PACIFIC SALMON COMMISSION
JOINT CHINOOK TECHNICAL
COMMITTEE REPORT

INCIDENTAL FISHING MORTALITY OF
CHINOOK SALMON: MORTALITY RATES
APPLICABLE TO PACIFIC SALMON COMMISSION
FISHERIES

REPORT TCCHINOOK (97)-1

January 1997

Membership of the Chinook Technical Committee

Canadian Members

Dr. Brian Riddell, Co-Chair, CDFO
Dr. Brent Hargreaves, CDFO
Mr. Wilf Luetke, CDFO
Ms. Barb Snyder, CDFO
Mr. Ken Wilson, CDFO

United States Members

Mr. Jim Scott, Co-Chair, NWIFC
Dr. Jeff Koenings, Co-Chair, ADF&G
Dr. Jim Berkson, CRITFC
Mr. Ed Bowles, IDFG
Dr. John Burke, ADF&G
Mr. John Carlile, ADF&G
Dr. John H. Clark, ADF&G
Dr. Doug Eggers, ADF&G
Mr. Gary Freitag, SSRAA
Mr. Dave Gaudet, ADF&G
Ms. Jennifer Gutmann, NWIFC
Dr. Kenneth Henry, NMFS
Mr. Gregg Mauser, IDFG
Ms. Marianne McClure, CRITFC
Mr. Scott McPherson, ADF&G
Dr. Sandra Moore, WDFW
Dr. Gary S. Morishima, QIN
Mr. Timothy W. Roth, USFWS
Mr. C. Dell Simmons, USFWS
Mr. Alex Wertheimer, NMFS
Mr. Ronald H. Williams, ODFW
Dr. Gary Winans, NMFS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Pacific Salmon Treaty recognizes the need to account for incidental fishing mortality and has instructed the Pacific Salmon Commission to "take into account such estimates of total chinook mortality in implementing the chinook rebuilding program" (paragraph 1(e) of the Chinook Annex). In 1987, the Chinook Technical Committee (CTC) reviewed agency reports and published literature on associated fishing mortality, and evaluated sources of associated mortality coastwide in marine and freshwater fisheries (CTC 1988). Since that report, substantial new information has become available on incidental mortality rates. This report reviews the information and recommends rates to be used for PSC fisheries in CTC analyses, and further recommends that fishery specific rates be applied as new information becomes available.

For hook-and-line fisheries, the CTC, recognized a range of hook-and-release mortality rates from 20 to 30% but applied a single mortality rate of 30% in both commercial troll and recreational fisheries. For net fisheries, the CTC recognized a range in mortality rates from 70 to 90%, but applied a single mortality rate of 90%. For the current report, the CTC considered commercial troll and recreational fisheries separately, and purse seine and gill net fisheries separately, because recent studies indicate that mortality rates can be substantially different between these gear types.

Commercial Troll. The CTC has been using a single hook and release mortality rate in the chinook model of 30% for commercial troll fisheries. For these fisheries, the CTC decided the available information supports using mortality rates that are specific for hook type (barbed, barbless) and fish size category (legal, sublegal). Total hook-and-release mortality rates recommended for these categories are:

Barbed, legal:	21.1%
Barbed, sublegal:	25.5%
Barbless, legal:	18.5%
Barbless, sublegal:	22.0%

The CTC also recommends calculating an additional mortality increment in CTC analyses for drop-off mortality. Drop-off mortality is composed of two components: (1) *escaped encounters*, fish that are hooked but escape from the gear; and (2) *predation mortality*, fish that are removed or lethally maimed by predators. Drop-off mortality is fishery specific, varying with hook type, escaped encounter rate, and predator encounter rate. Based on the current information available to the CTC, estimates of total drop-off mortality, expressed as a percentage of chinook brought to the boat (including both those retained and those released), are:

SEAK Troll (barbed hooks):	0.8%
Oregon Troll (barbless hooks):	2.5%
Average (barbed hooks):	1.7%

Most of the variability in the rates developed by the CTC was due to differences in predator encounters. Because drop-off mortality is calculated as a percentage of both retained and released chinook salmon, the drop-off mortality rate is only additive to the hook-and-release mortality rate

(which is a percentage of the fish _released_) for non-retention fisheries, when both legal and sublegal fish are released. In troll fisheries where legal-sized chinook are retained, total non-landed mortality must be calculated as two different components: hook-and-release mortality of sublegal fish, and drop-off mortality of both legal and sublegal fish.

