FISHERY RESEARCH

**Annual Performance Report**
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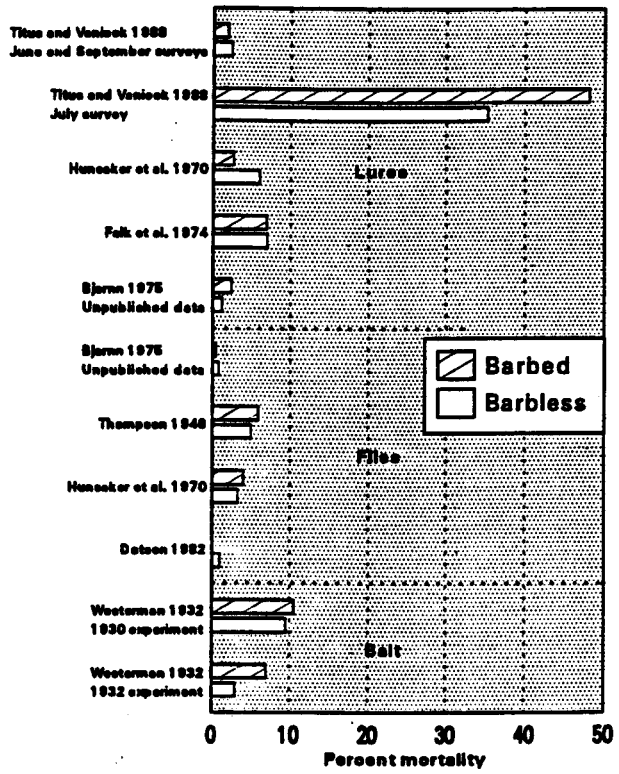


**PROJECT 4 WILD TROUT REGULATION STUDIES**
**Subproject1. Barbless Hook Evaluations**
**Subproject2. Regulation Workshop Development**

**PROJECT 5 ANGLER COMPLIANCE STUDIES**


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## TABLE OF CONTENTS

**Page**

**Subproject No. 1. Barbless Hook Evaluations**

ABSTRACT ..... 1

INTRODUCTION ..... 2

OBJECTIVES ..... 3

METHODS ..... 3

Individual Study Summary ..... 3
Meta-analysis ..... 4
Population Simulations ..... 6
Barbless Hook Survey ..... 9

RESULTS ..... 9

Individual Study Summary ..... 9
Meta-analysis ..... 12
Population Simulations ..... 12
Barbless Hook Survey ..... 12

DISCUSSION ..... 17

RECOMMENDATIONS ..... 21

ACKNOWLEDGEMENTS ..... 22

LITERATURE CITED ..... 23

## LIST OF TABLES

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 ..... 7

Table 2. Five natural mortality scenarios used for simulating effects of barbless hook regulations in Idaho fisheries for slow and medium growth stocks ..... 8

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## LIST OF TABLES (Cont.)

**Page**

Table 3. Summary of past individual hooking mortality studies directly comparing barbed versus barbless hooks. Sample sizes are in parentheses ..... 10

Table 4. Comparison of p-values obtained via four meta-analysis techniques that combined past barbed-versus barbless hooking mortality studies by gear type ..... 13

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..... 14

## LIST OF FIGURES

Figure 1. Summary of all past study trials directly comparing hooking mortality from catching and releasing nonanadromous trout with barbed versus barbless hooks ..... 11

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, and five times with either barbed or barbless hooks. Bars denote range of differences under five possible natural mortality scenarios. . 15

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..... 16

**Subproject No. 2. Regulation Workshop Development**

ABSTRACT ..... 26

**Project 5. Angler Compliance Studies, Subproject No.: 1**

ABSTRACT ..... 27

# ANNUAL PERFORMANCE REPORT

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## 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 1 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 is 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 lures 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.

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## 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 reduci,'g hooking losses for rainbow trout *Oncorhynchus mykiss* caught with bait. However, as 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):

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

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 regulation 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 |
| $t_o$ | -.12 | .12 | .52 |
| $L_{oo}$ | 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 = number of recruits at age 1;
$A_{max}$ = maximum age;
K, $t_o$ $L_{oo}$ = Von Bertalanlfy 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 mean hooking mortality of past studies summarized in this report;

Table 2. Five natural mortality scenarios used for simulating effects of barbless hook regulations in Idaho 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 babless hooks. Sample sizes are in parentheses.

