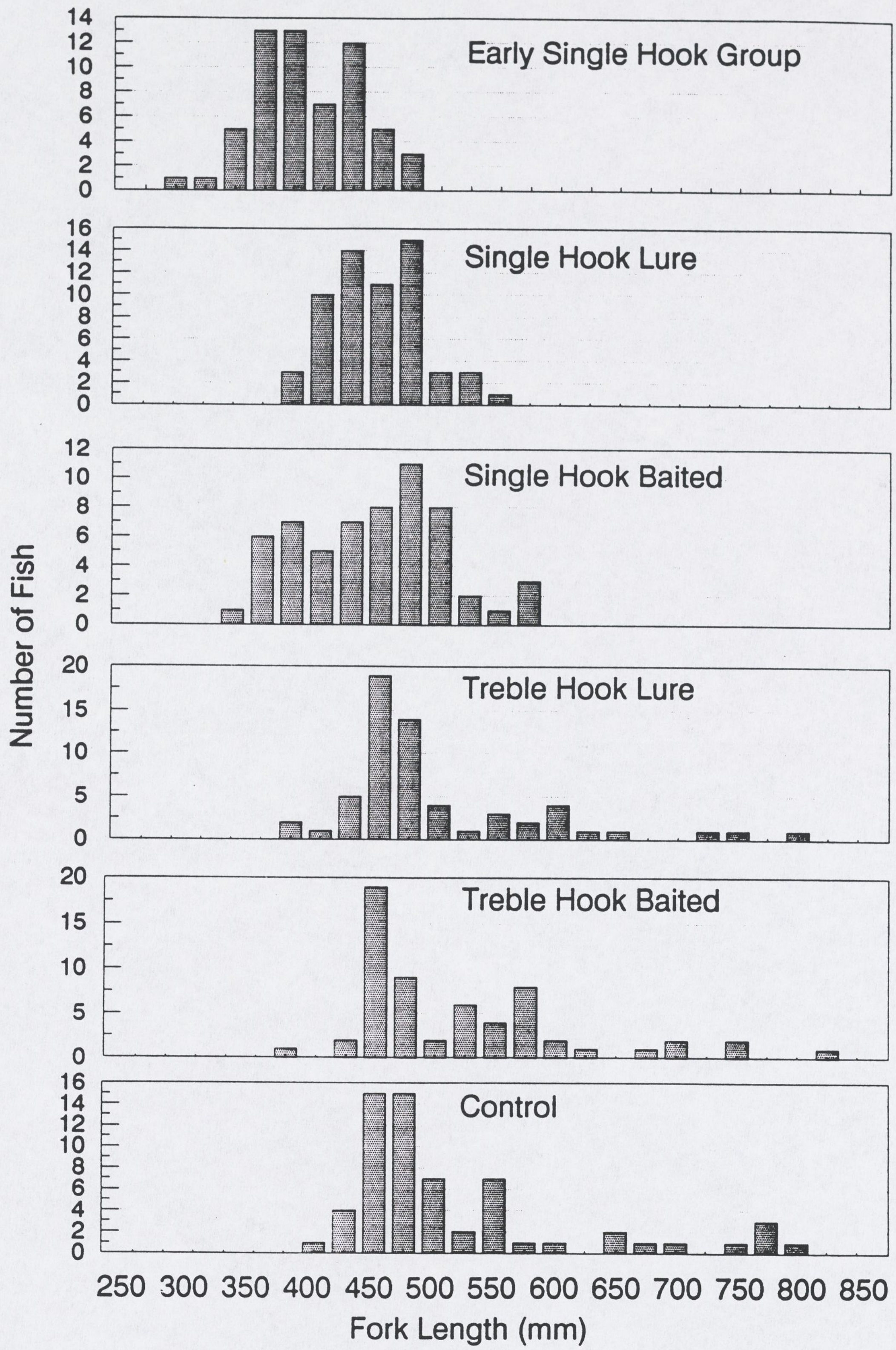

Figure 3. Fork length distributions of treatment groups of Dolly Varden captured with different sport fishing tackle and control (Beach seine).

