A SUMMARY OF SALMONID HOOKING MORTALITY

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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 This report summarizes the literature and some unpublished records on hooking mortality as it relates to salmonids under the jurisdiction of the Washington Department of Game.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 Unpublished records and personal communications were collected by calling knowledgeable professionals, not only from Washington, but from other states and provinces.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 successfully 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?

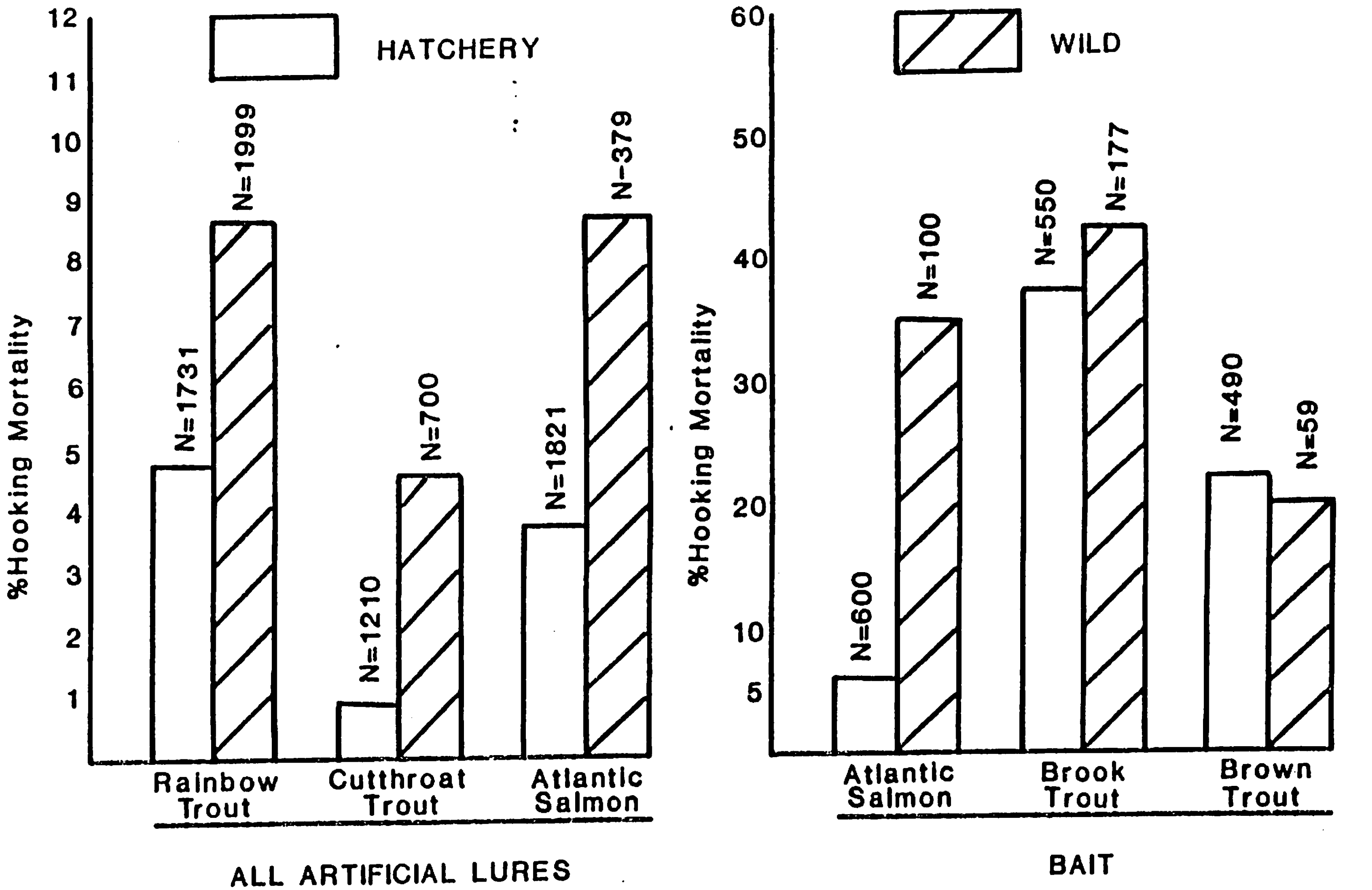


Figure 1. Comparison of hooking mortality between fish adapted to hatchery and wild environments. Only species with similar experiments done on hatchery and wild fish were included. Atlantic salmon are landlocked.

Cartographer Susan Peterson

Wydosky, et al (1976) compared various blood chemistry changes from hooked and playe.. 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.

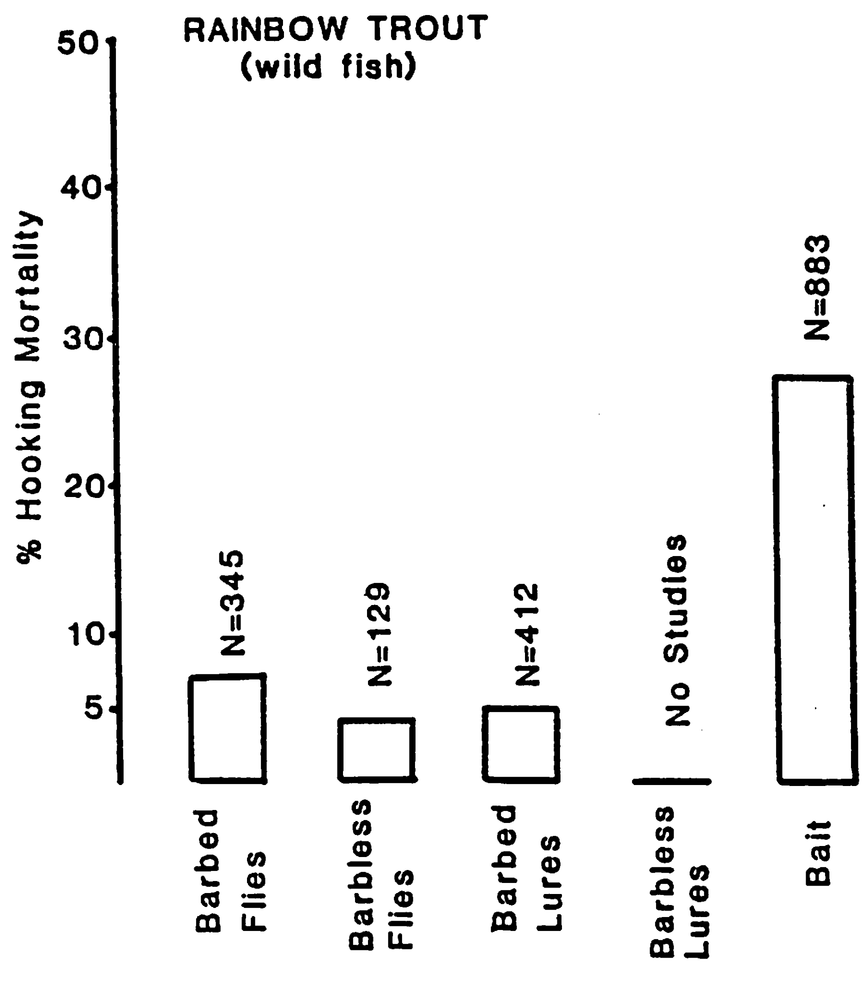
Figures 2 through 6 depict comparisons between hooking mortality caused by flies with barbed and barbless hooks, lures with barbed and barbless hooks and bait. Single hook and treble hook data were grouped together with the appropriate gear. Various hook sizes and treble vs. single hooks will be discussed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