| Study | Gear type | Species | Hooking mortality Barbed | Hooking mortality Barbless | Original significance Text ($X^2$ 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 | 35.3 (51) | OTG | 0.09 | 0.27 | 0.13 |
| Titus and Vanicek 1988 (spring/fall) | 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 cutthroat 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 |
| Bjornn 1975 (unpublished data) | flies | hatchery cutthroat trout | 0.4 (256) | 0.8 (264) | NT | 0.29 | 0.10 | 0.02 |
| Thompson 1946 | 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 rainbow trout | 20.5 (200) | 9.5 (200) | NT | 0.37 | 0.06 | 0.02 |
| Westerman 1932 (1932 trial) | bait | hatchery rainbow trout | 7.0 (200) | 3.0 (300) | NT | 0.02[b] | - - | 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] Denotes statistical significance.

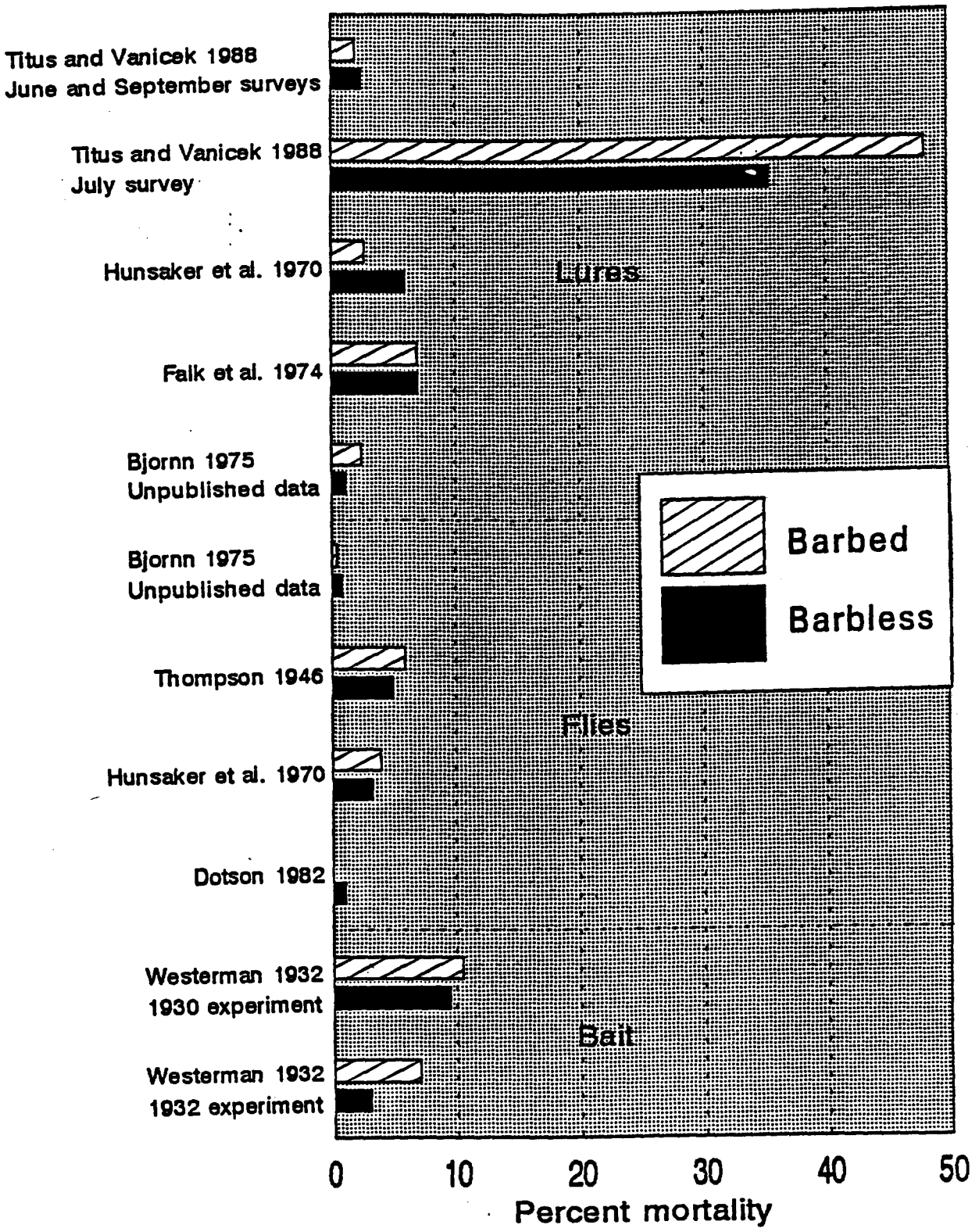


Figure 1. Summary of all past study trials directly comparing hooking mortality from catching and releasing nonanadromous trout with barbed versus barbless hooks.

