STT RECOMMENDATIONS FOR HOOKING MORTALITY RATES IN 2000 RECREATIONAL OCEAN CHINOOK AND COHO FISHERIES

Summary

The Salmon Technical Team (STT) reviewed recent and past information regarding studies of hook and release mortality for sport caught chinook and coho salmon. Literature reviews, recent studies where only personal communications were available, administrative reports, and council documents were evaluated to determine whether there is sufficient new information to warrant a change in the recreational fishery hooking mortality rates currently employed by the Pacific Fishery Management Council.

The STT recommendations are:

1) Apply a single, interim hook-and-release mortality rate (HRM) of 14% (compared to the current rate of 8%) to chinook and coho salmon of all sizes released from recreational ocean fisheries using trolling, mooching, and motor mooching methods, except for California-style mooching.

2) Continue to apply a weighted average of recreational troll and California-style mooching mortality rates to California recreational ocean salmon fisheries where California-style mooching is used, with California-style mooching HRM based on California Department of Fish and Game (CDFG) recommendations and weights based on the prevalence of fishing techniques in California recreational fisheries. For 2000 fisheries this procedure yields a rate of 24%.

3) Continue to apply an additional dropoff mortality rate of 5% to all fish caught by ocean salmon hook-and-line fisheries to account for dropoff mortality, predation loss, noncompliance, etc.

4) Support further research on estimating HRM, estimating encounter rates, and developing fleet profiles of fishing gear/methods and hook wound location, and gear-species-specific hook wound location mortality rates.

Introduction

Non-landed fishing mortality is becoming a more significant concern because of Endangered Species Act listings and the increasing proportion of ocean catch that is not retained as a result of non-retention fisheries and mass marked selective fisheries targeted at hatchery fish. Within the last few years, results of several studies of non-landed mortality have become available for hook and line fisheries from Central California to Northern British Columbia. The results of these newer studies have often been inconsistent with earlier ones, which has increased uncertainty regarding non-landed fishing mortality. Several recent studies have examined the research methods and conclusions of these studies. We do not attempt another in-depth analysis here, but rather summarize these studies and the recommendations of recent reviews in Appendix A.

There are several types of non-landed mortality rates involved with hook-and-line fisheries:

- *Immediate release mortality* rate is the proportion of fish released that die within 24 hours;
- *Short-term release mortality* rate is the proportion of fish released that die after 24 hours of release but within a few days (e.g., 4 days);
- *Delayed mortality* rate is the proportion of the fish released that die after the short-term;
- *Drop-off mortality* rate is the proportion of fish encountered by the gear that is killed without being brought to the vessel intact (e.g., lost to pinniped predation);
- Other mortality losses represent the proportion of handled fish which is killed before release (e.g., non-compliance).

The STT focused this review of available information on HRM, which includes immediate, short-term, and delayed mortality.

Background

In 1986, the STT adopted hooking mortality rates based on a Delphi consensus of a panel of experts after reviewing the available literature on HRM studies (Stohr and Fraidenburg 1986). At that time, a HRM of 30% was being applied to all hook and line fisheries in the US and Canada with an additional 5% mortality rate added to account for dropoffs (Stohr and Fraidenburg 1986). The HRM rates recommended and adopted were 30% for both chinook and coho in recreational and troll fisheries, adjusted to 26% for barbless hooks. This decision resulted in a single HRM rate of 26% applied to all Council hook and line fisheries. The STT adopted these recommendations, but applied an additional 5% mortality to account for drop-off and incidental mortality. Thus a total 31% mortality rate was applied to all salmon released from hook-and-line fisheries conducted in ocean waters, and a 5% dropoff and incidental mortality rate was applied to all landed catch.

By 1993, several additional studies on HRM had been conducted and the Washington Department of Fisheries (WDF), Puget Sound Treaty Tribes, and the Northwest Indian Fisheries Commission (1993) undertook a review of hooking mortality. They reviewed recent and previous studies and made recommendations that separate rates be applied to legal and sublegal chinook and coho salmon in recreational fisheries. The HRM rates recommended by WDF et al. (1993) for recreational fisheries using single point barbless hooks were:

Coho		Chinook	
Legal	Sublegal	Legal	Sublegal
7%	15%	10%	20%

WDF et al. (1993) made no recommendations for changes in rates applied to commercial fisheries, but recommended further research to investigate differences between HRMs rates in freshwater, estuarine, and marine fisheries, effects of terminal gear, size differences, species differences, and interactions among these factors.

In 1994, the STT reviewed recent HRM studies and the recommendations of WDF et al. (1993). The STT considered using weighted averages of rates estimated in published studies, which resulted in estimates of 6% HRM for coho salmon in recreational fisheries, and 10% HRM for chinook salmon in recreational fisheries. However, the STT concluded that there was insufficient information to justify using separate rates for chinook and coho in recreational fisheries, and recommended using an average rate of 8% for both species. The STT also recommended that rates of 24% for chinook and 35% for coho should be used for HRM in commercial fisheries using barbless hooks. They further recommended that all fisheries should have an additional 5% mortality added to account for dropoff mortality and 2% to account for other sources of mortality (e.g., predation, long-term mortality, non-compliance, etc.) applied to all contacted fish. Thus the total mortality rates recommended by the STT were:

Recreational Fisheries	Commercial Fisheries	
Both Species	Coho	Chinook
15%	42%	31%

The STT (1994) recommended further research into differences between barbed and barbless hooks, encounter rates and the efficacy of targeting individual species in single species fisheries, size distributions of fish encountered, and multiple encounters, and also recommended that HRM studies be conducted south of Cape Falcon for comparison with results from studies conducted in more northern waters.

The Council subsequently reduced the recreational HRM rates used in assessment modeling to 8%, and left commercial HRM rates at 26% for both chinook and coho salmon. An additional 5% mortality was

applied to all retained and released fish in commercial troll and recreational fisheries to account for dropoff mortality.