than those caught with treble hooks. He stated that this was because single hooks were often taken more deeply into the mouth and was more likely to inflict a more serious wound. More fish in my study were hooked in the eye, a potentially lethal location, in the single hook samples than in treble hook samples (Appendix A). This was probably due to the choice of the single hook rubber skirted jig as the single hook lure. This lure rides with the hook oriented upward, and was more likely to hook fish in the upper jaw than other lures. Both single hook mortalities were in fish hooked in the eye. These mortalities were both from the early single hook sample. This sample contained the smallest fish (Figure 2) which may have been a contributing factor to the two mortalities. These fish were 312 and 350 mm FL respectively, and were the smallest of the five hooking mortalities. Other mortalities ranged from 425 to 511 mm FL. A potential contributing factor to the slightly higher mortality in this group may have been higher water temperatures, approximately 10° C vs < 5° C for the other groups. Dotson (1982) found evidence for increased angler induced mortality in cutthroat trout at water temperatures above 15° C, but Marnell and Hunsaker (1970) found no evidence for this. Physiological stress due to the osmoregulatory changes necessary for anadromous fish to enter fresh water was suggested by Vincent-Lang et al. (1993) to contribute to hook and release mortality for coho salmon caught in an estuary. This effect could influence the mortality rate of angler-caught Dolly Varden, however, since the mortality rate in this group was not significantly higher than that of the later single hook group, or other treatment groups, these considerations have little management value for this species in northern areas.

ACKNOWLEDGMENTS

I would like to thank Matt Evenson, Richard Barnes, and Jack Winters for their assistance in the field. Pat Hansen provided biometric assistance for this project. This project and report were made possible by partial funding provided by the U.S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-9, Job Number R-3-3(b).

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Appendix A. Hook location and level of bleeding by gear type.

Single Hook Lure (Early Group)							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	32	0	0	0	0	0	32
Slight	10	16*	0	0	2	3	25
Moderate	1	1*	2	0	0	0	3
Heavy	0	0	0	0	0	0	0
Total	36	17**	2	0	2	3	60

Single Hook Lure							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	35	1	0	0	6	3	45
Slight	10	2	0	0	1	0	13
Moderate	1	1	0	0	0	0	2
Heavy	0	0	0	0	0	0	0
Total	46	4	0	0	7	3	60

Single Hook Bait							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	34	0	0	0	2	3	39
Slight	13	2	0	0	0	1	16
Moderate	0	0	3	0	0	0	3
Heavy	0	0	0	1*	0	0	1
Total	47	2	3	1*	2	4	59

Treble Hook Lure							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	14	0	0	0	0	6	20
Slight	26	3	0	0	1	3	33
Moderate	1	4	0	0	0	2	7
Heavy	0	0	0	0	0	0	0
Total	41	7	0	0	1	11	60

Treble Hook Bait							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	20	1	0	0	0	3	24
Slight	29	0	0	0	0	1	30
Moderate	2*	1	1	0	0	0	4
Heavy	0	1*	1	0	0	0	2
Total	51*	3*	2	0	0	4	60

All Single Hook							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	101	1	0	0	8	6	116
Slight	27	20	0	0	3	4	54
Moderate	1	2*	5	0	0	0	8
Heavy	0	0	0	1*	0	0	1
Total	129	23*	5	1*	11	10	179

-continued-.

Appendix A. (Page 2 of 2).

All Treble Hook							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	34	1	0	0	0	9	44
Slight	55	3	0	0	1	4	63
Moderate	3*	5	1	0	0	2	11
Heavy	0	1*	1	0	0	0	2
Total	92*	10*	2	0	1	15	120

All Baited Hooks							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	54	1	0	0	2	6	63
Slight	42	2	0	0	0	2	46
Moderate	2*	1	4	0	0	0	7
Heavy	0	1*	1	1*	0	0	3
Total	98	5*	5	1*	2	8	119

All Unbaited Hooks							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	81	2	0	0	6	9	97
Slight	40	21*	0	0	4	6	71
Moderate	2	6*	2	0	0	2	12
Heavy	0	0	0	0	0	0	0
Total	123	28**	2	0	10	17	180

All Fish Captured and Held							
Bleeding	Jaw	Eye	Gill	Tongue	Roof of Mouth	Snag	Total
None	135	2	0	0	8	15	160
Slight	82	23	0	0	4	8	117
Moderate	4	7	6	0	0	2	19
Heavy	0	1	1	1	0	0	3
Total	221	33	7	1	12	25	299
Deaths	1	3	0	1	0	0	5

* indicates a fish that died.