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

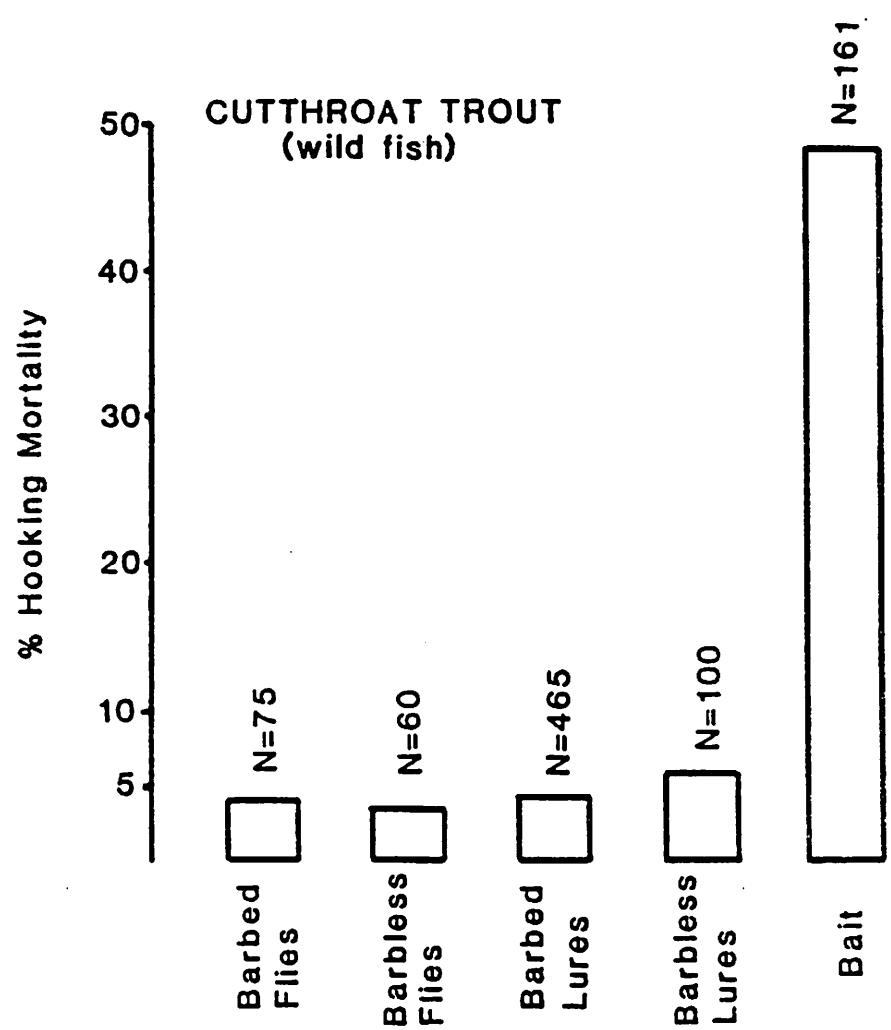


Figure 3. Hooking mortality associated with various gear and bait.