Recreational. For recreational fisheries, the CTC found large differences in hooking mortality between fishing techniques. Recent research has documented high mortality rates associated with "California mooching" fishing method. At this time, the CTC agreed that rates for hook-and-release mortality for recreational fisheries of concern to the PSC should not incorporate data from the California mooching studies. However, if this fishing technique becomes more common in PSC fisheries, then the CTC estimates will need to be revised accordingly.

The CTC has been using a single hook and release mortality rate in the chinook model of 30% for recreational fisheries. The CTC considered adjustments to mortality rates due to hook type (barbed/barbless) and size category. Because the available data are not conclusive or consistent on the effect of hook type, the CTC decided not to consider barbed/barbless hook differences for estimating hook-and-release mortality in recreational fisheries. The CTC decided that the available data supported different mortality rates for chinook salmon < 33 cm, but no size-related differences among larger. Because chinook < 33 cm are not common in PSC fisheries, the rate for the larger size class will be used, unless size distribution data from a particular recreational fishery indicates that the rate should be weighted for the proportion of small fish present. The CTC recommends for CTC model analyses the following total hook-and-release mortality rates for recreational fishing specific for the two size categories:

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

The CTC also recommends calculating an additional mortality increment for drop-off mortality in CTC analyses of recreational fisheries. This rate, based on the total chinook boated (landed catch and released catch), is fishery specific, varying with escaped encounter rate and predator encounter rate. Based on the current information available to the CTC, the following fishery specific rates are recommended:

SEAK:	3.6%
Puget Sound:	14.5%
Oregon:	2.7%

For fisheries where specific data are not available, the CTC will use the average of these rates, 6.9%, to estimate escaped encounters and predator losses.

Purse Seine. The CTC has been using a total non-retention mortality rate of 90% in the chinook model for purse seines. Recent studies indicate that chinook salmon mortality rates are potentially much lower for fish released from purse seines. The CTC recommends using a rate of 72% for total chinook non-retention mortality for all size classes of fish combined in CTC analyses. This rate is based on an average immediate mortality of 49% and a delayed mortality of 23%.

When size-distribution information is available, the CTC recommends using the following estimates of immediate and total non-retention mortality:

	Immediate	Total
small chinook:	62.8%	85.8%
medium chinook:	50.5%	73.5%
large chinook:	28.0%	51.0%

In terminal fisheries where chinook salmon are released and a specific portion are close to spawning (< 60 d), the delayed mortality should be weighted to account for the lower rate of 1.1% observed for such fish.

The CTC will use these rates as generalized estimates of purse seine non-retention mortality. However, immediate mortality is fishery- and time-specific because of such factors as the type of fishery, frequency of catch sizes (related to handling time and suffocation of the chinook), incidence of chinook in sets by time and area of the fishery, handling of the chinook during boarding, and size distribution of the chinook caught. When fishery specific information becomes available for particular model fisheries, the CTC will apply the more specific estimates.

Gill Net. Prior to this review, the CTC assumed 90% release mortality for gill nets. This mortality rate has not been applied in the chinook model, because chinook non-retention (CNR) restrictions in gill net fisheries have not been explicitly modeled. CNR gill net fisheries are unlikely to be implemented due to high expected mortality rate of the fish released. However, CNR periods are likely in gill net fisheries where a limit on total chinook landings is imposed.

Review of the available literature indicated that gill net release mortality rates can be highly variable and may be substantially lower than 90% for salmon in their final year of life and close to maturity. Chinook salmon released from gill-nets in chinook model fisheries, however, are likely to be small, immature fish. Until data are available for this age and size range, the CTC will use the 90% mortality rate previously assumed.