[Ca 1990s]

Should Bait Be Banned in No-Harvest Trout Fisheries?

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No-harvest regulations maintain excellent trout fisheries. Flies or artificial lures may be used, but under no circumstances will bait be permitted. This is not just dogma, it has been scientifically proven that baited hooks result in unacceptably high rates of mortality after trout are released. If trout are to be caught several times a year and perhaps a dozen times or more during their lifetime, bait angling must be banned. Well, maybe not.

Recently completed studies on two streams in Connecticut and one in Pennsylvania provide some evidence that bait fishing may not be all that disasterous in a no-harvest fishery. In fact, wild brown trout may do remarkably well in the face of substantial fishing pressure by bait fishermen.

The results of these studies in combination with findings from other research on wild trout populations provide a strong argument against the case for completely banning bait fishing in no-harvest trout areas. Yet, carefully controlled studies have consistently shown that hooking mortality associated with baited hooks can be quite high. This article explores the reasons for this apparent contradiction.

Hooking Mortality Studies

The concern over mortal wounds inflicted by baited hooks arose many years ago. The first published studies probably came out of Michigan in the early 1930's. Since then there have been at least 30 studies conducted on eight species of trout and salmon in which all types of terminal tackle have been tested. Tackle has included flies, artificial lures and baits; barbed versus barbless hooks; and single versus treble hooks.

Though results of these studies have varied somewhat, several generalizations have emerged. Some results have been surprising while others were as expected. The surprising results (at least to some experts) were that there was little difference in delayed mortality resulting from barbed versus barbless hooks, artificial lures versus flies, and single versus treble hooks.

As expected, mortality from baited hooks was consistently higher than that from flies or artificial lures. There appears to be at least two reasons for these differences. Trout that take baited hooks tend to swallow the bait and are deeply hooked. Removal of deeply embedded hooks results in severe tissue damage. Also, baited hooks tend to be implanted in certain critical areas of the mouth. The most sensitive regions are in the base of the mouth and the gill areas, where major blood vessels are located. These vessels carry large amounts of blood to and from the gills. A puncture wound to these vessels is likely to result in death.

Trout that take flies or artificial lures tend to be hooked near the periphery of the mouth, well away from major blood vessels. Removal of hooks from these peripheral areas does little damage. Several studies have shown that when artificials or flies implant in critical areas, death is likely to ensue -- but this happens much less frequently than with baited hooks.

Paul Mongillo, Washington Department of Fish and Game, did a comprehensive survey of hooking mortality studies. He found that among all trout and salmon species, hooking mortality associated with flies and artificial lures ranged from 0 to 18%, and averaged about 5%. With baited hooks the range was 6 to 49% with an average of about 27%.

The results of these studies have clearly influenced the philosophy of management agencies. Perhaps 40 or more years ago the perception had been that artificial lures were as harmful as baited hooks and that barbed hooks caused more damage than barbless hooks. These beliefs lead to flies-only restrictions on no-harvest or limited-harvest fisheries. And, in some states, only barbless flies were allowed.

As results from more studies became available, it was evident that artificial lures and barbed hooks were not particularly harmful. These facts prompted agencies to allow any type of unbaited tackle to be used in specially regulated fisheries. Flies-only regulations are becoming less common, though traditional flies-only areas will continue to be maintained for social rather than biological reasons.

I think it is safe to say that management agencies have been comfortable with the regulations they have adopted, because these regulations have a sound basis. Though some ardent fly fishermen may disdain any other type of angling, they have learned to live with spin fishermen who use artificials. In short, a peaceful coexistence has been achieved.

This peaceful coexistence may now be upset by results from some recent events. Events that were precipitated by chemical pollution, which lead to some unusual regulations.

Bait Angling in No-Harvest Fisheries

Chemical pollutants were discovered in two distant trout streams in 1976. These pollutants are carcinogenic. They had been concentrated in trout flesh and were deemed unsafe for human consumption. To protect the public, harvest of trout was prohibited and the management of these streams was radically changed.