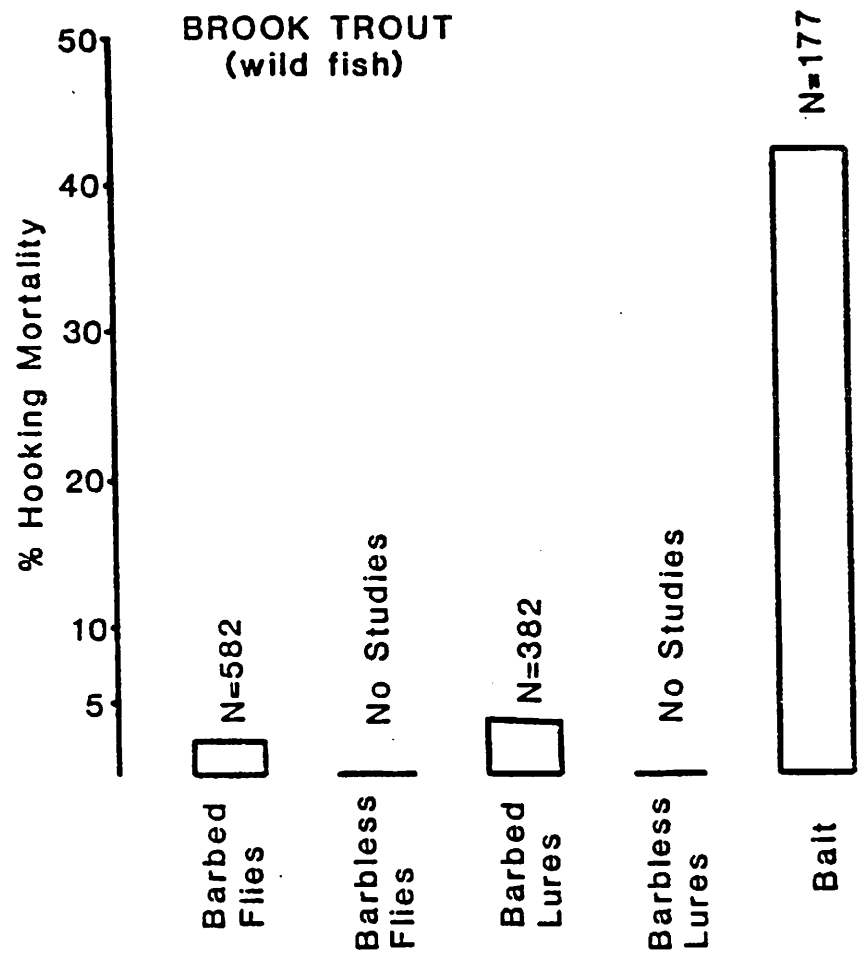


Figure 4. Hooking mortality associated with various gear and bait

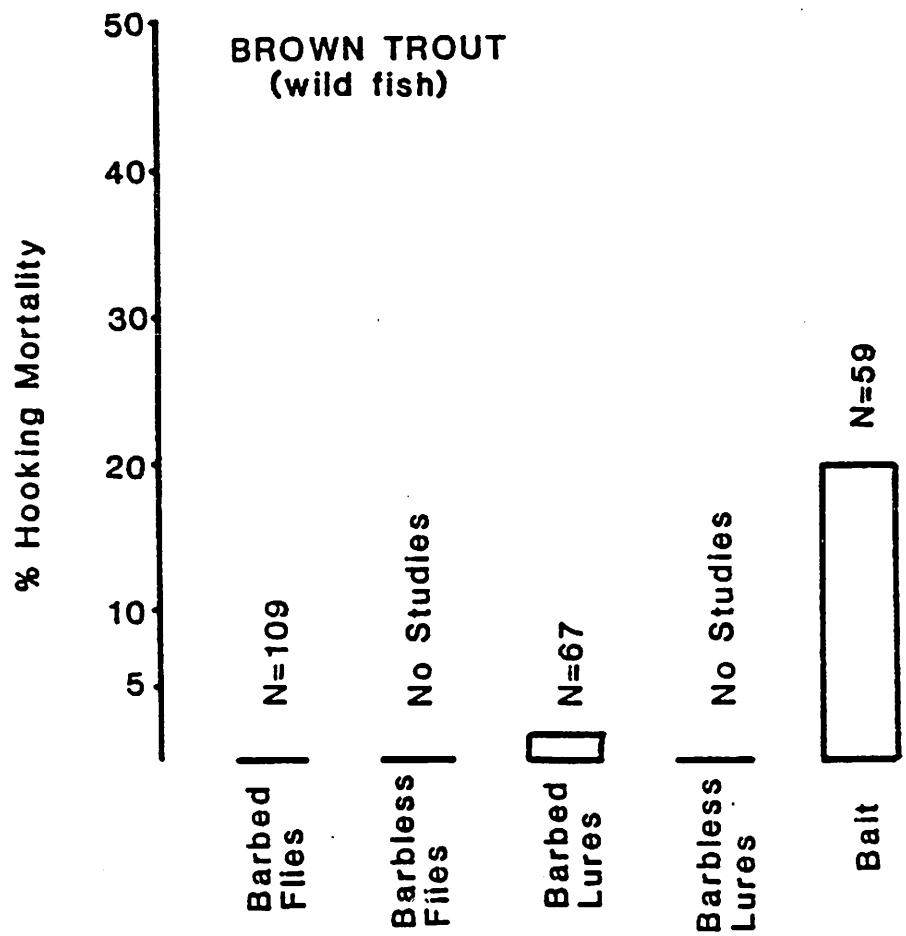


Figure 5. Hooking mortality associated with various gear and bait

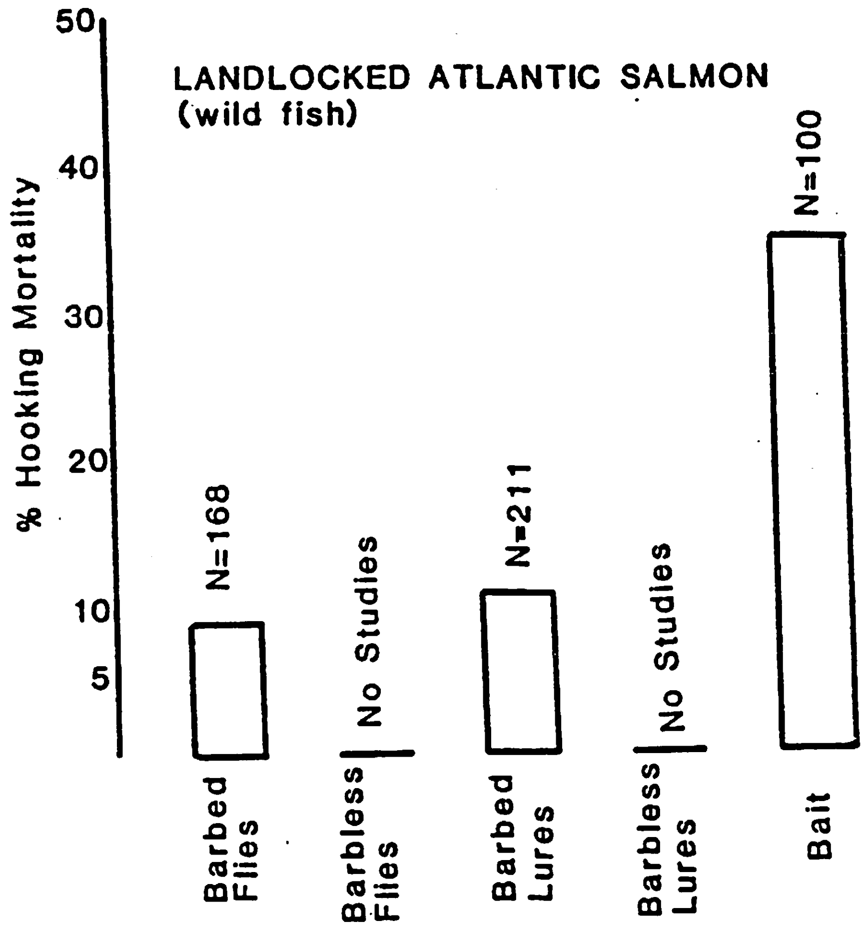


Figure 6. Hooking mortality associated with various gear and bait.