The drop-out mortality rates currently used in the chinook model were derived from the available literature. This a poorly investigated subject; the rates must be viewed as very uncertain. Rates are expected to vary from fishery to fishery due to variables such as mesh size, prevailing weather and sea conditions, and predator abundance. These rates will continue to be used, however, pending review of updated incidental mortality reports from the agencies. Gill net fisheries occur primarily in SEAK, Fraser River, Puget Sound, the Washington Coast, and Columbia River. Until better information is available, the CTC will use the following drop-out mortality rates for these fisheries:

SEAK:	2%
Fraser River:	8%
Puget Sound:	8% (includes some purse seine fisheries)
Washington Coast:	2%
Columbia River:	3%

1. INTRODUCTION

The Pacific Salmon Treaty recognizes the need to account for incidental fishing mortality and has instructed the Pacific Salmon Commission to "take into account such estimates of total chinook mortality in implementing the chinook rebuilding program" (paragraph 1(e) of the Chinook Annex). In 1987, the CTC reviewed agency reports and published literature on associated fishing mortality, and evaluated sources of associated mortality coastwide in marine and freshwater fisheries (CTC 1988). The CTC concluded that the coastwide magnitude of incidental fishing mortality for all sizes of chinook salmon is in the range of 30-50 percent of the reported catch.

Since the CTC review through 1987, substantial new information has become available on incidental mortality rates. The incidental mortality rate is defined as the proportion of fish captured, but not reported as landed catch, that subsequently die as a result of the capture and release process. This report reviews the information and recommends rates to be used for CTC analyses.

The total quantity of incidental mortality depends on both the incidental mortality rate and the number of fish encountered. The U.S. 1996 Letter of Agreement (LOA) requested that the Commission ask management agencies to provide the following information:

1) A description of sources of incidental mortality in fisheries, and factors contributing to incidental mortality.

2) Estimates of incidental mortality, methods used to derive estimates, and limitations of estimates.

3) Measures taken to reduce and minimize incidental mortality since 1985.

4) Measures that might be taken to further reduce incidental mortality, and factors limiting actions that can be taken.

The LOA further requested that the CTC review this information and advise the PSC and management agencies on potential means to reduce incidental mortality. The CTC anticipates undertaking this task upon receiving the reports from the management agencies.

1

2. ESTIMATION OF MORTALITY RATES

Estimates of catch-and-release mortality rates due to fishing have been made by: (1) judging the condition of the fish at landing; (2) observing fish for short (less than 1-d) or intermediate (2-6 d) time periods, usually by holding in tanks or net pens, but also by tracking radio or sonic tags; and (3) examining relative recovery rates of tagged and released fish. Because these types of experiments cannot be completely controlled, all of these estimates are subject to potential and unmeasured biases. Estimates of mortality based on fish condition require subjectively judging the viability of the fish at landing. Fish that are held or tagged are subject to additional handling and confinement stress, which may cause the estimate of mortality to be biased high. Conversely, these fish that are held are protected from predators during the initial recovery from the landing trauma, which may cause the estimate of mortality to be biased low.

Incidental fishing mortality of chinook salmon is often broken into two components: **immediate**, fish dead at landing; and **delayed**, fish that are alive at landing but die after release from injuries or handling stress. Studies in the literature are not consistent, however, in how these components are computed. Immediate mortality may include fish held for 1-5 hr after landing; delayed mortality may be the observed estimate of mortality following some short or intermediate observation period, or it may include adjustments to account for total delayed mortality resulting from the fishing encounter.

The Salmon Technical Team (STT) of the Pacific Fisheries Management Council also considered two other components in computing total non-landed mortality: **associated** and **drop-off** mortality (STT 1994). The STT (1994) defined associated mortality as additional mortality due to "predation, long-term mortality, and regulation non-compliance"; and drop-off mortality as the percentage of fish that escape from the gear prior to being brought to the boat and that die as a result of the encounter. The CTC decided to consider predation as a category of drop-off mortality rather than associated mortality. The CTC also felt that while regulation non-compliance is a potential source of unaccounted mortality that could be applied to any fishery, it should not be considered here as a component of the non-landed mortality rate. For the purposes of this report, associated mortality is thus limited to adjusting the estimated rate for long-term delayed mortality.