Spring Creek, a central Pennsylvania limestone stream, was probably the first trout fishery in the country to have a special regulations section, which was established in 1934. For many years the entire stream had been liberally stocked with catchable-size trout and it was famous for its enormous opening day pressure. Liberal harvest regulations prevailed on this 22-mile-long stream, except for a flies-only, no-harvest section known as Fisherman's Paradise, a mile-long section. Even though the stream was stocked, many sections supported a reasonably good population of wild brown trout.

The upper part of the Spring Creek watershed had been subjected to illegal disposal of kepone, mirex, and other contaminants that found their way into the groundwater and eventually into the stream. These contaminants were concentrated in trout flesh and when first discovered in 1976, mirex concentrations were more than 10 times higher than levels considered safe for human consumption. Initially the Pennsylvania Fish Commission discontinued stocking below the entry of a large spring, which appeared to be the major source of contaminants. In 1982 all stocking was suspended, the harvest of trout was prohibited, but because this was a pollution regulation, no restriction was placed on angling method or terminal tackle.

I instituted a study in cooperation with the Pennsylvania Fish Commission to determine the response of wild brown trout to this no-harvest regulation that allowed bait fishing. In 1988 we estimated the trout densities in 12 stream sections and conducted an angler survey that started in June 1988 and ran through May 1989. Some of the sections that we electrofished in 1988 were the same ones that Bruce Hollender, Area Fisheries Manager, surveyed in 1980. One of the stream sections that we included in the angler survey had been surveyed during the first two months of the 1976 fishing season. These data allowed us to compare both densities of wild trout and fishery statistics before and after the no-harvest regulations were implemented.

Only one of the sections that was surveyed in 1980 was still being stocked at that time. It is possible that stocking had some influence on the numbers of wild brown trout. When Hollender surveyed this section in July 1980, few stocked fish were present; the vast majority of the fish were wild. Apparently the stocked fish had been harvested or had died. So even in this section, the effects of stocking, if any, appear to have been short lived. Thus, the changes in numbers of wild trout that occurred between 1980 and 1988 were primarily in response to the no-harvest regulation.

Among the six stream sections surveyed in 1980 and 1988, numbers of wild brown trout increased in all of them. The average increase in numbers of age-1 and older trout (about 5 inches and longer) was 165% and in weight it was 100%. In two of these sections too few wild brown trout were captured in 1980 to allow estimation of population size. By 1988 densities had risen to 2,400 adult trout per mile. These increases were so astounding that one wonders if something besides liberal harvest suppressed the wild trout population prior to 1980. Even if these two sections are discounted, the increase in density among the other four sections was still 100%.

The evidence is compelling. Even a skeptic would have to agree that after harvest was prohibited, wild brown trout responded in a dramatic fashion. And more importantly, they responded while bait fishing was permitted. As one might expect, as trout densities increased under the no-harvest regulation, fishing success improved substantially.

In 1976 Jim Hartzler, a graduate student at Penn State, studied the trout fishery on a 3-mile stretch of Spring Creek, which was bordered by public land. At the time, this section supported few wild trout; the fishery was maintained by stocking 6,200 catchable-size trout. His survey began on opening day in mid

April and continued for 65 days.

Hartzler's results were similar to those of current surveys of stocked trout streams in Pennsylvania. Fishing pressure during the early part of the season is intense, but it quickly declines after about four weeks. On opening day Hartzler estimated that there were about 1,000 anglers on this 3-mile stretch of stream and accounted for about 5,300 hours of fishing. By mid-June fishing pressure had declined to about 140 hours per mile per week. Presumably, the main motivation of these anglers was to harvest trout.

We resurveyed the fishery in this same section in 1988 and 1989 and found dramatic differences relative to 1976. During the first two months of the 1976 season, fishing pressure was substantially higher than in 1989 -- 7,100 vs. 1,800 hours per mile. An important difference was that fishing pressure remained relatively high throughout the March to November survey when no-harvest regulations were in effect. Fishing pressure on stocked streams typically falls to near zero by July.

