A REVIEW OF RECENT STUDIES OF HOOKING MORTALITY FOR CHINOOK AND COHO SALMON WITH RECOMMENDATIONS FOR FISHERY MANAGEMENT AND FUTURE RESEARCH

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EXECUTIVE SUMMARY

The mortality rate for salmon caught and released during hook-and-line fisheries is an important component of the information needed to effectively manage salmon fisheries. The hooking mortality rate currently used by most fishery management agencies on the Pacific Coast is based on a review conducted in 1986. The rate recommended from the 1986 review is applied to coho and chinook salmon in both commercial troll and recreational fisheries. New studies on the hooking mortality of salmon caught by hook-and-line fisheries have been conducted since the 1986 review. This report summarizes the results of a review of these new studies by a group composed of technical representatives of the Washington Department of Fisheries, Puget Sound Treaty Indian Tribes, and the Northwest Indian Fisheries Commission.

These recent studies represent significant additions to the research on hooking mortality because: (1) the new studies looked at fisheries and geographic areas of interest (e.g., recreational salmon fisheries in the marine waters of Washington); (2) the new studies were often similar in experimental design which facilitated comparison of their estimates of hooking mortality; (3) the new studies looked at recent-year fisheries which have characteristics similar to what is expected in the near future; (4) many of the studies were reviewed with respect to short-comings of previous research before they were implemented and incorporated these comments into their experimental design; and (5) the recent studies attempted to examine various causal factors associated with hooking mortality as well as directly estimate a hooking mortality rate. These new studies represent the best scientific information now available and provide an opportunity to replace rates based on consensus opinion (the basis of the currently used estimate) with estimates made using experimental data.

Based upon a review of the new studies, the technical group recommends the following hooking mortality rates for recreational fisheries conducted in marine waters which require the use of barbless hooks:

Coho Salmon:	sublegal lengths -	**15%**
	legal lengths -	**7%**
Chinook Salmon:	sublegal lengths -	**20%**
	legal lengths -	**10%**

There was not sufficient information to recommend hooking mortality rates for chinook and coho salmon caught by recreational fisheries in estuarine and riverine areas. The available studies indicate that the hooking mortality rates for these areas may be different from those in marine areas. Therefore, we recommend that research to determine the hooking mortality rate for salmon caught by recreational fisheries in estuarine/riverine areas be considered a high priority, especially considering the magnitude of the catch in some estuarine fisheries (e.g., the Buoy 10 fishery at the mouth of the Columbia River). Of the several research recommendations we make, we feel this is the most important.

We concluded that there was not compelling evidence for recommending a change from the hooking mortality rate currently used for chinook and coho salmon caught and released by commercial troll fisheries.

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INTRODUCTION

Increasingly, managers of Pacific salmon (*Oncorhynchus spp.*) are using or considering selective-retention regulations for hook-and-line fisheries. These regulations require that fish with certain identifiable characteristics be released back to the water. Most commonly, these regulations require the release of all fish of a certain species or all fish smaller (or larger) than a specified size. In a recent development, several agencies have proposed a new approach to selective fisheries in which all hatchery-produced juvenile salmon would be marked by removal of a fin. Subsequently, the release of all unmarked fish in hook-and-line fisheries targeting the adult returns from the marked releases would be required. The goal of selective fishery management is to enable a fishery to harvest different groups of fish at different rates.

Effective planning for and management of selective fisheries which use hook-and-line gear requires reliable estimates of the rate of mortality caused by the hooking and subsequent release of a fish. Hooking mortality has been extensively studied for various freshwater species where selective fishing or complete non-retention regulations have been used. There is some literature on hooking mortality for Atlantic and Pacific salmon. However, through the mid-1980s this research did not result in a single, widely-accepted estimate of hooking mortality for use in the management of chinook (*O. tschawytscha*) and coho salmon (*O. kisutch*) caught in marine waters off the Pacific Coast. In 1986, Stohr and Fraidenburg (1986) conducted an innovative assessment of the collective opinions of a panel of experts (the Delphi Study) to arrive at a consensus estimate of hooking mortality for chinook and coho salmon. This estimate is the basis of the hooking mortality rates currently used for the management of commercial and recreational salmon fisheries along the Pacific Coast.

Recently, several new studies examined the hooking mortality rates of chinook and coho salmon caught by recreational fisheries in the marine waters of British Columbia and Washington and in estuarine/riverine areas of Alaska. New studies on commercial troll fisheries have been conducted in Alaska. In March 1993, an assignment was made by Washington state and tribal fishery managers to a technical team to review these recent studies and any other pertinent information (Appendix A). Based upon their review, the team was to recommend appropriate hooking mortality rate estimates for use in Pacific Coast recreational fishery management. The team worked on this project from June through August 1993. This report contains the review and recommendations of the team.

These recent studies represent significant additions to the research on hooking mortality conducted prior to the Delphi Study because: (1) the new studies looked at fisheries and geographic areas of interest (e.g., recreational salmon fisheries in the marine waters of Washington); (2) the new studies were often similar in experimental design which facilitated comparison of their estimates of hooking mortality; (3) the new studies looked at recent-year fisheries which have characteristics (such as size composition of fish) similar to that expected in the near future; (4) many of the studies were reviewed with respect to short-comings of previous research before they were implemented and

incorporated these comments into their experimental design; and (5) the recent studies attempted to examine various causal factors associated with hooking mortality as well as directly estimate a hooking mortality rate. In summary, these new studies provided an opportunity to replace rates based on consensus opinion with estimates made using experimental data.

THE DELPHI STUDY

In 1986, the Washington Department of Fisheries (WDF) conducted a Delphi study to determine hooking mortality rates for use by WDF and the Pacific Fishery Management Council in management planning for salmon fisheries (Stohr and Fraidenburg 1986). This study was in response to confusion about, and requests for, refined estimates of hooking mortality to use in the management of commercial troll and recreational salmon fisheries. The study focused on chinook and coho salmon, commercial troll and recreational fisheries, barbed versus barbless hooks, and the size of fish. Hooking mortality was defined as the proportion of fish hooked, retrieved, and released that would die as a result of being caught and released from that gear.

What Is A Delphi Study? "What choice should you make when there is little or no information to help inform your decision making?" This is the central question a Delphi study is supposed to answer. The technique was developed as one way to create consensus expert opinion in cases where absolute answers are unknown or impossible to obtain (Linstone and Turoff 1975). The process involves selecting a panel of experts (who are kept anonymous) and then, through a series of questionnaires, asking them to answer the pertinent questions under study. Between each series of questionnaires a project coordinator provides feedback to the panel by summarizing the results from each "round" of questioning plus circulating any supporting information provided by the panelists. This feedback (questionnaire results and documentation) is then available for the panel's use in answering the next questionnaire. This cycle, questionnaire followed by feedback, is repeated until the answers converge at a consensus. At this point the assumption is made that any consensus opinion emerging from the panel of experts is a more accurate answer than that available from other sources (Fusfeld and Foster 1971).