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* | | 0.03* | [b] |
| 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.

| | | 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/lures | 9 | 0.002 | -0.007 | -0.001 |

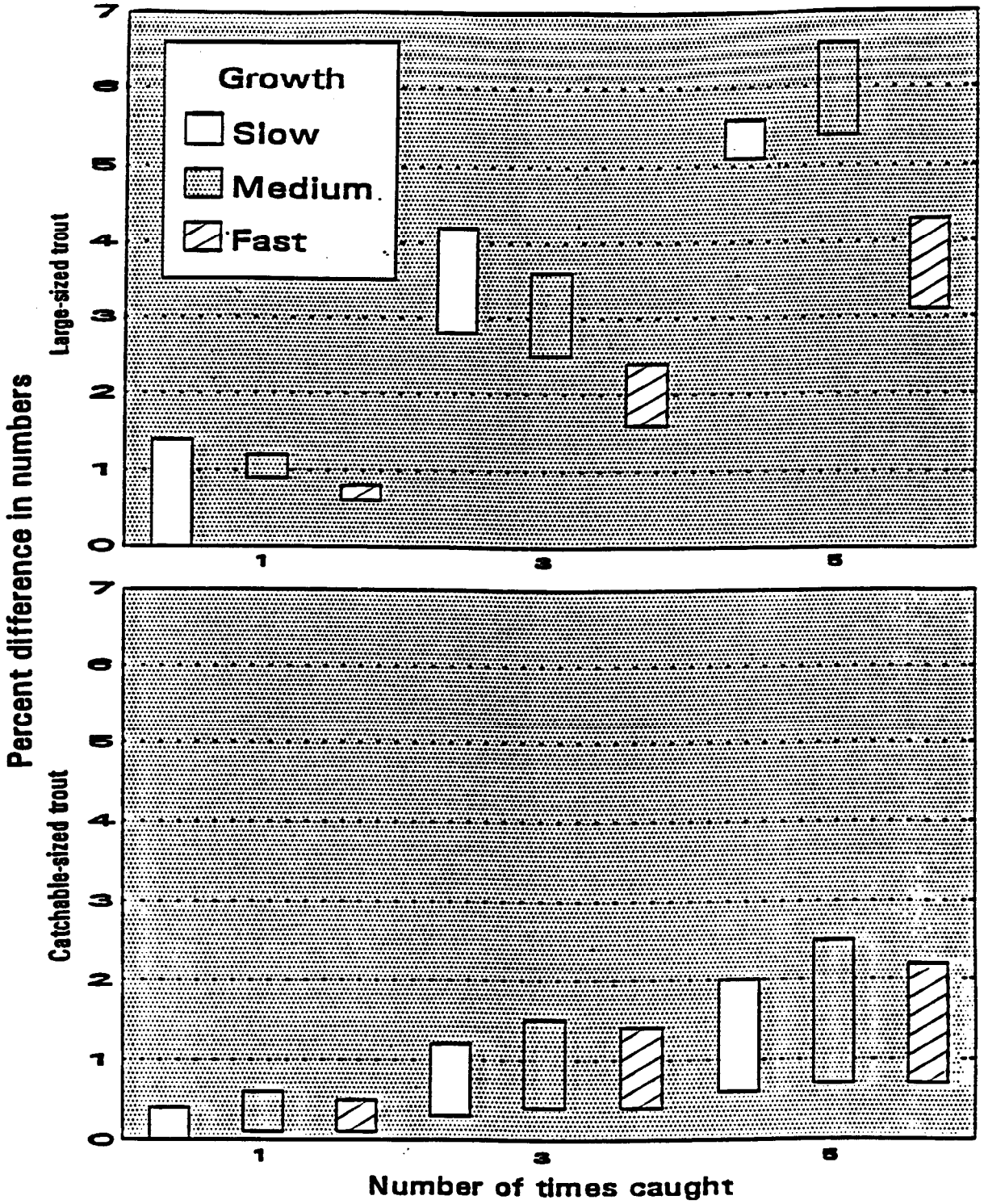


Figure 2. Percent difference in numbers of catchable-sized (>153 mm) and large trout (>254 or 305 mm) available to anglers in hypothetical fisheries of varying growth when all vulnerable fish in the populations are caught one, three, or five times with either barbed or barbless hooks. Bars denote range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