Perhaps even more impressive, was the change in fishing success. Catch rates of trout increased from 0.22 to 1.35 per hour from 1976 to 1988-89 and numbers caught per mile increased from 1,600 to 2,400. Of course, the vast majority of fish caught in 1976 were harvested while in our survey all were released. Clearly, the shift from a harvest to no-harvest regulation combined with the resurgence of wild trout brought about dramatic improvements in the sport fishery. However, it must be pointed out that the fishery in 1988-89 was not sustained wholly by wild trout. About 45% of the trout in this section were of hatchery origin, which we confirmed by examination of scales. Presumably these fish had escaped from a nearby state trout hatchery. Nonetheless, the response of the fishery would not have been realized without the no-harvest regulation.

The regulation change undoubtedly influenced the type of angler who fished this section. Though Hartzler did not gather information on types of terminal tackle that were used in 1976, it is likely that most anglers used bait and kept their catch. During the 1988-89 survey, the types of tackle used were flies 38%, artificial lures 9%, and bait 53%. Tackle appeared to have little effect on fishing success. The number of trout caught per hours for these three groups were 1.1, 1.3, and 1.3.

These statistics take on particular significance when we compute how many trout bait anglers caught and released, and how many of these released trout should have died as a result of wounds inflicted from baited hooks. We estimated that bait anglers caught and released 55% (4,800 per mile) of the total catch in this section. If hooking mortality was 25%, the approximate average of all studies summarized in the Mongillo study, the number of deaths due to bait fishing was 1,200 trout per mile -- 6% higher than the total trout density estimated from our population surveys in 1988. Or, to state this in another manner, if indeed hooking mortality was 25%, the entire trout population should have been wiped out by deaths from bait fishing.

That did not happen. The trout population in this section remains intact and fishing appears to be as good as ever. So what is the reason for this apparent disparity? One could argue that there is some error associated with any survey, and what we have here is simply a case of sampling error. Perhaps. It is not as easy to assign probable errors limits to this type of study as it is to something like a Harris poll, in which the reported error is typically $\pm 3\%$. I would argue that even if the error was $\pm 50\%$ in this study, we would still have an apparent disparity between what was expected and what happened.

Alternatively, we can accept the estimates as good ones. In which case we would have to conclude that hooking mortality could not be as high as 25%. And, we might further conclude that perhaps bait fishing is not likely to decimate trout populations in no-harvest trout fisheries. The latter conclusion is borne out by other studies.

The upper Housatonic River in northwest Connecticut had been managed as a put-and-take trout fishery since the 1920's. A flies-only section was designated in the 1940's, but otherwise management remained unchanged until 1980. PCB's were discovered in trout in 1976 and the following year a health advisory was issued, which warned that fish should not be consumed. The state temporarily discontinued stocking trout and then resumed stocking under a catch-and-release management plan.

Robert Orciari and Gerald Leonard, Connecticut Department of Environmental Protection, recently published the results from a

7-year study of this fishery. They monitored the trout population and fishery in a 5.9-mile section of stream, which was divided into two areas: any tackle (2.8 miles) and flies only (3.1 miles). The fishery was sustained wholly by brown trout that were stocked at three different sizes ranging from about 4.5 to 10.5 inches.

The no-harvest regulation contributed to good survival of stocked trout and as the study progessed, numbers of holdover trout (stocked in previous years) increased. Some stocked trout survived up to five summers. The average annual survival of brown trout stocked at ages of 12 months or more was about 40%. Such survival is exceptionally high compared to trout stocked in streams subject to harvest. Where fishing pressure is intense and harvest is allowed, even a 5% annual survival of stocked trout would be considered quite good.

During 1981, the first year of the new regulations, fishing pressure was modest. But, the following year it nearly doubled; between April and October there was an estimated 1,030 trips per mile. Fly fishermen accounted for 85% of the total pressure in both management areas and bait anglers accounted for 10%. Even in the section where any lure was permitted, fly fishermen made up 52% of the total anglers.

The Housatonic River fishery had not been surveyed when put-and-take regulations were in effect. The only available measures of fishing success are diaries kept by volunteers, most of whom were fly fishermen. Volunteers who kept diaries in 1981-1984 reported high catch rates of trout -- 1.47/hour, which was about the double the catch rate when harvested was allowed. These anglers were more skilled than the average fishermen interviewed after 1981. Among all anglers the average catch rate was 0.77/hour with little difference among tackle type: flies 0.80, lure 0.63, and bait 0.75 trout per hour.