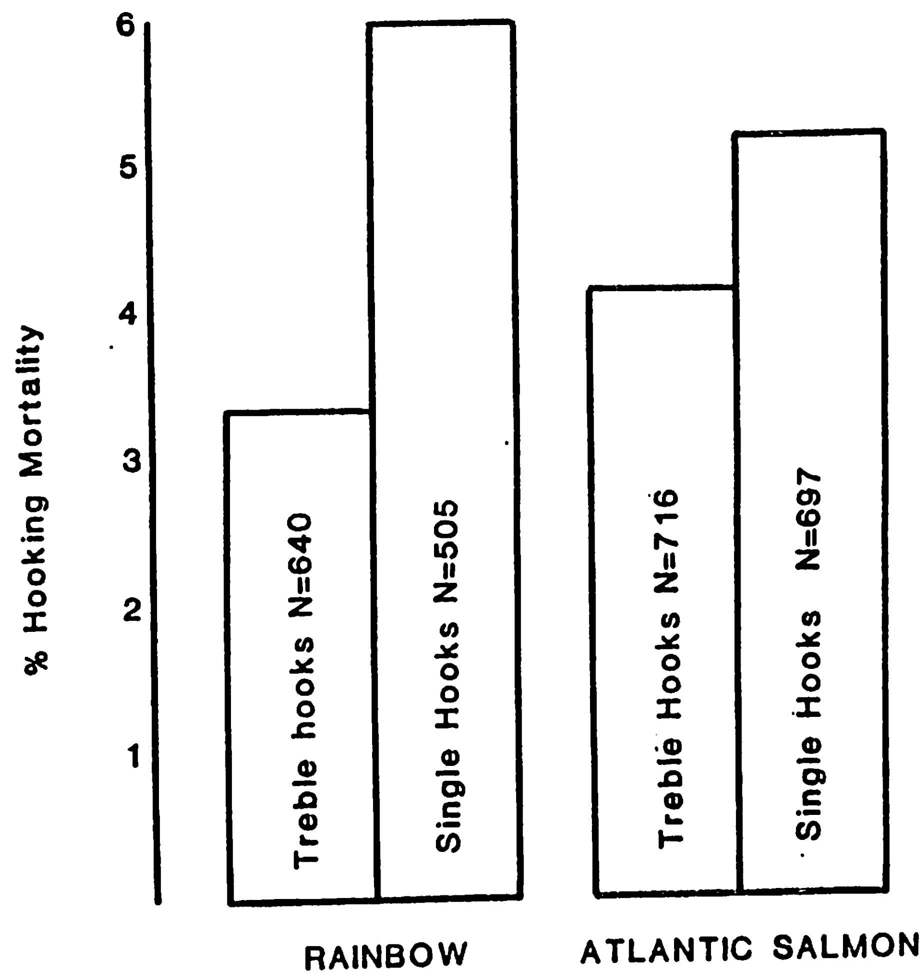


Figure 7. Comparison of hooking mortality betyween lures with treble hooks and single hooks.

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 wit 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

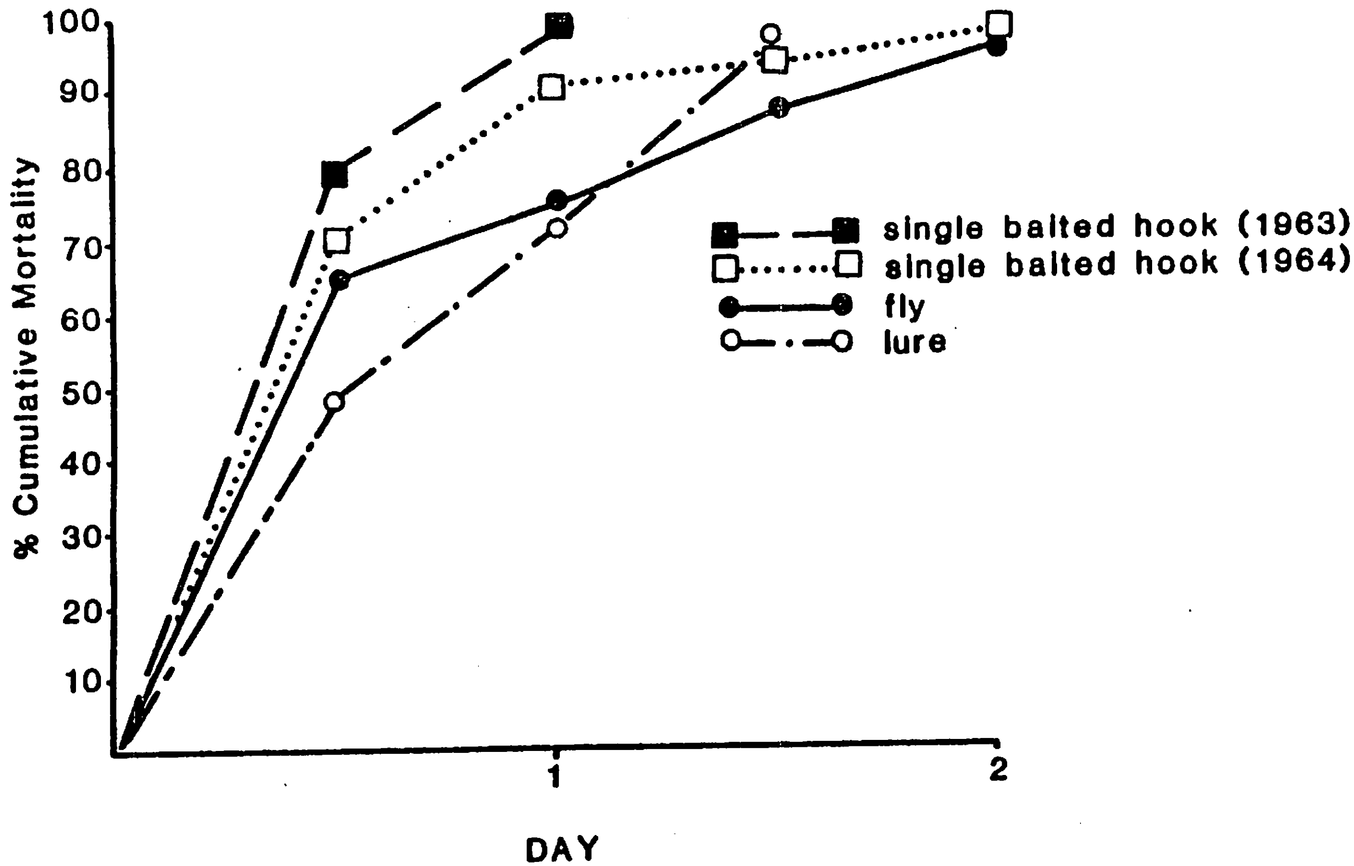


Figure 8. Cumulative mortality of wild rainbow trout caught on three types of gear (Stringer, 1967). Fish held for 10 days at 15-17°C.