2

3. HOOK AND LINE FISHERIES

The CTC (1988) reviewed available literature on immediate and delayed mortality of chinook salmon associated with hook and line fisheries. At that time, the CTC reached a consensus opinion that the total mortality of chinook salmon caught and released in the commercial troll fisheries ranges from 20% to 30%. This range included both fish dead when landed and those that are released alive but subsequently die. The CTC did not discuss the range for sport fisheries due to the lack of studies in the marine environment, but simply assumed the same rates as for the commercial troll fishery. Subsequent to the CTC review, several additional studies addressed incidental mortality in both commercial troll and recreational fishing. Two other groups have also reviewed and evaluated mortality rates associated with hook-and-line fisheries since 1987: WDF et al. (1993) and the STT of the Pacific Fisheries Management Council (STT 1994).

3.1 COMMERCIAL TROLL FISHERIES

Commercial trollers fish for salmon with an array of lures or baited hooks attached to 2-6 wire lines pulled through the water at 1-3 knots. Each wire line has 4-10 "spreads" attached at 3.7- to 7.3 m depth intervals. A spread consists of a rubber shock absorber with a snap, a monofilament leader, and the lure and hook assembly. Common types of lures are spoons, flashers with hootchies, plugs, and baited hooks. Configuration of the gear, including hook size, lure type, leader length, and depth fished varies depending on target species and size and lure type. Commonly used hook sizes off the Oregon coast are 5/0-6/0 commercial scale single hooks (NRC 1996a). In the Alaska troll fishery, hook sizes range from 5/0-9/0 commercial scale single hooks, with 6/0 the most common in chinook non-retention fisheries (Wertheimer et al. 1989). In the Canadian troll fishery, the hook sizes range from 5/0-8/0 commercial scale single hooks with 7/0 being the common size.

3.1.1 Commercial Troll - Recent Studies

Two sets of studies examining hooking mortality rates in commercial troll fisheries have been completed since the CTC 1987 review. Wertheimer (1988) and Wertheimer et al. (1989) examined mortality associated with chinook non-retention in southeast Alaska in 1986 and 1987, respectively. The NRC (1996) measured short to intermediate term mortality of chinook and coho salmon caught and released by commercial trollers off the Oregon coast in 1995.

Alaska--- In the research off southeast Alaska, chartered commercial trollers caught chinook salmon using their normal complement of lures that they would use during chinook non-retention fishing periods: hootchies with flashers, small plugs, and spoons. Captured chinook salmon were unhooked by the troller, anaesthesized using an electrically charged basket, measured, and tagged. The tagged fish were held in on-board tanks for an average of 20 min (6-60 min range)

3

prior to transfer into large marine net pens. Fish were held in the net pens for one to five fishing days (Wertheimer 1988) or four to six fishing days (Wertheimer et al. 1989) to determine intermediate mortality. Day 0 (immediate mortality) was based on the number of fish dead prior to transfer to the netpen, i.e., within one hour of landing. Day 1 mortality was based on the number of fish dying at the end of fishing day 1, i.e., within 2-12 hr of landing. Each additional holding day added 24 hr to these ranges. Fish were categorized as legal or sublegal based on 66 cm fork length, which was equivalent to a 28 in total length. A total of 506 chinook salmon were caught and monitored in 1986, and 913 were caught and monitored in 1987.