The advantages of a Delphi study are that it promotes clear communication about the issues that are uncertain, it tends to force an answer, and it encourages balanced participation and give-and-take concerning the available information (Zuboy 1981). The weaknesses of the technique are that results do not represent true experimental outcomes; rather it is a consensus opinion. Also, it does not generate new scientific data to increase our understanding of the issue under question. The technique is dependent upon the quality of the existing information and the interpretation of the experts.

Results. The panelists in the WDF Delphi study concluded that hooking mortality rates were higher for sublegal-sized fish than they were for legal-sized fish, but felt there was

insufficient data to quantify the differences. They also did not identify mortality rate differences by species or gear. The panel's consensus mortality rate estimates for hook-and-line fisheries (commercial or recreational) using barbed hooks was 30% for both chinook and coho salmon. A scale factor for converting the mortality rate for barbed hooks to a mortality rate for barbless hooks was not determined during the study. However, responses by the panel indicated that the appropriate factor was between 5% and 20%, from which the authors of the study recommended using 15% (i.e., the median of the panel's assessments). Thus, the recommendation from the Delphi study conducted by WDF was that a single hooking mortality rate of 30% be applied to chinook and coho salmon in both troll and recreational fisheries. This rate was to be reduced to 26% if barbless hooks were used in the fishery (Stohr and Fraidenburg 1986).

DESCRIPTION OF NEW STUDIES

We reviewed the results of eight studies which estimated the rate of hooking mortality for coho and/or chinook salmon. All these studies have been reported since the Delphi study (Stohr and Fraidenburg 1986). The studies were conducted in Washington, British Columbia, or Alaska. Four of these studies were presented in peer-reviewed fisheries journals while the other four studies were in reports that have not been as widely circulated. Important attributes and results of the new studies are summarized in Appendix B.

Commercial Fishery Studies

Two of the studies (Wertheimer 1988; Wertheimer et al. 1989) estimated hooking mortality rates for chinook salmon released by commercial salmon trollers. Both studies were conducted in the marine waters of Southeast Alaska. The study reported by Wertheimer (1988) was conducted during August 1986 and the study by Wertheimer et al. (1989) was conducted during August 1987. The design of the two studies was nearly identical. Chartered commercial trollers caught salmon using the terminal gear they would use to catch coho salmon during a chinook-salmon closure (plugs, spoons, and hootchies). All chinook salmon caught were anesthetized using an electrically charged basket prior to measuring and tagging the fish. Captured fish were held from one to five days (Wertheimer 1988) or four to six days (Wertheimer et al. 1989) in large marine net pens to monitor intermediate mortality. A total of 506 chinook salmon were caught and monitored in 1986 and 913 chinook salmon were caught and monitored in 1987. The lengths of the chinook salmon in both studies ranged from 27 cm to 106 cm.

Independent variables examined as possible factors influencing mortality were: length of fish, injury location, lure type, depth of fishing, vessel, and transfer time (from on-board tanks to the net pens). Stepwise logistic regression was used to identify the independent variables significantly related with mortality in both studies. Fish length and injury location were identified as major factors affecting mortality in both studies. Combining the results

of both studies, Wertheimer et al. (1989) concluded that a minimum-maximum range for the hooking mortality rate of troll-caught chinook salmon is 18.5% to 26.4%. Within this range, the appropriate rate depends upon the length composition of the catch.

Recreational Fishery Studies

The six remaining studies estimated a hooking mortality rate for salmon caught using recreational fishing gear. Two of the studies were conducted in estuary/freshwater areas and the rest were conducted in marine waters.

Estuarine/Freshwater Areas:

Both estuarine/freshwater studies were conducted in Alaska, one on coho salmon (Vincent-Lang et al. 1993) and one on chinook salmon (Bendock and Alexandersdottir 1992).

Vincent-Lang et al. (1993) estimated hooking mortality rates for coho salmon caught in two areas of the Little Susitna River, Alaska during July and August, 1988. Coho salmon were caught using baited, single-point, barbed hooks from a lower river area under tidal influence (estuarine) and an upriver area above tidal influence. Coho salmon caught by biologists and volunteer anglers in the estuarine area were double tagged and released (N = 384)[1]. The hooking mortality estimate for this area was based on the recovery of tags from the recreational fishery conducted in the river and at a weir about 30 km upstream of the tagging area. Tags not recovered at the weir or from the recreational fishery were assumed to have died due to hooking mortality. At the weir, a second sample of 77 coho salmon was collected by biologists with the same fishing methods used in the estuarine area. These fish were held in a live pen at the weir for five days. A control group of 77 coho salmon were netted at the weir, tagged identically to the hooked fish, and held with the angled sample.

Independent variables examined as possible factors influencing mortality were: injury location, presence/absence of bleeding, landing time, handling time, scale loss, and hook removal (i.e., was the hook removed or not). Independent variables significantly related with hooking mortality were examined using a series of chi-square tests. Injury location and hook removal were identified as significant explanatory variables at both fishing locations. Estimated mortality rates were 69% for the estuarine-caught group, 12% for the group caught at the weir, and 1% for the control group.

Bendock and Alexandersdottir (1992) examined the intermediate (one day to five day) hooking mortality of chinook salmon caught by anglers in the Kenai River, Alaska during four separate experiments conducted in 1989, 1990, and 1991. Chinook salmon

[1] N = sample size, total number of fish used by the study to estimate hooking mortality.

(N = 446 for the combined studies) caught by recreational anglers were tagged with radio transmitters and followed for five consecutive days. The fate (lived or died) of each tagged fish was determined from its movement pattern during the five-day monitoring period.

Independent variables examined as possible factors influencing mortality were: sex, length of fish, injury location, presence/absence of bleeding, hook type, terminal gear, angling method, fishing period, and handling time. Cox's proportional hazards regression model was used to identify the independent variables significantly related with mortality. Injury location and presence/absence of bleeding were identified as significant explanatory variables. There were no significant differences between experiments in overall mortality rates. Average mortality for all four experiments combined was 7.6%, and ranged from 4.0% to 10.6%. In all experiments, small males had the highest mortality rate (9.3% to 17.6%) when compared to large males and females (0.0% to 10.7%).

Marine Areas:

There are four studies that estimated hooking mortality rates for coho and/or chinook salmon caught in marine waters. Two of the studies were conducted in southern British Columbia and two in Washington. One study specifically examined hooking mortality rates for coho and chinook salmon during their first year of ocean residence (ocean age-0) and was limited to fish less than 30 cm (12 inches) in length. The other studies examined hooking mortality rates for coho or chinook salmon with a range of lengths typical to those encountered in most recreational fisheries.

1. Gjernes et al. (1993) examined hooking mortality rates for sport-caught coho and chinook salmon during their first year of ocean residence. They used fish less than 30 cm in length as a surrogate measure for ocean age-0 fish. Fishing was conducted during September and October, 1985 in the Strait of Georgia near Nanaimo, British Columbia. Angling was by volunteer anglers aboard a 10-m charter vessel. Fish were held a minimum of six hours (and up to 30 hrs) in live tanks on the vessel. A total of 124 chinook salmon and 289 coho salmon were monitored for hooking mortality.