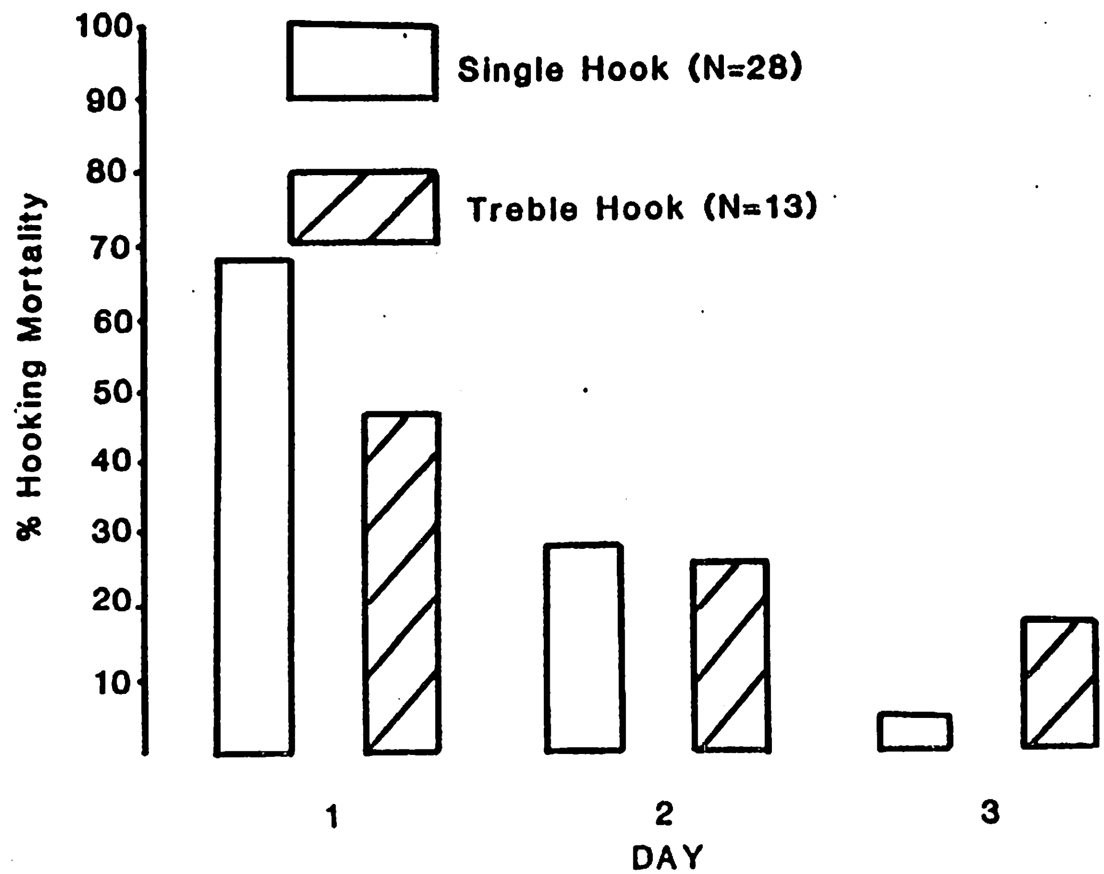


Figure 9. Effect of delayed hooking mortality in hatchery rainbow trout from two types of hooks on lures (Klein, 1965). Fish held for 3 days at 14.5° C.

(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

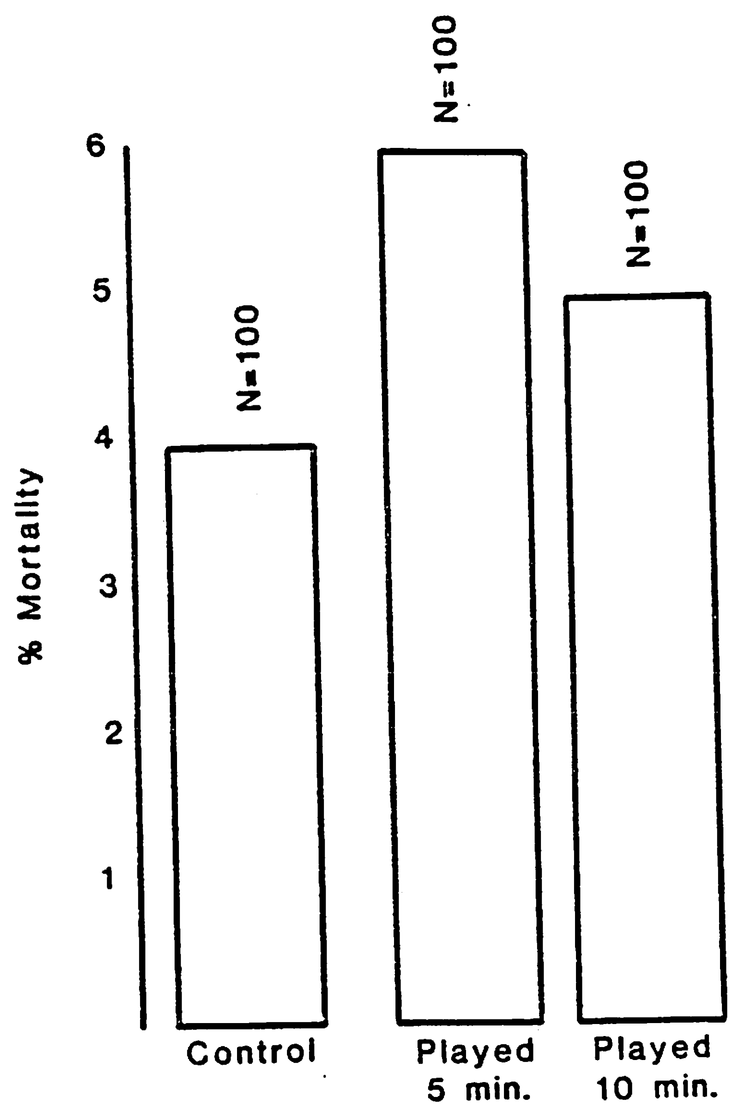


Figure 10. Mortality of wild cutthroat trout caught on lures and played for 5 and 10 minutes. (Marnell and Hunsaker, 1970)