In the early 1990s, CDFG began to investigate the hooking mortality associated with California-style mooching, in which whole bait is drifted head down. There was concern that this fishing method resulted in a higher incidence of hook wounds in deep, more lethal locations. Initial studies surveyed hook wound locations and applied mortality rates from Wertheimer's (1988) study of commercial troll hooking mortality rates (CDFG 1995a, 1995b). These studies indicated that hooking mortality associated with California style mooching was substantially higher than the mortality associated with trolling bait or lures. Further studies conducted by CDFG in which fish were held in onboard tanks confirmed the higher mortality associated with mooching, and suggested that the deeper hook wound locations also resulted in a higher proportion of delayed mortality because fish took longer to die from wounds to the gullet than from wounds to the gills or heart (Grover 1996, Grover and Palmer-Zwahlen in prep). In 1997 CDFG proposed that higher HRM rates be applied to California recreational fisheries based on a weighted average of mortality rates associated with mooching and trolling, with weights derived from data collected from fishery observations and profiles of the two fishing methods in California recreational fisheries (CDFG 1997a, 1997b). Since 1998, the PFMC has used the rates recommended by CDFG for California recreational fisheries.

Methods

At the November 1999 Council meeting, the STT reviewed the available information on HRM and considered various ways to estimate HRM in light of these research results. The efforts of the STT were limited to consideration of available information on HRM in recreational ocean fisheries. Based on its own deliberations, and discussions with the Scientific and Statistical Committee, the following methods were employed:

1) Estimate immediate HRM rates for each species as the median value of available estimates. Each study/gear/method treatment in recent recreational fishery confinement studies was considered as an independent estimate.[1] Because most confinement studies reported problems with holding fish for extended periods of time, and these holding problems were believed to contribute to additional mortality beyond that associated with hooking and release, only estimates of immediate mortality (occurring within 24 hr of capture) were used to estimate median HRM rates.

2) Expand estimates of immediate HRM for short-term HRM. Estimates of immediate mortality were expanded by the ratio of short-term mortality (within 96 hr) to immediate mortality reported in studies in which no problems were reported with holding conditions (NRC data collected in Neah Bay in September, 1992, and Puget Sound in 1992 and 1993):

Species	Sample size	24hr mortalities	96hr mortalities	96hr/24hr
chinook	330	32	38	1.19
Coho	538	25	33	1.32
combined	868	57	71	1.25

Because of the small number of studies and relatively small differences between the estimated expansions for both species, the data were combined to produce a single expansion factor of 1.25.

3) Expand short-term HRM estimates for delayed mortality beyond 96 hours. Short-term HRM estimates were expanded by a factor of 1.13, based on the recommendations of the Chinook Technical Committee

[1] Estimates based on sample sizes of fewer than 50 fish were excluded from consideration because results are statisitcally unreliable; these studies tended to produce the most extreme HRM estimates. Estimates of HRM from California-style mooching were also excluded because this method is unique to California and has an extremely high hooking mortality rate due to a high incidence of gut hooking; the Council has previously deferred to CDFG for estimates of HRM associated with this technique.

(PSC, 1997) as derived from Wertheimer (1988). This expansion is based on commercial troll studies on chinook only, and was initially derived to account for delayed mortality occurring beyond a 6-day holding period. No recreational fishery based estimates of delayed mortality or of 6-day holding mortality were available.

Results

Evaluation of the estimates included in this analysis finds no clearly identifiable differences in HRM rates between species, size, or terminal gear. Combining the data for both species gives a median immediate HRM of 10%. The STT therefore recommends that a single overall hook-and-release mortality rate of 14% be applied to chinook and coho salmon of all sizes released from recreational ocean fisheries that use trolling, mooching, and motor mooching methods, except for California-style mooching.

Immediate HRM	Adjusted for Short-Term HRM	Adjusted for Long-Term HRM
10.0%	12.5%	14.0%

For California recreational ocean salmon fisheries where California-style mooching is used, the STT recommends that a weighted average of recreational troll and California-style mooching HRM rates continue to be applied. The California-style mooching HRM should be based on CDFG recommendations, and the weights should reflect the profiles of fishing techniques in California recreational fisheries.

CDFG sample data on circle hook location frequencies from charter boats that used mooching techniques during 1998 and 1999 provide a means of estimating the HRM rate for this fishery. Applying location-specific HRM rates estimated during earlier research studies involving the R/V Mako to the hook location relative frequencies resulted in a California-style long-term HRM estimate of 36%. The formula used to estimate HRM for California recreational fisheries is (CDFG, 1997b):

$$HRM = (w_T * HRM_T) + (1-w_T)*HRM_M$$

with

$$w_T = (T_P * T_S) / [(T_P * T_S) + (M_P * M_S)]$$

and

Notation	Quantity	Value
T_P	P(angler days trolling)	0.46
T_S	# shakers per troll angler day	0.51
HRM_T	HRM: troll	0.14
M_P	P(angler days mooching)	0.54
M_S	# shakers per mooch angler day	0.31
HRM_M	HRM: mooch	0.36

The resulting HRM is 23.2%. The STT recommends that this rate be used as the 2000 estimate of HRM for California recreational fisheries.

The STT recommends that an additional dropoff mortality rate of 5% continue to be applied to all fish

encountered in ocean salmon hook-and-line fisheries to account for dropoff mortality, predation loss, noncompliance, etc.

Discussion

Species Differences - Many studies and previous reviews have noted size- and species-related differences in HRM rates (Cox-Rogers 1998; NRC 1999; WDF et al. 1993). Although individual studies have reported differences in HRM between chinook and coho salmon, the patterns and averages for both species are remarkably similar (Figure 3, Tables 1,2). The average immediate HRM rates for all studies combined (total mortalities/total fish captured) are 10.0% for chinook (Table 1) and 9.6% for coho (Table 2). The median point estimates of immediate HRM rate for samples of at least 50 fish are 9% for chinook and 10.3% for coho. The STT does not believe that these differences are great enough to justify using separate rates for chinook and coho, and recommends combining the immediate HRM data for both species and using the resulting median rate, which is 10%.