   Independent variables examined as possible factors influencing mortality were: barb type (barbed/barbless), hook type (single point/treble point), and injury location. Recursive causal models were used to identify the independent variables significantly related with mortality. Injury location was identified as the most important explanatory variable. The ranges of estimated hooking mortality rates across all barb/hook combinations were: 6.4% to 16.9% for coho salmon; and 23.3% to 40.0% for chinook salmon.

2. Gjernes (1990) reports two separate experiments that estimated the hooking mortality rate for larger (> 30 cm) coho and chinook salmon. Both experiments were conducted in the Strait of Georgia near Nanaimo.

The coho salmon experiment was conducted during May 1986. All fish (N = 83) were caught by biologists fishing from a 10-m vessel. Fish were held in a live tank while on the vessel. They were later transferred to a marine net pen where they were held a minimum of 24 hrs. Three barb/hook combinations were used: single-point, barbed; single-point, barbless; and treble-point, barbed. This study did not conduct analyses to determine significant causal factors influencing hooking mortality rates. Hooking mortality rates ranged from 3.2% to 18.2% across the barb/hook combinations examined.

The chinook salmon experiment was conducted from April to June 1987. All fish (N = 152) were caught by biologists trolling flashers and hootchies with single-point, barbed hooks from a sport fishing boat. Fish were held in an on-board live tank and later transferred to a marine net pen. These fish were held a minimum of 24 hrs and up to 72 hrs. This study did not conduct analyses to determine significant causal factors influencing hooking mortality rates. The overall hooking mortality rate was 9.9%.

3. Natural Resources Consultants (1991) conducted a hooking mortality experiment in the Strait of Juan de Fuca near Sekiu, Washington during May and June 1989. Both coho (N = 146) and chinook (N = 67) salmon were captured. Fishing was conducted from a variety of small, sport-fishing boats. Anglers used tandem (two single-point hooks rigged in tandem) "mooching" rigs with single-point, barbless hooks. Sixteen different anglers representing a combination of volunteer anglers and biologists participated in the experiment. Captured fish were held in on-board live tanks until transferred to a marine net pen. They were held at least 24 hrs in the pen. There were no analyses conducted to determine significant causal factors influencing hooking mortality rates. Hooking mortality rates were 6.8% for coho salmon and 9.0% for chinook salmon.

4. NRC (1993) conducted another hooking mortality experiment involving only coho salmon (N = 536) in the Strait of Juan de Fuca near Sekiu, Washington during September 1992. Fishing was conducted from a 17-m charter boat using a variety of terminal gears. More than 30 different volunteer anglers participated in the experiment. Captured fish were held in on-board live tanks and later transferred to a marine net pen where they were held at least 96 hrs.

   Independent variables examined as possible factors influencing mortality were: length of fish, injury location, number of hooks (single or tandem rig), handling time, scale loss, contact with boat, and whether or not a landing net was used. Stepwise logistic regression was used to identify the independent variables significantly related with mortality. Injury location was identified as the major factor affecting mortality. The overall hooking mortality rate was 6.2%.

Issues Common to All Studies

Two common criticisms of hooking mortality studies are related to the holding of the fish to observe mortalities occurring after the hooking event. One criticism is that holding the fish for extended periods of time induces its own mortality and that mortalities due to holding and handling stress are incorrectly attributed to hooking mortality. Therefore, the hooking mortality rate may be over-estimated by studies where the fish are held for extended periods of time. Mortalities due to holding could best be addressed by the use of control groups (i.e., holding a similar group of fish captured by a benign method under conditions identical to the hooked fish). However, because of the difficulties in capturing a true control group only one of the reviewed studies used this approach. As described in the previous section, Vincent-Lang et al. (1993) used a control group in their study of sport-caught coho salmon in a freshwater area. The control group had a 1% mortality rate in comparison to a 12% mortality rate for the group that had been caught using sport gear. Five of the studies (Wertheimer 1988; Wertheimer et al. 1989; Gjernes et al. 1993; NRC 1991; NRC 1993) discuss the issue of holding-induced mortalities.

The second criticism related to holding is that the length of time the captured fish are held and monitored for mortality is not sufficient. The concern is that there may be mortalities due to hooking that occur after the fish are released from the holding facility. Therefore, hooking mortality rates may be under-estimated because there are mortalities occurring after the period of observation. For this discussion, we have categorized hooking mortalities into four groups: (1) immediate mortalities - those occurring between the time of landing and before transfer to a long-term holding facility (usually within several hours of capture); (2) one-day mortalities - those that occur during the first 24 hrs fish are held in a long-term facility; (3) 2-to-6 day mortalities - those that occur after the first 24 hrs of holding; and (4) delayed mortalities - those that occur after the fish are released from the holding facility.

The observations of each study for the first three groups are summarized in Table 1. A common conclusion of the studies was that the majority of the mortalities due to hooking occur during the first 24 hrs after capture. For the studies that reported on fish held at least 48 hrs, from 76% to 93% of all mortalities occurred during the first 24 hrs after capture (Table 1). In nearly all the researchers' opinions, the expected number of mortalities occurring after the holding period (i.e., delayed mortalities) is very small. However, several studies (Wertheimer 1988; Wertheimer et al. 1989; Gjernes 1990) stated that fish with a hook injury involving the eye may be subject to delayed mortality as these fish were often swimming sluggishly at the time of release. Specific to chinook salmon, Wertheimer (1988) states "It is unlikely that a high proportion of immature fish with this type of injury would survive." However, a relatively small proportion (5% to 20%) of fish sustained eye injuries in any of the studies. None of the studies attempted to directly estimate delayed mortalities.

Another common criticism of hooking mortality studies is that anglers participating in the experiment alter their behavior and handle the fish more gently than the "typical" angler. Participants in experiments, as demonstrated by various psychological studies, have a

Table 1. Summary of the percent of total mortalities by time period for each study (when reported).

STUDY	HOLDING TIME	SPECIES (N)[a]	% MORTALITIES BY TIME COMPONENT[b]		
			IMMEDIATE	1 DAY	2 TO 6 DAY
Wertheimer 1988	1 to 5 days	chinook (N = 108)	41%	52%	7%
Wertheimer et al. 1989	4 to 6 days	chinook (N = 168)	18%	64%	18%
Vincent-Lang et al. 1993		coho	NOT ADDRESSED		
Bendock and Alex-andersdottir 1992	monitored for 5 days	chinook	77% of mortalities occurred within first 48 hrs.		
Gjernes et al. 1993	6 - 30 hrs	chinook, coho (N = 76)	All but one mortality within 15 min. of placement in holding tank		
Gjernes 1992	24 - 72 hrs	chinook (N = 15)	All but two mortalities occurred within 1 hr of capture		
Gjernes 1992	at least 24 hrs	coho (N = 6)	All but one mortality occurred within 20 min. of capture		
NRC 1991	24 - 72 hrs	chinook, coho (N = 16)	50% of mortalities within 12 hrs of capture. All deaths within 24 hrs.		
NRC 1993	96 - 104 hrs	coho (N = 33)	70%	6%	24%

[a] N = total number of mortalities during holding period.