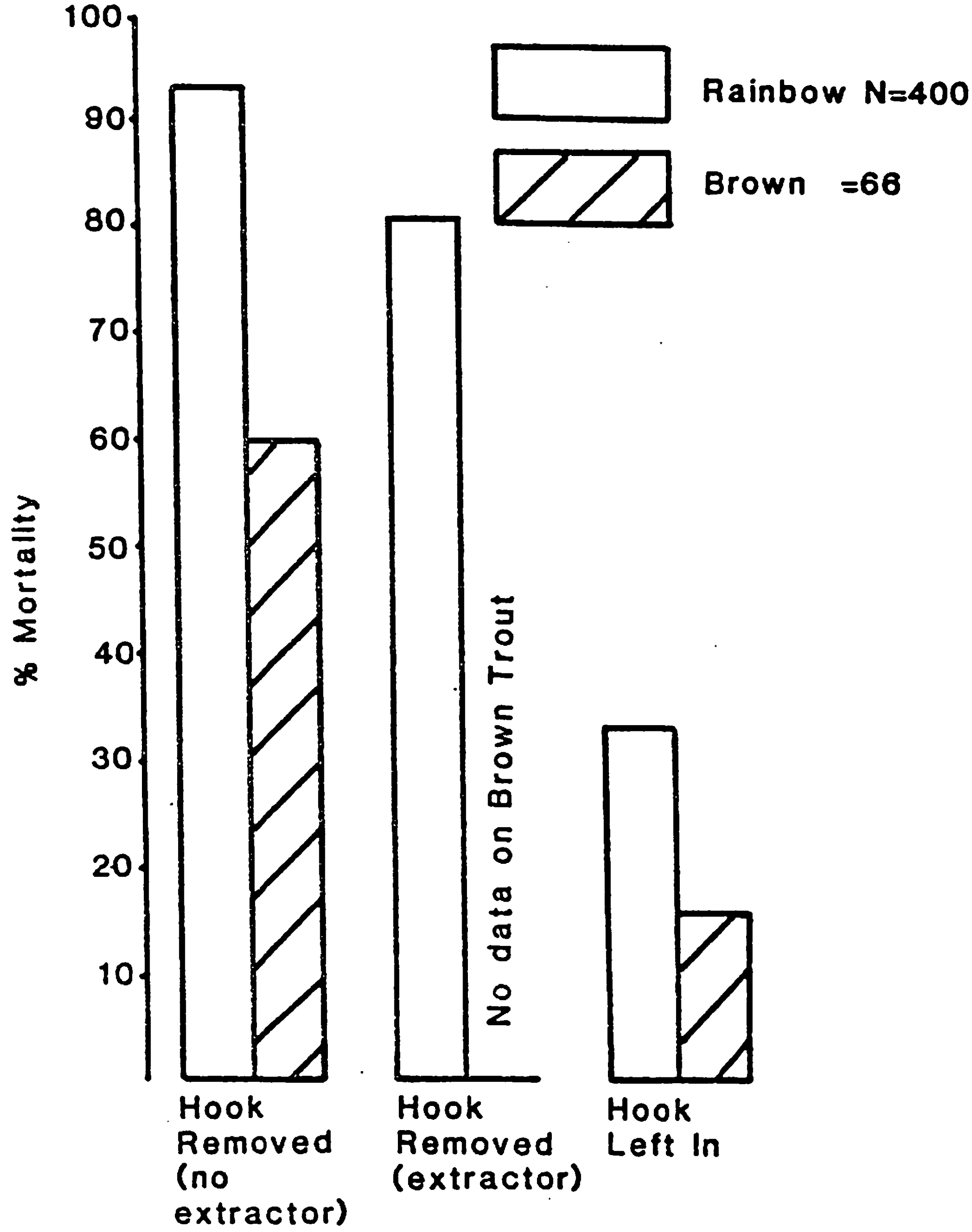


Figure 11. Differential mortality of deeply hooked rainbow trout (Mason and Hunt, 1967) and brown trout (Hulbert and Engstrom-Heg, 1980) related to handling procedures. All fish were caught on worms.