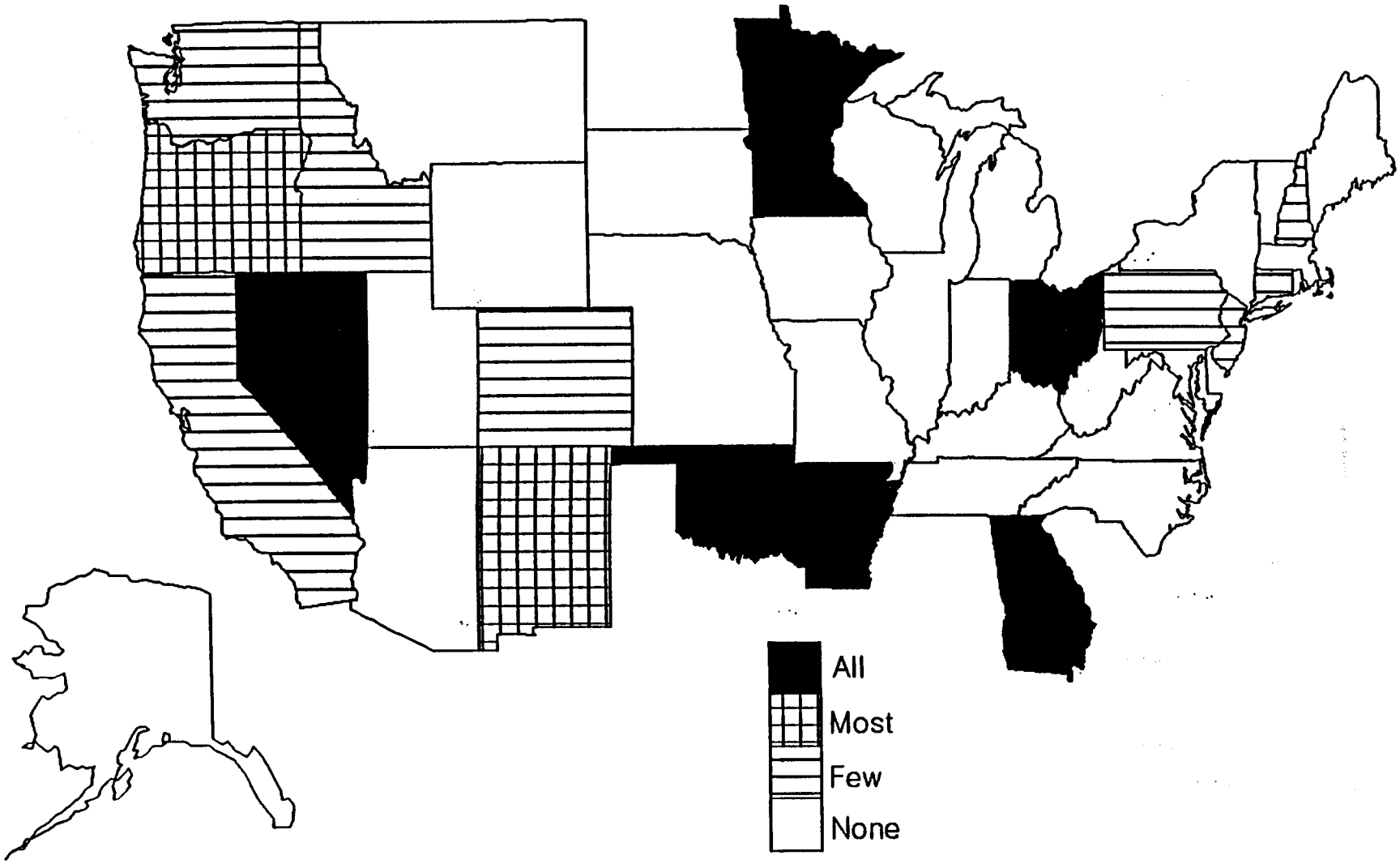


**Figure 3. Prevalence of barbless hook requirements in special regulation fisheries for resident trout in U.S. streams. States missing from the map do not have resident trout stream fisheries with special regulations meeting our definition.**

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 'pest 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 mode!!ng 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.

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**ANNUAL PERFORMANCE REPORT**

State of: Jdaho

Grant No.: F-73-R 7. 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.

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**ANNUAL PERFORMANCE REPORT**

State of: Idaho

Grant No.: F-73-R-17. Fshery 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 the Idaho Department of 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 Panhandle Regional 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 Panhandle Regional 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.

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IDAHO DEPARTMENT OF FISH AND GAME

Steven M. Huffaker, Chief
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