[b] Immediate = mortalities before transfer to net pens; 1 Day = mortalities within 24 hrs of transfer to net pens; 2 to 6 Day = all mortalities after first day of net pen holding and before release.

tendency to alter their behavior according to their perception of what the proper behavior is within the experimental context (NRC 1991). The expectation in this research is that the participating anglers would attempt to handle their fish in a manner which would reduce mortality. This behavior could tend to bias study results if handling were a significant causal factor in mortality. Both NRC studies (1991; 1993) considered angler experience and handling in their experimental design and examined it as a factor in their mortality rate analyses. They considered both the skill of the angler (NRC 1991) or the deckhand (NRC 1993) responsible for unhooking the fish. NRC (1991) concluded that even though anglers may have developed knowledge of the intent of the experiment, attempts by anglers to modify their behavior in a way that lowers mortality were negated by the so called "mayhem factor" of a real-life fishing situation.

Other landing and handling factors and their relationship to hooking mortality have been examined by one or more of the studies. The factors examined include: amount of time fish was played, amount of time fish was out of water during unhooking, whether or not a net was used to land the fish, whether or not the fish contacted the boat during landing, degree of de-scaling, and type of tool used to unhook the fish. A clear association of any of these factors with the hooking mortality rate was not demonstrated in any of the studies.

Injury location was identified as the most important factor affecting mortality in all of the studies. This assessment was done both quantitatively using multivariate regression or analysis-of-variance type models (Wertheimer 1988; Wertheimer et al. 1989; Bendock and Alexandersdottir 1992; Gjernes et al. 1993; NRC 1993) or more subjectively based on univariate chi-square tests or the observations of the experimenters (Gjernes 1990; Vincent-Lang et al. 1993; NRC 1991). Certain injury locations were noted to be particularly lethal. Most notably injuries involving the gills, gill arches, and isthmus caused a much higher mortality rate than other locations.

STRATIFICATION

Based on our review of the new literature, we determined that six major stratification factors should be considered for hooking mortality estimates. The motivation for the stratification is that there may be different hooking mortality rates among strata. The six stratification factors we considered were:

1. Fishery type (recreational/commercial troll),
2. Species (chinook/coho),
3. Fish size,
4. Fishing area (marine/estuarine/freshwater),
5. Fishing platform (large boats/small boats/charter boats), and
6. Terminal gear (barb/barbless hooks, single/treble hooks, hook size, single/tandem rigs, etc.).

A discussion of each of these stratification factors follows. In some cases, the significance of a stratum was clearly demonstrated by one or more of the studies. In other cases, study results were ambiguous and definitive conclusions were difficult to arrive at. We based our assessment of the significance of each stratification factor on: (1) tests for significant differences between levels defined for a stratification factor, when possible; (2) an examination of general trends exhibited in the data, both within and between studies; and (3) a more subjective determination based on how logical it was to expect differences among the levels of a stratification factor.

Fishery Type (Recreational/Commercial Troll)

Only two of the new studies (Wertheimer 1988; Wertheimer et al. 1989) applied directly to commercial hook-and-line fisheries. Both of these studies were conducted in Alaska using commercial troll gear typically used to target coho salmon during a chinook salmon non-retention fishery. The authors of these studies recommended hooking mortality rates of 26% and 22% for sublegal and legal-sized chinook salmon, respectively. While these studies are not directly comparable to the recreational studies due to different experimental methods and the time/areas they were conducted, the hooking mortality rates estimated from these studies were generally much higher than the rates estimated by the new studies for marine recreational fisheries. We concluded that separate hooking mortality rate estimates for each fishery type are appropriate. Logically, this is not unexpected due to differences both in gear type used (e.g., larger hooks and heavier weights in commercial fisheries) and fishing methods (e.g., potentially greater detection time before small fish are retrieved from commercial lines). The results of these studies are consistent with the hooking mortality rate from the Delphi study.

For recreational fisheries in marine waters, however, the new studies conducted in Washington and British Columbia suggest that actual hooking mortality rates may be less than the estimates currently in use. Gjernes (1990) estimated hooking mortality rates from 3% to 18% for legal-sized coho and chinook salmon caught using sport gear in marine waters (Table 2). He recommended using somewhat higher rates, from 7% to 15%, to account for differences in fishing gear and methods used in his study compared to the gear typically used by salmon anglers in marine waters. Gjernes et al. (1993) estimated hooking mortality rates from 6% to 40% for ocean age-0 coho and chinook salmon (Table 2). NRC (1991; 1993) estimated hooking mortality rates from 6% to 9% for chinook and coho salmon caught in marine recreational fisheries. Because the results from these studies are consistent and the estimates are generally much lower than the hooking mortality rate currently used, we concluded that hooking mortality rates for salmon caught in recreational fisheries are significantly lower from the rate currently used by Pacific Coast fishery management agencies. Determination of new estimates for management planning, however, must be assessed within each of the major areas of stratification discussed below.

Table 2. Summary of hooking mortality estimates for coho and chinook salmon caught by recreational fisheries in marine waters.

LENGTH DATA Mean (Range)	HOLDING TIME	TIME Months Year	RATE BY HOOK TYPE = #Died/#Caught				OVERALL MORTALITY	STUDY
			Single Barbed	Single Barbless	Treble Barbed	Treble Barbless		
COHO SALMON								
47 cm (34 - 62)	at least 24 hrs	May-June 1989		10/146 6.8%			10/146 6.8%	NRC 1991
Unknown	at least 96 hrs	Sep. 1992		33/536 6.2%			33/536 6.2%	NRC 1993
(< 30 cm)	6-30 hrs	Sep.-Oct. 1985	11/79 13.9%	12/71 16.9%	12/76 15.8%	4/63 6.4%	39/289 13.5%	Gjernes et al. 1993
(30 - 55 cm)	at least 24 hrs	May 1986	1/31 3.2%	1/30 3.3%	4/22 18.2%		6/83 7.2%	Gjernes 1990
CHINOOK SALMON								
67 cm (31 - 101)	at least 24 hrs	May-June 1989		6/67 9.0%			6/67 9.0%	NRC 1991
12" (< 30 cm)	6-30 hrs	Sep.-Oct. 1985	14/40 35.0%	10/43 23.3%	10/25 40.0%	3/16 18.8%	37/124 29.8%	Gjernes et al. 1993
(36 - 82 cm)	at least 24 hrs	Apr.-June 1987	15/152 9.9%				15/152 9.9%	Gjernes 1990

Species (Chinook/Coho)

The sample sizes in the four studies representing marine recreational fisheries (Gjernes 1990; Gjernes et al. 1993; NRC 1991; NRC 1993) are generally small which complicates the interpretation of the statistical comparisons of hooking mortality rates for chinook and coho salmon. Further, mortality rate has been demonstrated to be influenced by fish size (see below), and species and length are related. With these qualifications, the limited cases where comparisons between species can be made do suggest that there is a difference in hooking mortality rates between chinook and coho salmon.