Fish Size - The effect of fish size on HRM is a function of the relative size of the gear to the fish, the type of terminal gear, and the fishing method used. The lowest level of HRM occurs when fish are too small to be fully vulnerable to the gear. For coho salmon, it appears that very small fish (<30cm) may have higher HRM than intermediate size fish, but that HRM increases for larger fish. For chinook salmon, there is not as clear a size trend in HRM, though it appears that small fish may suffer higher HRM than larger fish (CTC 1997), and, for California-style mooching, estimates based on hook wound location suggest that legal-size chinook have consistently higher HRM rate than do sublegals (CDFG 1995b). This pattern suggests a similar, though less pronounced, size dependence of HRM for chinook as is apparent for coho. Higher HRM in small fish has been attributed to greater damage caused by hook wounds associated with the greater size of terminal gear in relation to the fish. Because hooks are larger in relation to the size of fish, they cause relatively larger wounds and greater physical damage in small fish. In coho salmon, the increase in HRM in large fish has been attributed to the behavior of fish and the relationship between the size of fish and the size of the bait. Canadian studies conducted in 1999 reported a pronounced increase in HRM with fish size for mooching that was not observed for other trolling (Cox-Rogers personal communication). It has been observed that larger fish tend to ingest hooks more deeply and thus have a tendency to sustain hook wounds in deeper, more critical locations, and that this tendency is more pronounced with more passive bait presentation methods (Cox-Rogers personal communication). While the greater damage to small fish tends to result in rapid death, the deep hook wound locations in the back of the mouth, gullet, and gut tend to result in higher delayed mortality rates.

Year/Study Effects - Part of the difficulty in interpreting the relationship of HRM to fish size stems from the confounding of size with year (and study) effects. Gear, technique, holding times, methods, and estimation methods vary widely among studies. The relationships between HRM estimates and variability in research methods can be evaluated only through controlled experimental design.

Most of the small fish (< 30 cm) for both chinook and coho came from one study carried out in BC in 1985 (Gjernes 1990, Gjernes et al. 1993). These fish suffered higher HRM rates than did larger fish in subsequent studies, but fish this small are very rarely encountered in Council fisheries. Most of the larger fish for both species were caught in 1996, 1997, and 1998 (Cox-Rogers 1998, NRC 1998, NRC 1999, Grover and Palmer Zwahlen 1998, in prep.).

Similar effects confound the interpretation of delayed mortality during holding and effects of different terminal gear and fishing methods. Canadian studies held fish for only 24 hr; the holding studies by NRC off the Oregon coast and by CDFG off the California coast were conducted in 1996 and 1997 when conditions were not conducive to holding fish for extended periods of time. The CDFG study estimated 8% holding mortality of control fish in four days. The only studies that attempted to estimate delayed mortality by holding fish for up to 4 days, and in which holding effects were not identified as an additional source of mortality, were the NRC studies in 1992, and 1993 in Puget Sound and 1992 in Neah Bay. Even within these studies, some data were not reported because of high mortality, although it was attributed to adverse environmental conditions.

The immediate and short-term HRM rates (<24 hr) reported in studies with poor holding conditions and high delayed mortality are probably reasonably accurate. The NRC studies in 1996 and 1997, which reported some of the highest delayed mortality, also reported some of the higher estimates of immediate and short-term mortality. While it is probable that a significant proportion of the delayed mortality is attributable to holding fish in adverse conditions and that fish released would not be subject to the additional stress encountered during the holding period, fish captured in the fishery while these studies were in progress would have been subject to the same environmental conditions while they were being landed, and would probably suffer higher mortality than would fish caught in more benign conditions.

While the interaction of factors confounds attempts to distinguish between sources of variability in observed HRM rates, it appears that variability in rates over time is at least as great as the variability between locations for fisheries using similar gear and methods.

Fishing Gear/ Method Effects – The data presently available lack the resolution to distinguish statistically between different fishing methods, with the exception of California-style mooching. For all other methods, differences between HRM associated with mooching, trolling bait, and trolling lures have been inconsistent and minor compared with the between-year and between-study variability.

The influence of fishing technique on HRM is apparent in results of CDFG research using circle hooks. CDFG research demonstrated that relatively large circle hooks when drift mooched with bait in the head-up position eliminated gut hooking of sublegal fish; this gear-method increases gut hook rates as fish size increases (CDFG 1996).

The effect of fish behavior was also demonstrated by the CDFG studies. A statistically significant difference was observed between the contact rate of sublegal fish per angler day for troll and mooch. Mooching gear contacted a significantly smaller portion of sublegals than did the troll gear. This difference may related to the behavior of smaller fish, which are more likely to chase down prey than to eat drifting dead bait. In addition, the angler can influence the gut hook rate (and the HRM) when mooching by feeding line or setting the hook when a strike is noticed.

Hook Location and Fleet Profiles. Available information indicates that there is a strong relationship between hook wound location and HRM rates, and that hook location is a function of gear and fishing technique. The procedure employed by the STT to estimate HRM for California recreational fisheries uses a weighted average the HRM rates associated with mooching and trolling, with weights derived from the relative frequency of angler days of the two fishing methods from the previous year and the number of sublegal encounters per angler day (CDFG 1997b). The STT recommends that similar approaches be used to estimate fishery-specific HRM rates whenever the data permit.