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

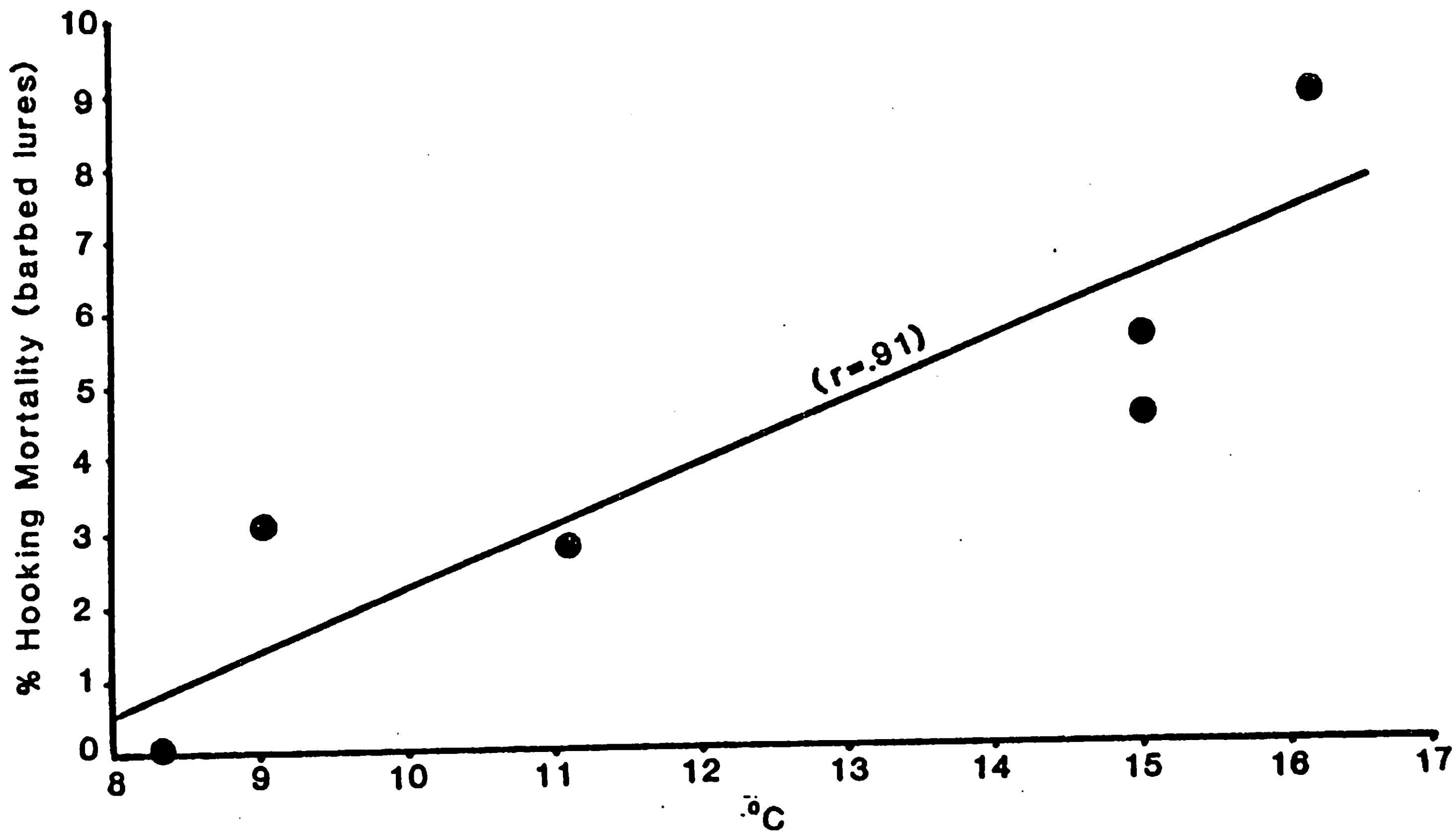


Figure 12. Regression of hatchery rainbow trout hooking mortality on rising water temperatures(Dotson, 1982).

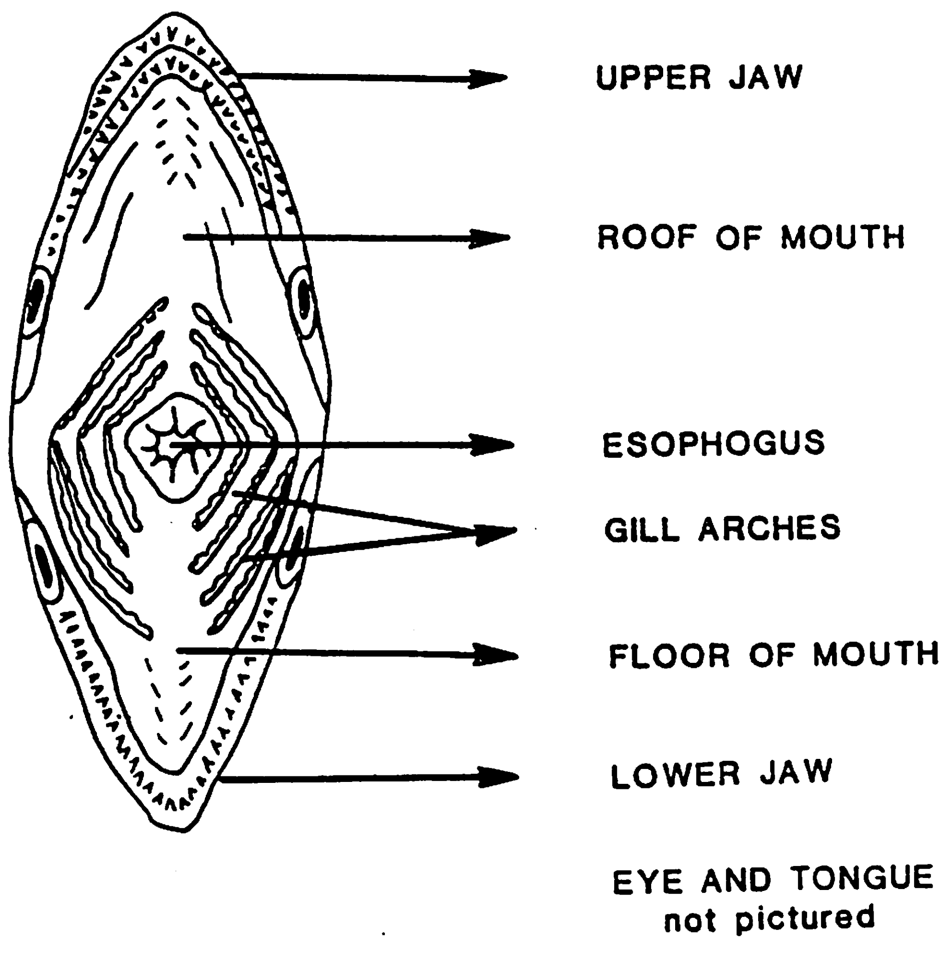


Figure 13. Diagrammatic view of a salmonid mouth illustrating hook placement areas.