The differences appear to be more pronounced for small, ocean age-0 salmon (fish less than 30 cm in length). In the study of small salmon by Gjernes et al. (1993), within a given gear configuration, two of the comparisons show a significant difference between species. The other two comparisons are not significantly different, but the statistical power of these tests is low due to small sample sizes (Table 2). If the different gear configurations are combined, these data show a significant difference between the hooking mortality rate for ocean age-0 chinook and coho salmon. Qualitatively, the point estimates for small chinook salmon are in all cases greater than for small coho salmon, and the overall rate for small chinook salmon is about twice that of small coho salmon. From this evidence, we concluded that the hooking mortality rate for ocean age-0 chinook salmon is higher than the rate for similar age coho salmon.

There is limited data available for chinook salmon greater than 30 cm in length. Comparisons of hooking mortality rates between legal-sized coho and chinook salmon can be made using the NRC (1991) data and the Gjernes (1990) data (Table 2). Neither of these comparisons is statistically significant, but the power of these tests is low due to small sample sizes. Qualitatively, in all cases where direct comparisons can be made, the rates for chinook salmon are higher than for coho salmon, although the differences are smaller than those observed for ocean age-0 salmon. While the data on species differences for legal-sized salmon is not as clear as for the smaller fish, we concluded that a difference does exist. The main justification for our conclusion is the significance of the data for the smaller salmon and because the direction of the differences between species is consistently in the same direction for all size groups. Because the information is ambiguous for legal-size salmon, future research should address this issue.

Fish Size

The influence of size of fish on hooking mortality rate was examined by most of the studies. Wertheimer (1988) and Wertheimer et al. (1989) present the most complete analysis of the effect of fish length on hooking mortality rate. For commercial troll-caught chinook salmon, the rate of hooking mortality was shown to be a function of length with smaller fish subject to a higher hooking mortality rate than larger fish. Bendock and Alexandersdottir (1992) found that smaller male chinook salmon had a higher hooking mortality rate than larger male or larger female chinook salmon. The studies by Gjernes (1990) and Gjernes et al. (1993) present data that indicate there may be differences in

hooking mortality rates between small (lengths less than 30 cm) and large (lengths greater 30 cm) coho and chinook salmon. However, these comparisons are complicated by the fact the experiments were conducted at different times and they involve small sample sizes when the size comparisons are made within a barb/hook gear type. Because fish size was identified as a significant factor affecting hooking mortality rates by the troll fishery studies, and there were data from other studies supporting this, we concluded that fish size (length) is a significant factor affecting hooking mortality.

Area of Catch (Marine/Estuarine/Riverine)

Based on limited data on sport-caught coho salmon in the Little Susitna River, Alaska, there may be a higher hooking mortality rate for salmon caught in estuarine areas compared to those caught in riverine areas (Vincent-Lang et al. 1993). Vincent-Lang et al. (1993) noted that the higher mortality in the estuarine area was partially due to a higher incidence of fish hooked in the gills or gullet and to a higher frequency of hooks being left in the fish when hooked in the head or mouth compared to the riverine area. Baranski (1980) reported differences in mortality between estuarine and riverine areas when using gill nets to capture chinook salmon for hatchery brood stock in the Skagit River. Baranski reiterated an opinion of many researchers that the higher mortality in the estuarine area was probably because the fish were in the transition zone between saltwater and freshwater and had not yet acclimated to the habitat change. No data exist to directly compare hooking mortality in marine areas with either riverine or estuarine areas. Based on the observations of Vincent-Lang et al. (1993) and Baranski (1980), we concluded that area of catch may be an important factor influencing hooking mortality. Due to the lack of data comparing areas, however, we feel further research on the effect of area of catch on hooking mortality is warranted.

Fishing Platform

None of the studies directly examined differences that could be attributed to the fishing platform. The commercial troll studies (Wertheimer 1988; Wertheimer et al. 1989) used power-troll vessels. The estuarine and riverine studies (Vincent-Lang et al. 1993; Bendock and Alexandersdottir 1992) used river boats, shore angling, or weirs. The studies of marine recreational fisheries conducted in Canadian waters (Gjernes 1990; Gjernes et al. 1993) used 10-m charter vessels and smaller private boats. The studies of marine recreational fisheries conducted in Washington used both small boats (NRC 1991) and a 17-m charter vessel (NRC 1993).

In these studies there were no instances where the platform factor was varied while all other factors remained relatively equal. Even the two NRC studies with different sizes of boats were conducted two years apart with other factors besides boat size differing between the years. Because of insufficient information, we were unable to draw conclusions about differences in hooking mortality rates between fishing platforms.

Terminal Gear

The majority of the data on differences in hooking mortality rates between terminal gears are from recreational fisheries in marine areas. While the information from the different studies is complementary, it is not directly comparable. There were important differences in the terminal gear used (i.e., hook types, hook sizes, and rigging) between the studies. Only one study examined differences between terminal gears in a freshwater fishing area.

Marine Areas:

The terminal gears used in the two NRC studies (1991; 1993) were more uniform than in the Canadian studies by Gjernes (1990) and Gjernes et al. (1993). Importantly, the gear used in the NRC studies more closely represents the typical fishing configurations used in marine recreational fisheries in Washington than do the Canadian studies (i.e., the NRC studies emphasized two, single-point, barbless, hooks rigged in tandem). The differences between the studies in gears used are summarized below.

KEY TERMINAL GEAR DIFFERENCES - MARINE STUDIES	
CANADIAN STUDIES	NRC STUDIES
• Single (size 1/0 and 4/0) and treble (size 4) point hooks • Tandem double and single hook sets • Barbed and barbless hooks • Lures • Trolling	• Single point hooks (for 1989 size 2/0 front and 1/0 trailing and for 1992 4/0 front and 3/0 trailing) • Tandem double hook sets • Barbless hooks only • Mostly herring bait, some lures • Mostly mooching, some trolling

Estimated hooking mortality rates for the major gear types examined in the studies of marine recreational fisheries are summarized in Table 2. Sample sizes are generally insufficient to draw definitive conclusions about mortality rate differences between the different terminal gears. In the NRC studies where tandem-hook riggings were used, the trailing hook was implicated as possibly causing more or increasing the frequency of lethal wounds (NRC 1993).

Freshwater Areas:

One study considered terminal gear differences in a freshwater recreational fishery for chinook salmon (Bendock and Alexandersdottir 1992). No significant differences in hooking mortality rates were found between bait, artificial lures, or bait/lure combinations.

RECOMMENDATIONS

Management Recommendations

Although we considered information from our review of all studies in determining our recommended hooking mortality rates for recreational fisheries, we gave more emphasis to those experiments which used the gear types predominant in the recreational fisheries of interest: single-point, barbless hooks. We also recognized that if any particular experiment was repeated, the point estimate of mortality would probably not be exactly reproduced. Therefore, we did not use any specific point estimate or specific combination of point estimates but recommended a rate (to the nearest whole percentage) consistent with the available data.