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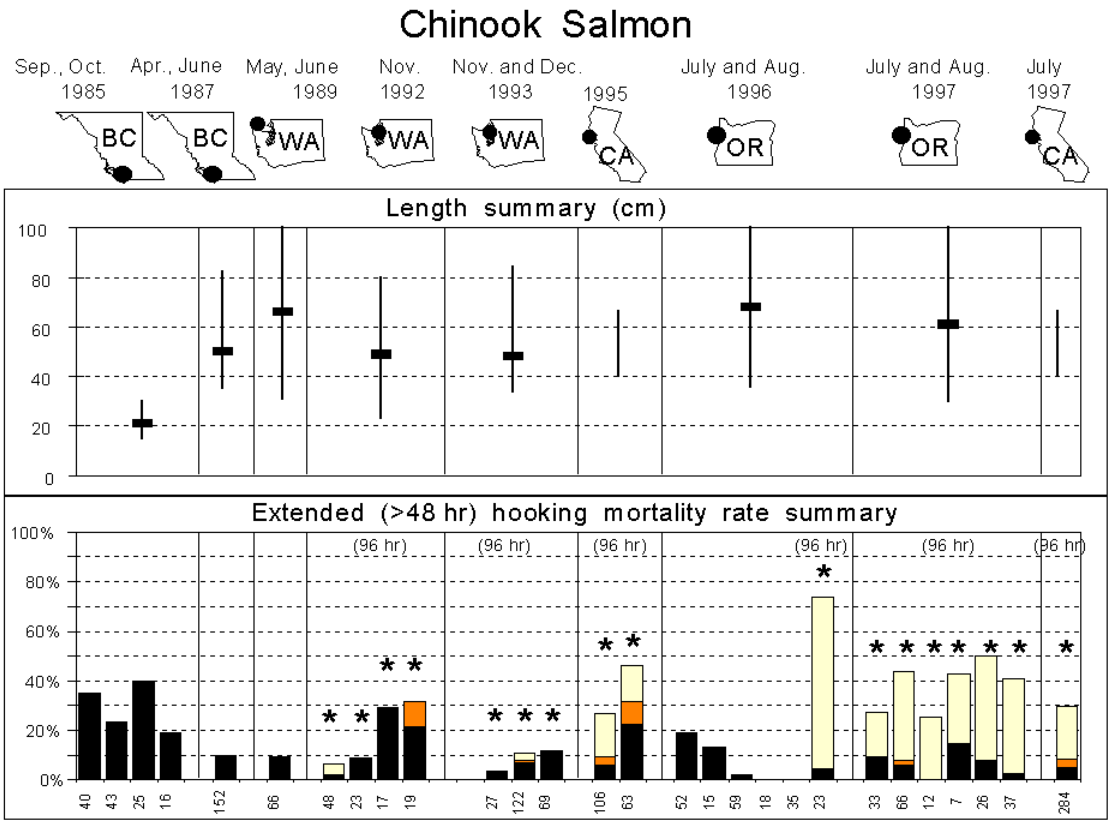

Figure 1. Estimates of short-term hooking mortality of chinook salmon caught on recreational gear from recent studies. The upper panel shows the location and year of the study. The center panel shows the size range and mean size of fish captured. The bottom panel shows mortality for different gear/ method combinations, with immediate mortality (<24hr) as solid bars, intermediate (24-36 hr) as shaded bars, and extended (96 hr) mortality as open bars. Sample sizes are shown below the axis, and samples that held fish for 96 hr are marked with an asterisk. (Figure from Dr. Robert Conrad, personal communication.)

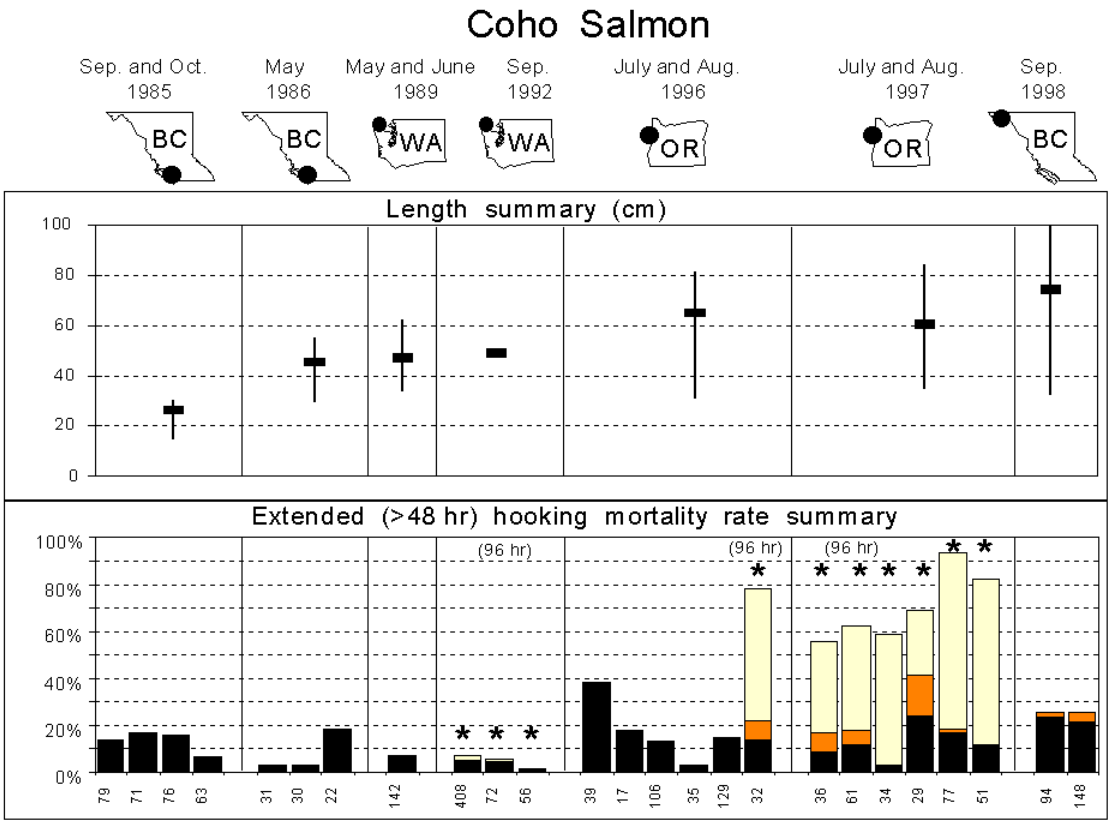

Figure 2. Estimates of short-term hooking mortality of coho salmon caught on recreational gear from recent studies. The upper panel shows the location and year of the study. The center panel shows the size range and mean size of fish captured. The bottom panel shows mortality for different gear/ method combinations, with immediate mortality (<24hr) as solid bars, intermediate (24-36 hr) as shaded bars, and extended (96 hr) mortality as open bars. Sample sizes are shown below the axis, and samples that held fish for 96 hr are marked with an asterisk. (Figure from Dr. Robert Conrad, personal communication.)