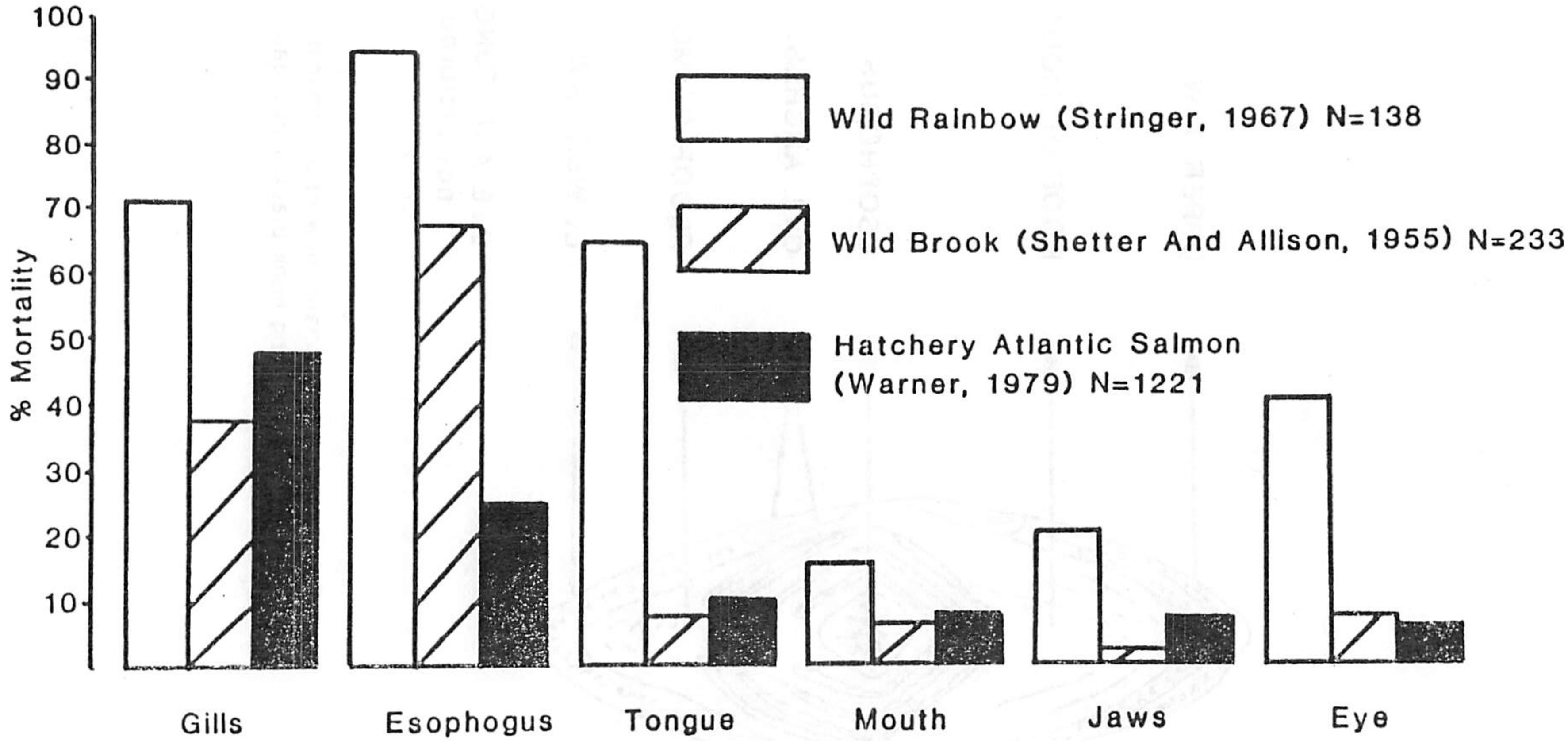


Figure 14. Mortality of three species of salmonids caught on various gear types related to anatomical hooking site.

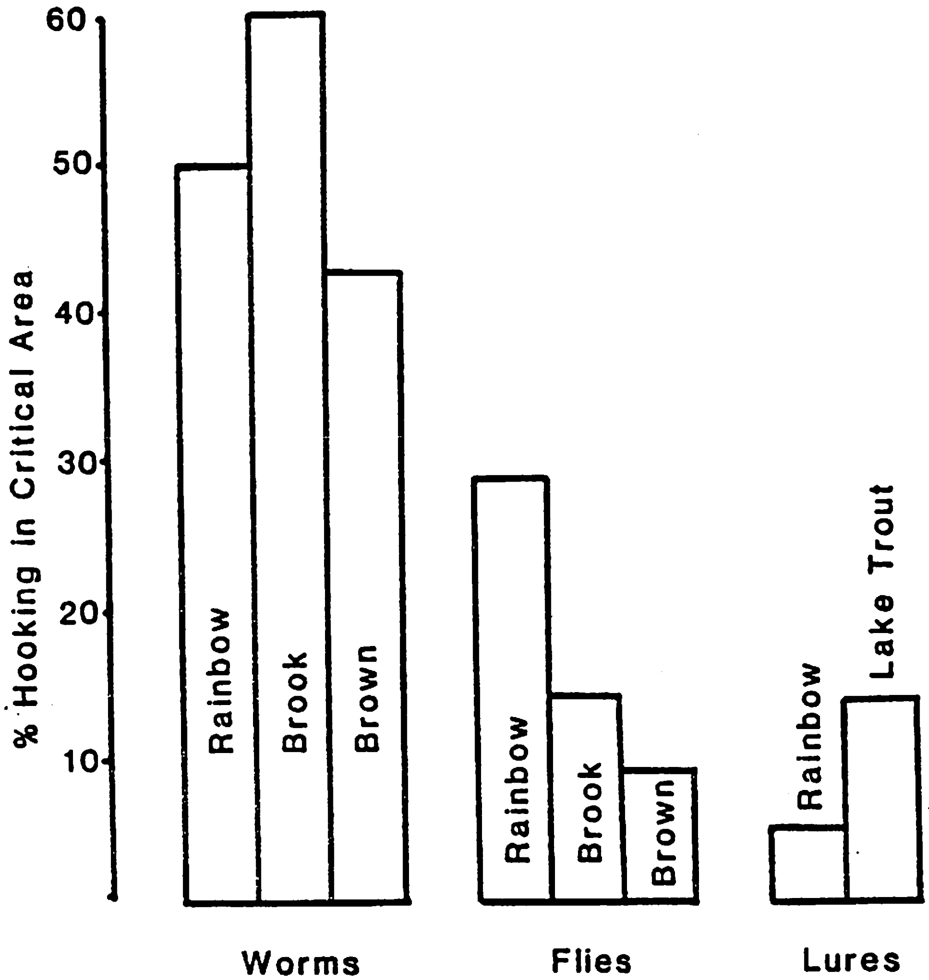


Figure 15. Percent hooking occurance in critical areas (Esophogus, gills, tongue, eye) for various species and gear types. Data from Shetter and Allison, 1955, Falk et al, 1974 and Stringer, 1967.

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 Flies	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[b]	Time Held	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