Marine Recreational Fisheries:

We recommend different hooking mortality rates for coho and chinook salmon. We also recommend different rates for sublegal and legal-sized fish. Although the available information does not conclusively demonstrate that legal-size coho and chinook salmon are subject to different hooking mortality rates, we believe that the risk of management error is greater with an assumption that no difference exists. For recreational fisheries in marine waters that require the use of barbless hooks, we recommend the following hooking mortality rates:

Coho Salmon:	sublegal lengths -	**15%**
	legal lengths -	**7%**
Chinook Salmon:	sublegal lengths -	**20%**
	legal lengths -	**10%**

Coho Salmon. The estimate of 15% for sublegal sized coho salmon was based on the 16.9% estimate for coho salmon less than 30 cm in length caught on single-point, barbless hooks (Gjernes et al. 1993). It was reduced to 15% because the sublegal category includes fish above the 30 cm length in the fisheries where it would be applied. The estimate of 7% for legal-sized coho salmon was based on the 6.8% (NRC 1991) and 6.2% (NRC 1993) estimates for ocean age-1 coho salmon caught on single-point, barbless hooks.

Chinook Salmon. The estimate of 20% for sublegal sized chinook salmon is largely derived from the estimate of 23% for chinook salmon less than 30 cm in length caught on single-point, barbless hooks (Gjernes et al. 1993). It was reduced to 20% because the sublegal category includes fish above the 30 cm length in the fisheries to which it would be applied. The estimate of 10% for legal-sized chinook salmon was based on the estimates of 9.0% for larger chinook salmon caught on single-point, barbless hooks (NRC 1991) and 9.9% for larger chinook salmon caught on single-point, barbed hooks (Gjernes 1990). Also, this rate is half that proposed for sublegal sized chinook salmon which is consistent with the available information.

We recognize that fishery managers use different hooking mortality rates for barbed and barbless hooks but we could not find support for different rates in the studies we reviewed. Our inability to detect a difference between barbed and barbless hooks is likely due to sample sizes insufficient for the degree of difference which may exist between these two gear types. Because we could not detect differences among terminal gear configurations, we felt that the preferable approach was to use the data from those studies that used gear configurations that most closely resembled the gear used in the fisheries to which the hooking mortality rate will be applied.

Estuarine/Riverine Recreational Fisheries:

Coho Salmon. There was only one study with information on the hooking mortality rate of coho salmon caught by recreational fisheries in estuarine/riverine areas (Vincent-Lang et al. 1993). This study was conducted in Alaska. Because of uncertainty about the applicability of the results of this study to estuarine/riverine fisheries outside Alaska, we have no management recommendations on hooking mortality rates for coho salmon caught by recreational fisheries in these areas.

Chinook Salmon. There was only one study with information on the hooking mortality rate of chinook salmon caught by recreational fisheries in estuarine/riverine areas (Bendock and Alexandersdottir 1992). This study was conducted in Alaska and the large size of the fish in the study was not typical of those caught by freshwater fisheries in Washington, Oregon, or California. Because of uncertainty about the applicability of the results of this study to other estuarine/riverine fisheries, we have no management recommendations on hooking mortality rates for chinook salmon caught by recreational fisheries in these areas.

Commercial Troll Fisheries:

Chinook Salmon. We concluded that there was not compelling evidence for recommending a change from the hooking mortality rate currently in use. Although Wertheimer et al. (1989) recommended different hooking mortality rates for sublegal and legal-sized chinook salmon caught and released by commercial troll fisheries, the difference in the recommended rates was small (about 4%).

Coho Salmon. There was no new information on hooking mortality rates for coho salmon caught and released by commercial troll fisheries. Therefore, we recommend no change from the rate currently used.

Research Recommendations

Our review identified several areas of research that should be completed to improve our understanding of hooking mortality and potentially improve management. These research recommendations come from our review of the six stratification factors. We present these recommendations in a ranked list (highest research priority listed first) that reflects the

relative potential for each factor to provide a significant opportunity to improve management. For each recommendation, we indicate why we consider it to be an area with important research potential.

Marine versus Estuarine or Freshwater Areas. There is limited information for coho salmon caught by recreational fisheries in freshwater areas from Alaska (Vincent-Lang et al. 1993) and from research gillnetting for chinook salmon in Washington (Baranski 1980). This information indicates salmon may be more vulnerable to hooking and/or handling mortality in estuarine areas. We consider this issue important given the magnitude of the catch in some estuarine fisheries (e.g., the Buoy 10 fishery at the mouth of the Columbia River).

Terminal Gear Differences. The NRC studies of marine recreational fisheries (NRC 1991; 1993) observed that the trailing hook in a tandem hook rig was implicated in most of the mortalities they observed. This raises a potential option of reducing hooking mortality impacts in marine recreational fisheries through gear management. But before different hooking mortality rates are used for alternative terminal gear configurations, the differences in mortality rates should be documented. We consider this important because tandem hooks are the predominant gear used in Washington and, therefore, most of the salmon hooked and released are exposed to this gear.

Size Differences. We concluded that fish size is significantly related to hooking mortality. However, the available research did not focus on the legal and sublegal sizes of salmon used for fisheries management in Washington, Oregon, or California. Future research should incorporate the legal/sublegal size definitions actually used in the fisheries of interest.

Species Differences. We concluded that hooking mortality rates are different for chinook and coho salmon caught by recreational fisheries. But some of the information we reviewed was ambiguous, especially for legal-sized chinook salmon. Generally, interpreting the data for chinook salmon was complicated by small sample sizes in all of the recreational fishery studies. More studies, with larger sample sizes, for estimating the hooking mortality rates for chinook salmon are needed.

Interactions. During our review of the new information, we consistently encountered interpretation difficulties due to the potential effect of confounding variables. For example, it was difficult to isolate differences in hooking mortality rates between different terminal gears because of confounding variables like fish size. Our understanding of hooking mortality rates would be improved by experimental designs that analyze these kinds of interactions between study variables. In general, we recommend that future research concentrate on increasing sample sizes for fixed fishing variables rather than examine more kinds of fishing variables.

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APPENDIX A

Assignment to technical team to review hooking mortality rates.

March 9, 1993

HOOKING MORTALITY RATES -- RECREATIONAL FISHERIES

Recent research on recreational hooking mortality rates has been conducted by the Canadian Department of Fisheries and Oceans (CDFO) and Natural Resources Consultants (NRC) - a private consulting firm located in Seattle, Washington. This work has been designed to address a number of problems associated with previous studies.

A task team of Washington Department of Fisheries (WDF) staff and Washington treaty tribal staff is being formed to review this new scientific information. It is anticipated that this review will be completed by June and provided to the Pacific Fisheries Management Council (PFMC) shortly thereafter. It is our intent to present our findings to the Council at the September meeting. Subsequent to that presentation, we will request that the Council take action, as necessary, to implement the findings of our review for 1994 pre-season planning and in-season management.