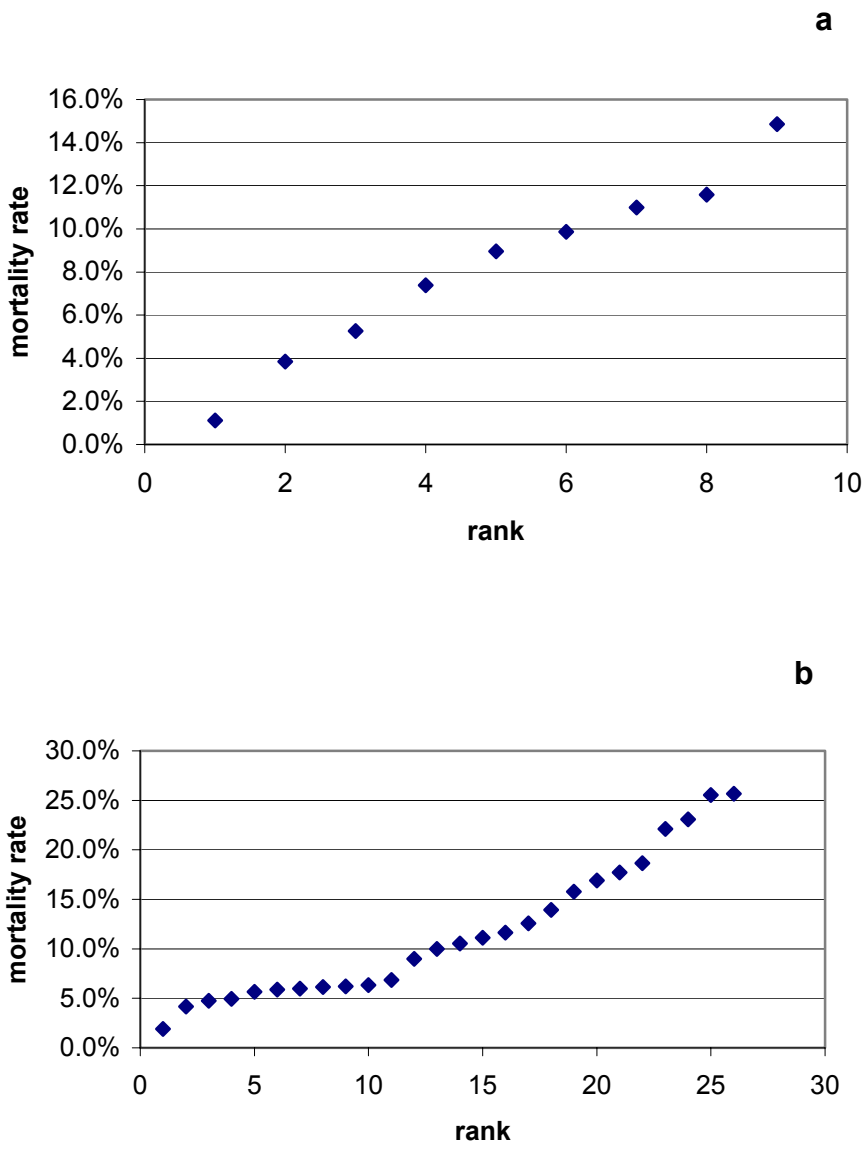

Figure 3. Immediate (<24 hr) hook-and-release mortality rates for (a) chinook and (b) coho salmon from recent confinement studies. Data are all point estimates of HRM for individual gear/method combinations based on samples of at least 50 fish ranked in order of mortality. The median estimate for chinook is 9.0% and the median estimate for coho is 10.25%

Table 1. Estimates of immediate (<24 hr) hook-and-release mortality for chinook salmon based on confinement studies. The average mortality rate for all studies combined (total deaths/total captures), excluding the estimate for California-style mooching, is 10.0%.

Study	location	size	gear	method	hook type	captures	deaths	Immediate mortality	Total mortality
NRC 1996	OR	28-87 cm fl	anchovy/herring	troll	4/0 + 3/0 barbless	19	0	0.0%	0.0%
NRC 1996	OR	28-87 cm fl	flasher + bait	troll	4/0 barbless	47	0	0.0%	0.0%
NRC 1997	OR	32-79 cm fl	anchovy/herring	mooch	3/0 circle	12	0	0.0%	0.0%
NRC 1996	OR	28-87 cm fl	anchovy/herring	troll	4/0 barbless	90	1	1.1%	1.6%
NRC 1992	WA area 10	23-84 cm tl	cut-plug herring	mooch	4/0 + 3/0 barbless	48	1	2.1%	2.9%
NRC 1997	OR	32-79 cm fl	flasher + bait	troll	4/0 + 3/0 barbless	37	1	2.7%	3.8%
NRC 1992	WA area 10	23-84 cm tl	cut-plug herring	troll	4/0 + 3/0 barbless	27	1	3.7%	5.2%
NRC 1996	OR	28-87 cm fl	flasher + bait	troll	4/0 + 3/0 barbless	78	3	3.8%	5.4%
NRC 1997	OR	32-79 cm fl	anchovy/herring	mooch	4/0 + 3/0 barbless	76	4	5.3%	7.4%
NRC 1996	OR	28-87 cm fl	anchovy/herring	mooch	4/0 + 3/0 barbless	37	2	5.4%	7.6%
NRC 1997	OR	32-79 cm fl	anchovy/herring	mooch	4/0 barbless	43	3	7.0%	9.9%
NRC 1992	WA area 10	23-84 cm tl	flasher + lure	troll	4/0 barbless	122	9	7.4%	10.4%
NRC 1997	OR	32-79 cm fl	flasher + bait	troll	6/0 siwash	26	2	7.7%	10.9%
NRC 1992	WA area 10	23-84 cm tl	cut-plug herring	troll	4/0 + 3/0 barbless	23	2	8.7%	12.3%
NRC 1989	WA area 5	31-101 cm fl	cut-plug herring	motor mooch	2/0 + 1/0 barbless	67	6	9.0%	12.6%
Gjernes 1990	s. BC	35-80 cm fl	flasher + lure	troll	4/0+4/0 barbless	152	15	9.9%	13.9%
NRC 1996	OR	28-87 cm fl	anchovy/herring	mooch	4/0 barbless	91	10	11.0%	15.5%
NRC 1992	WA area 10	23-84 cm tl	flasher + lure	troll	5/0 + 5/0 barbless	69	8	11.6%	16.4%
NRC 1997	OR	32-79 cm fl	anchovy/herring	CA mooch	4/0 barbless	7	1	14.3%	20.2%
Gjernes 1990-92	N BC area 1	71-105 cm fl	cut-plug herring	motor mooch	5/0 + 3/0 barbed	101	15	14.9%	21.0%
Gjernes 1985	s. BC	<30 cm	flasher + lure	troll	4 treble barbless	16	3	18.8%	26.5%
NRC 1992	WA area 10	36-67 cm fl	cut-plug herring	troll	4/0 + 3/0 barbless	16	3	18.8%	26.5%
Gjernes 1985	s. BC	<30 cm	flasher + lure	troll	1/0 barbless	43	10	23.3%	32.8%
NRC 1992	WA area 10	23-84 cm tl	flasher + lure	troll	4/0 barbless	17	5	29.4%	41.5%
NRC 1992	WA area 10	23-84 cm tl	flasher + lure	troll	5/0 + 5/0 barbless	19	6	31.6%	44.6%
Gjernes 1985	s. BC	<30 cm	flasher + lure	troll	1/0 barbed	40	14	35.0%	49.4%
Gjernes 1985	s. BC	<30 cm	flasher + lure	troll	4 treble barbed	25	10	40.0%	56.5%