The success of the catch-and-release fishery on the Housatonic River provided the impetus for a carefully designed study of similar regulation changes on the Farmington River in northwest Connecticut. The Farmington River supported the largest put-and-take trout fishery in the state with annual stockings of about 46,000 trout in 27 miles of stream.

William Hyatt, Connecticut Department of Environmental Protection, supervised a study in which the put-and-take fishery in 1983 and 1984 was compared with data from 1988 and 1989 after a no-harvest regulation was implemented on 2.7-mile stretch. Like the Housatonic River fishery, there were no tackle restrictions and the stream was stocked annually with brook, brown, and rainbow trout.

Within a year after catch-and-release fishing was instituted, numbers of holdover trout increased. Annual survival of brown and rainbow trout ranged from 33 to 37%, which was comparable to that in the Housatonic River. However, the most dramatic changes occurred in the fishery statistics.

After the regulation change, the number of fishing trips doubled -- from 1,060 to 2,190 per mile. Increases in catch rate were even more impressive; these increased from 0.26 to 0.77 trout per hour. The combined effect of higher fishing pressure and improved catch rates produced a nearly fivefold increase in total numbers of trout caught -- from about 3,800 to nearly 18,000. Presumably, most of the 3,800 were harvested, while all of the 18,000 trout should have been released.

An important outcome of the no-harvest regulation on the Farmington River, which was also true for Spring Creek and the Housatonic River, was that fishing pressure remained relatively high throughout the time when the stream was in fishable condition. Because there was no closed season, anglers could fish there before the regular season opening. This extended fishing season certainly contributed to the high total fishing effort. Thus, even though total effort doubled, the average number of anglers on the stream at any one time was not double that under put-and-take regulations.

Fly fishermen made up the largest proportion of anglers (76%) on the no-harvest section of the Farmington River, which was similar to the Spring Creek and the Housatonic River fisheries. Bait anglers followed with 20% of the total and lure fishermen accounted for 4%. Bait angling tended to be highest in spring and declined thereafter.

A hooking mortality study was also conducted on the Farmington River. Catches from volunteer anglers were held in cages in the stream for three days to assess mortality. Of the 50 trout caught with bait, 10% died and of the 22 fish caught on flies, none died. Hyatt suggested that the bait anglers were well aware of the concern over hooking mortality and that they may have been more careful in their handling of the fish than the average bait angler would be.

Hyatt used three different hooking mortality rates to estimate the number of deaths due to bait angling. His low value of 10% was taken from the Farmington River study, the moderate value of 25% is an average of a large number of studies, and the high value of 62% is the extreme for such studies. Estimated mortality rates from the moderate and high values exceeded the actual mortality rates that Hyatt estimated from time of stocking until midsummer. He concludes that the actual number of trout lost to hooking mortality is less than the moderate rates (25%) that he used. This is the same conclusion that I reached after analyzing the Spring Creek data.

Do results of these studies suggest that hooking mortality from baited hooks is as low as that from flies? No -- that would be an unwarranted conclusion. Rather, I think the results suggest that hooking mortality was not as high as one might predict from experimental studies. And, that losses due to hooking mortality were not sufficiently high to prevent these fisheries from substantially improving under no-harvest regulations.

Why might bait fishing not be harmful?

There are three reasons for the apparent low rates of hooking mortality in these studies.

First, no-harvest regulations that allow for any tackle type are not heavily used by bait anglers. On the Connecticut rivers bait anglers accounted for only 10 to 20% of the total and at Spring Creek they made up 38% of all anglers. Though solid data are not available, it is likely that bait anglers constituted the majority of fishermen when harvest was allowed on these fisheries. According to anglers who have fished Spring Creek for many years, bait fishing was the norm and fly fishermen were in the minority. The assumption here is that the majority of bait anglers harvest their catch and that when harvest is prohibited, many will fish elsewhere.

The second reason is that with no-harvest regulations there is a shift in the most commonly used baits. We noted a high incidence of minnow baits on Spring Creek with few anglers using worms, salmon eggs, cheese, etc. Unfortunately, we did not systematically collect data on bait types, so that this observation must be considered subjective. The use of relatively large baits, such as minnows, should lead to fewer incidents of deeply hooked fish.