Cumulative mortality rates over the holding period were similar between the two years. Cumulative mortality for 1986, with 95% confidence intervals in parentheses, was 20.5% (9.0-31.9) for legal chinook salmon and 24.5% (20.1-29.0) for sublegal chinook salmon. In 1987, they were 19.0% (15.5-22.5) and 18.3% (14.0-22.6) for legals and sublegals, respectively. When the two data sets were combined, cumulative mortality was 18.5% (15.4-21.6) for legals and 21.7% (18.6-24.8%) for sublegals (Table 1). Location of the hooking wound was the most significant variable associated with mortality. Size of fish also affected mortality; mortality was significantly higher for smaller fish (Wertheimer et al. 1989).

In this type of holding experiment, several factors may bias the observed mortality relative to the true rates occurring in the fishery. The observed mortality during the holding period may be biased low because the fish are protected from predation while recovering from the hooking trauma, and because some fish may be lethally wounded but have not yet died (long-term delayed mortality). However, the observed rates may also be biased high because the additional stress of handling and holding may cause fish to die that would have survived the hooking encounters.

Tag recovery data have been used to estimate delayed mortality, including the long-term component. Wright (1970) and Butler and Loeffel (1972) assumed no delayed mortality for fish with certain categories of superficial injuries, and then calculated delayed mortality for all other injury categories. Combined with observations of immediate mortality from their studies, Wright (1970) and Butler and Loeffel (1972) could then generate estimates of the minimum total hooking mortality.

To address some of the bias inherent in holding and observing delayed mortality, Wertheimer (1988) and Wertheimer et al. (1989) used observations from their studies to recalculate the estimates of total delayed hooking mortality derived from the tag recovery data of Wright (1970) and Butler and Loeffel (1972). The total delayed mortality was re-estimated by replacing the assumption of no mortality for superficial wounds with observed values of mortality for these wounds. These estimates still assume that these superficially injured fish suffer no additional mortality beyond the observation period, and no predation mortality due to the hooking mortality, but does not require such assumptions about more severely injured fish. This estimate assumes that none of the observed mortality of these superficially injured fish was due to additional handling or the holding environment. It thus represents a maximum estimate of mortality relative to this assumption.

4

Table 1. Daily and cumulative mortality of legal- and sublegal-sized chinook salmon caught on commercial troll gear and held in seawater netpens. Cumulative mortality may differ slightly from the sum of daily mortality due to rounding.

Study	Days Held	Number Held		Number Deaths		Daily Mortality (%)		Cumulative Mortality (%)	
		Leg	Sub	Leg	Sub	Leg	Sub	Leg	Sub
Alaska:	0	658	761	18	57	2.7	7.5	2.7	7.5
Wertheimer (1988);	1	658	761	74	89	11.2	11.7	14.0	19.2
Wertheimer et al.	2	643	686	7	6	1.1	0.9	15.1	20.1
(1989)	3	615	564	5	2	0.8	0.4	**15.9**	**20.4**
(Sublegal < 28 in)	4	598	494	8	2	1.3	0.4	17.2	20.8
	5	401	303	5	3	1.2	1.0	18.5	21.8
	6	185	124	0	0	0	0	**18.5**	**21.8**
Oregon:	0	445	581	39	71	8.8	12.2	8.8	12.2
NRC (1996)	1	445	581	9	21	2.0	3.6	10.8	15.8
(Sublegal < 26 in)	2	445	581	29	23	6.5	4.0	**17.3**	**19.8**

Wright (1970) estimated a minimum delayed mortality of 7.7% (Table 2) based on the condition of legal and sublegal chinook salmon at the time of tagging. Wertheimer (1988) recalculated these data using the observed 9.9% mortality for fish with minor injuries, and derived an estimate of delayed mortality of 16.8%. Combined with Wright's (1970) estimate of 4% for immediate mortality, this increases Wright's estimate for hooking mortality from 11.7% to 20.8% (Table 2).