Table 2. Estimates of immediate (<24 hr) hook-and-release mortality for coho salmon based on confinement studies. The average mortality rate for all studies combined (total deaths/total captures), excluding the estimate for California-style mooching, is 9.6%.

Study	location	Size	gear	method	hook type	captures	deaths	mortality rate	Total mortality
NRC 1996	OR	32-98 cm fl	anchovy/herring	troll	4/0 + 3/0 barbless	52	1	1.9%	2.7%
NRC 1997	OR	28-93 cm fl	anchovy/herring	mooch	3/0 circle	35	1	2.9%	4.0%
Gjernes 90b	s. BC	30-55 cm	lures	troll	1/0 barbed	31	1	3.2%	4.6%
Gjernes 90b	s. BC	30-55 cm	lures	troll	1/0 barbless	30	1	3.3%	4.7%
NRC 1992	WA area 4B	35-75 cm tl	flasher + lure	troll	4/0 + 3/0	72	3	4.2%	5.9%
NRC 1992	WA area 4B	35-75 cm tl	cut-plug herring	troll	4/0 + 3/0	464	22	4.7%	6.7%
Cox-Rogers 1999	N BC area 4	Small	cut-plug herring	motor mooch	4/0 + 5/0 barbless	81	4	4.9%	7.0%
NRC 1996	OR	32-98 cm fl	anchovy/herring	troll	4/0 barbless	247	14	5.7%	8.0%
NRC 1992	WA area 4B	35-75 cm tl	various	troll	4/0 + 3/0	577	34	5.9%	8.3%
Cox-Rogers 1999	N BC area 4	Small	cut-plug herring	troll	4/0 + 5/0 barbless	134	8	6.0%	8.4%
Cox-Rogers 1999	N BC area 3	Small	cut-plug herring	troll	4/0 + 5/0 barbless	65	4	6.2%	8.7%
NRC 1996	OR	32-98 cm fl	flasher + bait	troll	4/0 barbless	306	19	6.2%	8.8%
Gjernes 1985	s. BC	<30 cm	flasher + lure	troll	4 treble barbless	63	4	6.3%	9.0%
NRC 1989	WA - area 5	34-62 cm fl	cut-plug herring	motor mooch	2/0 + 1/0 barbless	146	10	6.8%	9.7%
Cox-Rogers 1999	N BC area 3	Small	lures	troll	4/0 + 5/0 barbless	78	7	9.0%	12.7%
Cox-Rogers 1999	N BC area 4	Small	lures	troll	4/0 + 5/0 barbless	120	12	10.0%	14.1%
NRC 1997	OR	28-93 cm fl	flasher + bait	troll	4/0 + 3/0 barbless	57	6	10.5%	14.9%
Cox-Rogers 1999	N BC area 3	Small	cut-plug herring	motor mooch	4/0 + 5/0 barbless	54	6	11.1%	15.7%
Gjernes 1990-92	N BC area 1	59-83 cm fl	cut-plug herring	motor mooch	5/0 + 3/0 barbed	103	12	11.7%	16.5%
NRC 1996	OR	32-98 cm fl	flasher + bait	troll	4/0 + 3/0 barbless	143	18	12.6%	17.8%
Gjernes 1985	s. BC	<30 cm	flasher + lure	troll	1/0 barbed	79	11	13.9%	19.7%
NRC 1996	OR	32-98 cm fl	anchovy/herring	mooch	4/0 + 3/0 barbless	21	3	14.3%	20.2%
Gjernes 1985	s. BC	<30 cm	flasher + lure	troll	4 treble barbed	76	12	15.8%	22.3%
NRC 1997	OR	28-93 cm fl	anchovy/herring	mooch	4/0 barbless	37	6	16.2%	22.9%
Gjernes 1985	s. BC	<30 cm	flasher + lure	troll	1/0 barbless	71	12	16.9%	23.9%
NRC 1997	OR	28-93 cm fl	flasher + bait	troll	6/0 siwash	79	14	17.7%	25.0%
Gjernes 90b	s. BC	30-55 cm	lures	troll	treble barbed	22	4	18.2%	25.7%
NRC 1997	OR	28-93 cm fl	anchovy/herring	mooch	4/0 + 3/0 barbless	59	11	18.6%	26.3%
Cox-Rogers 1999	N BC area 1	Larger	cut-plug herring	motor mooch	4/0 + 5/0 barbless	95	21	22.1%	31.2%
NRC 1996	OR	32-98 cm fl	anchovy/herring	mooch	4/0 barbless	65	15	23.1%	32.6%
Cox-Rogers 1999	N BC area 3	46-85 cm	cut-plug herring	motor mooch	4/0 barbless	94	24	25.5%	36.1%
Cox-Rogers 1999	N BC area 3	46-95 cm	cut-plug herring	motor mooch	4/0 + 4/0 barbless	148	38	25.7%	36.3%
NRC 1997	OR	28-93 cm fl	anchovy/herring	CA mooch	4/0 barbless	29	12	41.4%	58.4%

Appendix A
Summary of Recent Studies and Analyses of Hooking and Release Mortality Rates

Recent Studies

NRC Studies
Natural Resources Consultants have carried out a number of HRM studies in recent years both in Puget Sound and on the coast of Oregon.