Third, bait fishermen that we observed tended to drift their baits in a manner similar to wet fly or nymph techniques. Many even fished an upstream dead drift. With this type of fishing, I would expect anglers to set the hook at soon as the fish strikes, thus reducing the incidence of deep hooking. Anglers who allowed their baits to lie on the bottoms of deep holes were rare.

The latter two reasons for the apparently low rates of hooking mortality are largely speculative. Data on bait choice and fishing method would not be difficult to collect and should be investigated. Perhaps we have been wrongfully stereotyping bait fishermen into a single category that does not accurately represent this segment of the angling public. A fresh, unbiased examination of bait anglers may provide some surprising results.

Management Implications

Am I suggesting that bait angling be allowed on all existing no-harvest fisheries? Certainly not. However, I am suggesting that this issue merits careful re-examination. Besides the Farmington River study, I am aware of only one other study in which the effects of bait angling were carefully studied.

Spencer Turner, Missouri Conservation Department, documented the fishery on the Meramec River, which was managed as a trophy trout area. The fishery was supported by stocked brown trout and wild rainbow trout. For several years the bag limit was three trout per day and the minimum length limit was 15 inches, and any tackle was permitted. Bait anglers constituted about 50% of the fishing pressure. Bait angling was then prohibited because trout suffered high mortality rates. Turner showed that after prohibition of bait, annual mortality of brown trout decreased from 83% to 57% and hooking mortality decreased from 27% to 4%. These data certainly supported the notion that bait angling was harming the trout population.

Results from a companion study, that was conducted at the same time as the Meramec River survey, suggest that data from the Meramec River should be interpreted with caution. The North Fork of the White River had the same bag limit and size limit as the Meramec River, and bait fishing was permitted. The North Fork fishery was also supported by stocked brown trout and wild rainbow trout. Trout populations in the North Fork increased even more than in the Meramec River, where bait was prohibited. During the same time period, total annual mortality of brown trout declined from 75% to 40% in the North Fork, even though hooking mortality increased from 9% to 20%.

Reasons for the improvement in the trout population of the North Fork are not obvious. Perhaps some environmental factor was responsible for increased survival. The important point is that trout populations in the Meramec River did not improve relative to those in the North Fork; thus one cannot safely conclude that the elimination of bait fishing in the Meramec River was solely responsible for reduced trout mortality. A second important finding was that hooking mortality accounted for a minor portion of total mortality. Other causes, presumably natural ones, were eliminating a large number of trout each year.

This study highlights the need for further investigations. Even though Turner's study was well designed, factors beyond his control appeared to have greatly influenced the results. The unexpected and uncontrollable are common in field experiments.

For the moment, let's assume additional studies confirm that most no-harvest trout fisheries can sustain high catch rates and desirable sizes of trout while still permitting bait angling. Would such findings lead to a major overhaul in current regulations? I think not. And I would further suggest that trout fishing in general could benefit.

Regulations are not likely to be overhauled because of the importance of public opinion and tradition. The regulations of most, if not all states, reflect both biological and social factors. The number and size of fish that may be harvested is often a function of the amount of protection needed to ensure the well being of the species in question. However, many regulations are adopted because of social reasons, such as not opening the season for bass on Mother's Day. Harvest may be highly restrictive because anglers perceive that additional restraints are needed, even though biological data do not indicate that such restrictions are needed.

Fishing is a sport and like many sports, tradition is an important aspect. Certain stream segments have been designated as flies-only for many years -- these are part of the sport's tradition. To attempt to change this tradition, could bring the rath of a multitude of anglers down upon an agency. Agencies need angler support and to invite such an uprising would not be wise. In short, I suspect that agencies will avoid tampering with well-established, traditional fisheries.

On the other hand, to allow bait fishing on no-harvest areas might provide agencies with an opportunity to increase the mileage of no-harvest waters. Just as agencies may be reluctant to alter current flies-only regulations, they may also be reluctant to propose new no-harvest waters that exclude bait anglers. If they can provide an improved fishery without excluding any segment of the angling public, it may be easier to enlist local support for establishment of new no-harvest fisheries. The end result could be more miles of high quality, no-harvest fisheries.

<u>Opinions expressed here do not necessarily represent those of the U.S. Fish and Wildlife Service nor the Pennsylvania State University.</u>