Jointly presented to PFMC on 3-12-93 by Bob Turner and Jim Harp.

APPENDIX B

Tables Summarizing Important Attributes and Results of the Studies Reviewed.

APPENDIX B

Reference	Bendock and Alexandersdottir, (1992)			
Study Group	mature chinook small male	mature chinook large male	mature chinook female	mature chinook combined size and sex
Fishing location	Riverine	Riverine	Riverine	Riverine
Time of Year	May - July, 1989,90,91	May - July, 1989,90,91	May - July, 1989,90,91	May - July, 1989,90,91
Angler Population	Actual Anglers	Actual Anglers	Actual Anglers	Actual Anglers
Fishing Platform	River Boat	River Boat	River Boat	River Boat
Terminal Gear	lure, lure/bait combo	lure, lure/bait combo	lure, lure/bait combo	lure, lure/bait combo
Hook size/type	single or treble, 1 or 2 hooks	single or treble, 1 or 2 hooks	single or treble, 1 or 2 hooks	single or treble, 1 or 2 hooks
Holding Time	radio telemetry, five day tracking	radio telemetry, five day tracking	radio telemetry, five day tracking	radio telemetry, five day tracking
Fish size(range,mean)				46-116.5cm, 87.2cm
Sample Size	125	143	178	446
Immediate Mortality				
Delayed Mortality	15	5	11	31
Total Mortality	12%	3.5%	6.18%	7.6%
Injury location	...	...	...	(a)
Angler handling	...	...	...	(b)
Bleeding	...	...	...	(a)
Scale loss	-	-	-	-

(a) Hooking location and bleeding were significant factors in mortalities.
(b) Playing and handling time were not significant factors in mortalities.

APPENDIX B

Reference	Gjernes, T. (1990)			
Study Group	2nd ocean yr coho, hook A	2nd ocean yr coho, hook B	2nd ocean yr coho, hook C	2nd ocean yr coho, all hook groups
Fishing location	Marine	Marine	Marine	Marine
Time of Year	May, 1986	May, 1986	May, 1986	May, 1986
Angler Population	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers
Fishing Platform	10 m charter vessel	10 m charter vessel	10 m charter vessel	10 m charter vessel
Terminal Gear	lures, sport troll	lures, sport troll	lures, sport troll	lures, sport troll
Hook size/type	1/0 barbed, single	1/0 barbless, single	#4 treble barbed	combined
Holding Time	minimum 24 hr	minimum 24 hr	minimum 24hr	minimum 24 hr
Fish size(range,mean)	...	...	...	30-55cm,45cm [1]
Sample Size	31	30	22	83
Immediate Mortality	1	single hooks combined, left	4	5
Delayed Mortality	1	single hooks combined, left	0	1
Combined	3.3%, (0.4-11.2% 95%CI)	single hooks combined, left	18.2% (5.2-40% 95%CI)	7.2% (2.7-14.6% 95%CI)
Injury location	(a)	(a)	(a)	(a)
Angler handling	n/a	n/a	n/a	n/a
Bleeding	(a)	(a)	(a)	(a)
Scale loss	(b)	-	-	-

(a) mortality mainly due to hook injury involving gills or associated major blood vessels
(b) one delayed mortality >50% scale loss from netting

1 lengths from mortalities only

APPENDIX B

Reference	Gjernes, T. (1990)			
Study Group	small shaker chinook (blackmouth)	shaker chinook (blackmouth)	keeper chinook (blackmouth)	all chinook (blackmouth)
Fishing location	Marine	Marine	Marine	Marine
Time of Year	April-June, 1987	April-June, 1987	April-June, 1987	April-June, 1987
Angler Population	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers
Fishing Platform	10 m charter vessel	10 m charter vessel	10 m charter vessel	10 m charter vessel
Terminal Gear	lures, sport troll	lures, sport troll	lures, sport troll	lures, sport troll
Hook size/type	4/0 barbed, tandem	4/0 barbed, tandem	4/0 barbed, tandem	4/0 barbed, tandem
Holding Time	minimum 24 hr	minimum 24 hr	minimum 24hr	minimum 24 hr
Fish size(range,mean)	35-<45cm	45-62cm	>62cm	35-82cm
Sample Size	32	98	22	152
Immediate Mortality				
Delayed Mortality				
Total Mortality	12.5%	8.2% (3.5-14.2% 95%CI)	13.6%	10% (5.7-16% 95%CI)
Injury location	(a)	(a)	(a)	(a)
Angler handling	-	-	-	-
Bleeding	(a)	(a)	(a)	(a)
Scale loss	-	-	-	-

(a) Virtually all mortalities sustained injuries to major blood vessels (gills or heart area) and exhibited considerable bleeding. Seven released fish were blind in one eye from hook injury.

APPENDIX B

Reference	Gjernes et al, (1992)				
Study Group	1st ocean yr coho, hook A	1st ocean yr coho, hook B	1st ocean yr coho, hook C	1st ocean yr coho, hook D	1st ocean yr coho, all hook groups
Fishing location	Marine	Marine	Marine	Marine	Marine
Time of Year	Sept.- Oct. 1985	Sept.- Oct. 1985	Sept.- Oct. 1985	Sept.- Oct. 1985	Sept.- Oct. 1985
Angler Population	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers
Fishing Platform	10 m charter vessel	10 m charter vessel	10 m charter vessel	10 m charter vessel	10 m charter vessel
Terminal Gear	lures, sport troll	lures, sport troll	lures, sport troll	lures, sport troll	lures, sport troll
Hook size/type	1/0 barbed, single	1/0 barbless, single	#4 treble barbed	#4 treble barbless	combined
Holding Time	minimum 6 hr	minimum 6 hr	minimum 6 hr	minimum 6 hr	minimum 6 hr
Fish size(range,mean)	...	...	...	...	< 30cm, 25.8cm [1]
Sample Size	79	71	76	63	289
Immediate Mortality	11	12	12	4	38
Delayed Mortality	0	0	0	0	1
Total Mortality	14%	17%	16%	6%	13.5% (9.7-17.7 %95%CI)
Injury location	...	...	...	...	(a)
Angler handling	-	-	-	-	-
Bleeding	...	...	...	...	(a)
Scale loss	-	-	-	-	-

(a) Hook configuration determines probability of hooking in a lethal location (gills and/or associated major blood vessels), indirectly determining mortality.