1989 - Chinook and coho were caught with mooching gear by recreational anglers fishing out of Sekiu on the Strait of Juan de Fuca. A total of 213 fish were captured and held in net pens. Most fish were held for 48 hr., with a few held longer and some held for 14 to 27 hr. Some data were collected in September, but discarded because of higher mortality attributed to a lethal plankton bloom. HRM was estimated at 6.85% for coho and 8.96% for chinook. Most mortalities occurred in the first 12 hr (NRC 1991).

1992 - Coho were sampled from a charterboat fishing out of Neah Bay in August and September. Terminal tackle included cut plug herring, flashers with flies, and surface trolled flies. The August portion of the study was curtailed due to high holding mortalities; the study was resumed in September. Only results from data collected in September were originally reported (NRC 1994), though August data were subsequently reported in a review conducted for the Pacific States Marine Fisheries Commission (NRC 1999). Immediate (<24 hr) HRM was estimated to be 4.3%, with a short-term (4-day) HRM rate of 6.2% (NRC 1994).

1992 - Juvenile chinook (blackmouth) were sampled with chartered sport fishing boats in the fall/winter fishery in Puget Sound. Fish were held at the Edmonds fishing pier. The study was repeated in 1993 with fish held at NMFS Manchester field station. Terminal gears used flasher and hoochie, flasher and spoon, or drift mooched plug cut herring on a tandem mooching rig. Immediate HRM was estimated to be 8.8%, with a short-term HRM of 11.5% (NRC 1999) [previously reported as 10.2% (NRC 1994), and 9.2% (NRC 1998)].

1996 - Chinook and coho were caught with sport fishing gear from a charterboat, held in onboard holding tanks, and transferred to (raceways at the Newport Ore-Aqua facility) broodstock tubes in Yaquina Harbor. A variety of trolling and mooching terminal gear and methods were evaluated. High holding mortality rates (92% for chinook and 88% for coho) led to discontinuation of the holding portion of the experiment and subsequently mortality was observed only during the onboard holding period. Short-term HRM was estimated at 6.1% for chinook and 15.3% for coho (NRC 1999) [previously reported as 4% for chinook and 8% for coho (NRC 1998)].

1997 - The 1996 study was repeated with charterboats fishing out of Newport and Coos Bay. A variety of trolling and mooching methods was used. Fish were placed in broodstock tubes in the onboard holding tanks and then tethered in Yaquina Bay or offshore near Yaquina and Coos Bays. The broodstock tubes were checked at the time of transfer to long-term holding to estimate immediate HRM, and at the end of 4 days to estimate delayed mortality. Short-term HRM was estimated at 6.1% for chinook and 12.9% for coho (NRC 1999) [previously reported as 8% for chinook and 16% for coho (NRC 1998)].

CDFG Studies

1992 - A study was initiated to estimate the prevalence of mooching and trolling in California fisheries and to determine whether or not the two methods had different hooking mortality rates. Recreational anglers in the San Francisco and Monterey port areas were interviewed and asked about the methods and gear used and the numbers of fish released.

1993 - Angler interviews were repeated and the mortality rates of trolling and California -style mooching in California recreational fisheries were compared. Recreational fishing on charterboats was monitored by observers. Fishing method, dropoffs, depth, and location were recorded. Species and hook wound location was recorded for released fish. Species, length, hook wound location, and bleeding severity were recorded for retained fish. An attempt was made to obtain comparable sample sizes for trolling and mooching. HRM was estimated by applying the mortality rates for hook wound location estimated by Wertheimer (1989) to the observed distributions of wound location by fishing method. Estimated mortality for trolling was 12.3% for legal size fish and 12.8% for sublegal fish. Estimated mortality for mooching was 60.9% for legal size fish and 46.9% for sublegal fish (CDFG 1995a).

1994, 95 - Methods used in 1993 were repeated in 1994 and 1995 with similar results (CDFG 1995b).

1995 - Chinook were caught from a research vessel using California-style mooching with 2/0 barbless hooks. Fish were held in an onboard holding tank for 24 to 34 hr. Observed HRM was 37%, with 62% of the fish hooked in the gullet. Researchers postulated that most gullet-hooked fish would subsequently die (Grover 1995).

1996 - Chinook were caught using California-style mooching with barbless circle hooks, J hooks, and J hooks with blockers. Various bait orientations were used. Fish were held in the onboard holding tank for 4 days with the tanks checked for mortalities at least twice daily. Observed mortality rates were 59.8% for J hooks (with and without blockers), and 33.3% for circle hooks, with the majority of mortality occurring between 48 and 96 hr (Palmer-Zwahlen and Grover 1997).

1997 - Chinook were caught using California-style mooching with 3/0, 4/0, and 5/0 barbless circle hooks. Fish were held up to 96 hr in an onboard holding tank and checked at 12 hr intervals. Mortality at 96 hr. was 31% with the majority of mortality occurring between 48 and 96 hr (Grover and Palmer-Zwahlen 1997).

DFO Studies

1992-93 - Cut-plug herring were motor mooched at Langara Island in British Columbia for chinook and coho (Terry Gjernes personal communication cited in Cox-Rogers 1998). Details of the study (sample sizes, hook arrangement, holding facilities, holding times, etc.) are not given, but HRM rates of 15% for chinook and 10% for coho are reported.