1 lengths from mortalities only

APPENDIX B

Reference	Gjernes et al. (1992)				
Study Group	1st ocean yr chinook, hook A	1st ocean yr chinook, hook B	1st ocean yr chinook, hook C	1st ocean yr chinook, hook D	1st ocean yr chinook, all hook groups
Fishing location	Marine	Marine	Marine	Marine	Marine
Time of Year	Sept.- Oct. 1985	Sept.- Oct. 1985	Sept.- Oct. 1985	Sept.- Oct. 1985	Sept.- Oct. 1985
Angler Population	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers	Experienced Volunteers
Fishing Platform	10 m charter vessel	10 m charter vessel	10 m charter vessel	10 m charter vessel	10 m charter vessel
Terminal Gear	lures, sport troll	lures, sport troll	lures, sport troll	lures, sport troll	lures, sport troll
Hook size/type	1/0 single barbed	1/0 single barbless	#4 treble barbed	#4 treble barbless	combined hooks
Holding Time	minimum 6 hr	minimum 6 hr	minimum 6 hr	minimum 6 hr	minimum 6 hr
Fish size(range,mean)	...	...	...	...	< 30cm, 21.4cm [1]
Sample Size	40	43	25	16	124
Immediate Mortality	14	10	10	3	37
Delayed Mortality	0	0	0	0	0
Total Mortality	35%	23%	40%	19%	29.8% (22.3-38.3% 95%CI)
Injury location	...	...	...	...	(a)
Angler handling	-	-	-	-	-
Bleeding	...	...	...	...	(a)
Scale loss	-	-	-	-	-

(a) Hook configuration determines probability of hooking in a lethal location (gills and/or associated major blood vessels), indirectly determining mortality.

1 lengths from mortalities only

APPENDIX B

Reference	NRC, Inc. (1991)	NRC, Inc. (1993)	NRC, Inc. (1992)	NRC, Inc. (1991)
Study Group	Coho	Coho 4 day holding	Coho early release, algae bloom	chinook (blackmouth)
Fishing location	Marine	Marine	Marine	Marine
Time of Year	May-June, 1989	September, 1992	August, 1992	May-June 1989
Angler Population	Researcher/Volunteer	Volunteers	Volunteers	Researcher/Volunteers
Fishing Platform	small craft	56 foot Charter Vessel	56 foot Charter Vessel	small craft
Terminal Gear	herring mooch, some lure, some troll	herring mooch, some lure, some troll	herring mooch, some lure, some troll	herring mooch, some lure, some troll
Hook size/type	1/0 - 2/0 barbless, tandem	3/0 - 4/0 barbless, tandem	3/0 - 4/0 barbless, tandem	1/0 - 2/0 barbless, tandem
Holding Time	48 hr (some 24hr)	four days	24 hrs	48 hrs
Fish size(range,mean)	34-62cm, 47cm	n/a		31-101cm, 66.7cm
Sample Size	146	536	>600	67
Immediate Mortality	combined below	23		combined below
Delayed Mortality	10	10		6
Total Mortality	6.85% (3.37-12.5% 95%CI)	6.2% (4.3%-8.5% 95%CI)	5.6%	8.96% (3.37-12.25% 95%CI)
Injury location	(a)	(a)		(a)
Angler handling	(b)	(b)		(b)
Bleeding	(a)	(a)		(a)
Scale loss	(c)	(c)		(c)

(a) Hooking location heavily influenced bleeding (isthmus, gills, operculum, throat, i.e. areas of major arterial/venous blood vessels), concluded that hooking location was significant in determining mortality.
(b) Concluded that dominant factor in mortalities was hook wound and that angler handling was virtually not a contributing factor in mortalities.
(c) Concluded that scale loss was not a significant factor in mortalities.

APPENDIX B

Reference	Vincent-Lang et al. (1993)		
Study Group	Mature Coho, Estuary	Mature Coho, Up River	Mature Coho, Up River Control
Fishing location	Estuarine	Riverine	Riverine
Time of Year	July-August, 1988	July-August, 1988	July-August, 1988
Angler Population	Researcher/Volunteers	Researcher/Volunteers	Researcher
Fishing Platform	Shore	Shore	weir
Terminal Gear	Bait, drift	bait, drift	dip net
Hook size/type	2/0 barbed, single	2/0 barbed, single	none
Holding Time	Tagged, upriver trap	five day	five day
Fish size(range,mean)			
Sample Size	384	77	77
Immediate Mortality			
Delayed Mortality	266	9	1
Total Mortality	69.3% (64-74.6% 95%CI)	11.7% (3.8-19.6% 95%CI)	1.3 (-1.9-4.5% 95%CI)
Injury location	(a)	(a)	-
Angler handling	(b)	(b)	-
Bleeding	(a)	(a)	-
Scale loss	(c)	-	-

(a) Hook location significant, also hook removal/non-removal was significant but was not independent from hook location (as was bleeding).
(b) Play and handling time was not significant.
(c) Scale loss was considerable in estuarine caught fish but was not significant.

APPENDIX B

Reference	Wertheimer, 1988.	
Study Group	sublegal chinook <66cm	legal chinook >65cm
Fishing location	marine	marine
Time of Year	August, 1986	August, 1986
Angler Population	commercial troller	commercial troller
Fishing Platform	power troller	power troller
Terminal Gear	4 wire lines 8-10 lures/line	4 wire lines 8-10 lures/line
Hook size/type	6/0 barbed, single	6/0 barbed, single
Holding Time	1-5 days	1-5 days
Fish size(range,mean)		
Sample Size	398	108
Immediate Mortality	10.0%	3.7%
Delayed Mortality	14.5%	16.8%
Total Mortality	24.5% (20.1-29% 95%CI)	20.5% (9.0-31.9% 95%CI)
Injury location	(a)	(a)
Angler handling	-	-
Bleeding	(a)	(a)
Scale loss	-	-

(a) Hooking location was significantly associated with mortality, fish hooked in the gills had the highest mortality.

APPENDIX B

Reference	Wertheimer et al. (1989)			
Study Group	sublegal chinook (<53cm)	sublegal chinook (53-65cm)	sublegal chinook (all)	legal chinook (>65cm)
Fishing location	marine	marine	marine	marine
Time of Year	August, 1987	August, 1987	August, 1987	August, 1987
Angler Population	commercial troller	commercial troller	commercial troller	commercial troller
Fishing Platform	power troller	power troller	power troller	power troller
Terminal Gear	4 wire lines 8-10 lures/line	4 wire lines 8-10 lures/line	4 wire lines 8-10 lures/line	4 wire lines 8-10 lures/line
Hook size/type	6/0 barbed, single	6/0 barbed, single	6/0 barbed, single	6/0 barbed, single
Holding Time	4-6 days	4-6 days	4-6 days	4-6 days
Fish size(range,mean)			<66cm, mean=56	>65cm, mean=72.9cm
Sample Size	93	270	363	550
Immediate Mortality			4.7%	2.55%
Delayed Mortality			13.6%	16.45%
Total Mortality	20.4%	17.4%	18.3% (14-22.6% 95%CI)	19.0% (15.5-22.5% 95%CI)
Injury location	...	...	(a)	(a)
Angler handling	...	...	(b)	(b)
Bleeding	...	...	(a)	(a)
Scale loss	-	-	-	

(a) Hooking location was significant and corresponded to wounds in proximity to major concentrations of blood vessels.
(b) No evidence of direct increase top mortality due to transfer time or handling stress.