1998 - Professional guides were contracted to compare single and double hook rigs with motor mooching in northern BC (Cox-Rogers 1998). Coho were the species targeted and fish were held for up to 24 hours. The fish encountered in this study were notably larger than coho typically encountered in Council fisheries, and the researchers commented on the tendency for larger coho to swallow the bait deeper and be hooked in more critical locations. A total of 242 large coho salmon were captured and observed. Hook wounds locations were classified as: Out (fish not hooked at time of landing), Deep Mouth (throat, gill arch, posterior portions of mouth and tongue, etc), Outer Mouth (hooks easily visible and easily removed), and Body/Head (fish hooked outside the mouth). Though differences were noted in hook wound location, there were no differences in estimated mortality rates. HRM rate for both hook arrangements combined was 25.6%.

1999 - Hooking mortality studies were conducted in three areas of northern BC to investigate recreational coho HRM (Steven Cox-Rogers, personal communication):

At Dundas Island (Area 3) recreational fishing vessels were chartered from July 26-30, and fish were caught using motor-mooched cut-plug herring, trolled cut-plug herring, and trolled artificial lures on downriggers. No significant differences were apparent between gears. Fish were small (mean post-orbital to fork length of 59.3 cm) and were held in tanks and net pens for 24 hr. HRM was estimated to be 8.6% from a sample of 197 fish.

At Stevens Island (Area 4) similar methods were employed from August 12-18 with similar results. Fish

were again reported to be small (mean post-orbital length of 60.1 cm) and 24 hr HRM estimated to be 7.2% from a sample of 335 fish.

At Langara Island, lodge guests were sampled from August 23-30. The only fishing method employed was motor-mooched plug-cut herring. Coho were held in tanks for 24 hr, and were reported to be larger than in areas 3 and 4 (mean post-orbital length of 64.3 cm). HRM was reported to be 22.1% from a sample of 95 fish.

Recent Reviews

CTC 1997

The Pacific Salmon Commission's Joint Chinook Technical Committee (CTC) reviewed incidental fishing mortality for chinook salmon in commercial troll, recreational, gillnet, and seine fisheries (PSC 1997). For recreational chinook fisheries, the CTC noted differences in mortality rate dependent on hook type (barbed vs. barbless), fishing technique (troll vs. mooch), and size of the fish. The CTC developed recommendations by adjusting the HRM rates estimated in recent studies to a standard 6 day holding period based on rates observed in NRC 1991, NRC 1994a, and Gjernes et al. 1993, and then further adjusting the 6-day mortality rate estimates for long-term mortality by multiplying the standardized 6-day rates by 1.13 based on Wertheimer (1988).

The CTC attempted to quantify dropoff mortality further in 2 categories: escaped encounters, and predation mortality. Escaped encounters were assumed to be hooked in peripheral locations and died at the rate observed for chinook hooked in the mouth in NRC 1991 and NRC 1994a. Fish removed from the gear by predators were assumed to suffer 100% mortality.

CTC recommendations for HRM rates in PSC recreational fisheries were:

chinook $\geq$33 cm: 12.3%
chinook <33 cm: 32.2%

Since most PSC recreational fisheries do not encounter many fish <33 cm, the CTC recommended that the rate of 12.3% be applied unless there was evidence that significant numbers of smaller chinook were encountered, in which case, a weighted average of the two rates should be applied. They further recommended that area specific dropoff mortality rates should also be applied to all fish boated (landed catch + released catch). Their recommended drop-off mortality rates were:

Southeast Alaska	3.6%
Puget Sound	14.5%
Oregon	2.7%

PSARC 1999

Cox-Rogers, et al.(1999) reviewed hooking mortality rates in recreational fisheries to develop recommendations for rates to be applied to recreational fisheries in British Columbia. Rates currently applied in BC are 10% for coho and 15% for chinook, and do not account for drop-off, incidental, or long-term mortality.

They did not develop specific recommendations for rates to be applied, but did conclude that:

1) For British Columbia marine recreational fisheries, hooking mortality for coho and chinook is likely dependent on the gear and methods used. Region-wide hooking mortality rates are not appropriate.

2) For British Columbia marine recreational fisheries, assumed hooking mortality rates for coho and chinook assessment/management modeling should take into account gear and method differences.

3) Assessment programs should be developed to quantify gear and method-specific hooking mortality rates for coho and chinook in major British Columbia marine recreational fisheries where information is lacking. Creel surveys should routinely collect information on the fishing methods being used in specific fisheries.

4) Assessment programs should be considered to address the delayed effects of hooking mortality on long-term survival and the ability of released coho and chinook to return and spawn successfully.

NRC 1999

In the fall of 1998,Natural Resources Consultants conducted a review of hooking mortality studies for the Pacific States Marine Fisheries Commission (NRC 1999). This review was conducted on behalf of the Pacific Fishery Management Council, and included both commercial troll and recreational salmon fisheries.

NRC (1999) noted the large variability in experimental methods employed by field studies for handling, calming, and holding fish, as well as variability in environmental conditions, during the studies. They observed that while immediate and short-term HRM rates were highly correlated with hook-wound location, the relationship between hook wound location and mortality becomes obscured for longer holding periods. The researchers attributed this mortality to stress from poor holding conditions.

Additional Analysis of Reported Results

The database for individual fish held in confinement studies (NRC 1999) was obtained from Doug McNair and additional statistical analyses were performed by Dr. Robert Conrad (SSC and Northwest Indian Fisheries Commission). When immediate (<24 hr), one day (24-36 hr), and extended (~96 hr) mortality are viewed by study and year, it is readily apparent that studies conducted in the late 1990s had higher mortality rates than studies conducted in the late 1980s and early 1990s (Figs. 1, 2). Another striking difference is the proportionate increase in long-term mortality relative to immediate mortality. For the NRC studies in Oregon this increase has been attributed to holding conditions, but, for the CDFG (1997) study, the difference has been attributed the tendency for deep hook wounds associated with California-style mooching to take longer to kill fish than more severe wounds in less critical locations.

It is also evident that apparent size dependence of mortality for coho is confounded by year/study effects (Fig.1). Coho less than 30 cm were encountered only in the 1985 DFO study, and coho greater than 60 cm were encountered primarily in 1996 though 1998 in NRC and DFO studies. There is far less difference in the size ranges of chinook between studies, with the single exception of the 1985 DFO study, in which most chinook were under 30 cm (Fig. 1).