Butler and Loeffel (1972) estimated delayed mortality of 5.1% for 2,107 sublegal chinook caught on either barbed or barbless hooks (approximately 50% on each hook type), assuming no delayed mortality for fish hooked in the maxillary. The formula used to calculate this percentage was inappropriate: this estimate of delayed mortality should be 14.1% (Wertheimer 1988). Wertheimer (1988) and Wertheimer et al. (1989) recalculated these data, substituting observed mortality of jaw or jaw plus cheek-hooked fish, and derived estimates of delayed mortality of 17.2-18.4%. Combined with Butler and Loeffel's (1972) observed immediate mortality of 8% for sublegal chinook salmon caught on barbed hooks, these estimates give a range of total hooking

5

Table 2. Delayed mortality estimates for chinook salmon caught on commercial troll gear, based on relative tag recovery rates.

Study	Injury Category	Size Category	Tagged Fish Released	Tagged Fish Recovered	Mortality Assumed for "best" category	Estimated Delayed Mortality	Estimated Immediate Mortality	Total Mortality Estimate
Wright (1970)	Condition	All (Legal and Sublegal)	1,749	305	Good = 0% 9.9%[1]	7.7% 16.8%[1]	4.0%	11.7% 20.8%[1]
Butler and Loeffel (1972)	Wound Location	Sublegal (<26")	1,938 (2,107 captured)	587	Maxillary - hooked = 0% 0%[2] 4.2%[3] 5.6%[3]	5.1% 14.1%[2] 17.2%[3] 18.4%[3]	8.0% (Barbed hooks)	13.1% 22.1%[2] 25.2%[3] 26.4%[3]

[1] Based on recalculation of Wright data using the 9.9% mortality observed by Wertheimer (1988) for fish with minor injuries.

[2] Based on recalculation of Butler and Loeffel data corrected for computational error (Wertheimer 1988)

[3] Based on recalculation of Butler and Loeffel data (corrected), using the 4.2%-5.6% mortality rate observed for jaw hooked fish (Wertheimer et al. 1989).

mortality of 22.1%-26.4%. The low end of the range would hold if all delayed mortality of jaw-hooked fish was actually due to handling. Wertheimer et al. (1989) recommended using the high end of the range, 26%, as a point estimate of hooking mortality of sublegal chinook salmon. Because the observed holding mortality of legal chinook salmon in their studies was 85% of that of sublegal fish, Wertheimer et al. (1989) also suggested a point estimate of 22% for legal chinook salmon.

Oregon--- Off the Oregon coast in 1995, NRC (1996) chartered five commercial trolling vessels to fish for coho and chinook salmon. Spoons and flashers with hootchies were the two types of lures used as representative of gear normally fished by commercial trollers on the Pacific coast. Captured salmon were unhooked by the troller; examined, measured, and tagged; and then placed in an on-board holding tank. Some of the fish were anaesthesized prior to examination; others were handled without anaesthetic. Fish were held up to 5 hr in the on-board tanks, and were then transferred to net pens suspended in Charleston Harbor. Mortality occurring in the holding tanks was considered Day 0 mortality. The net pens were checked every 24 hr after fish were placed in them. Day 1 mortality was based on fish that had been held 25-29 hr since capture. The fish were held in the net pens for 2 to 4 days. The original experimental design was to hold all fish for four days. For the first two days of the holding period, observed mortality in the netpens was correlated with wound locations, consistent with other hooking mortality studies. After Day 2, however, mortality increased greatly, and there was no association between wound location and death. The researchers concluded that conditions in the netpen were not suitable for extended holding, and caused the high mortality observed after Day 2. They therefore reduced holding time to 2 d, and excluded mortality data for fish held for the longer period.

A total of 1,261 chinook salmon were captured over 19 days of fishing. Problems were identified with the holding tank on one vessel, the Oceana, which had high (50%) post-hooking mortality. The 218 chinook salmon captured by this vessel were excluded by the investigators from their analysis. For the other 1,043 chinook retained, mortality after Day 0 was 12.2% for sublegal (<26 in total length) chinook salmon, and 8.8% for legals. Cumulative mortality for sublegals and legals was 15.8% and 10.8% through Day 1, and 19.8% and 17.3% through Day 2 (Table 1). (If the 218 chinook from the Oceana are included in the mortality computation, the Day 2 rates are increased by approximately 3%.)

As noted above, hooking location was significantly associated with mortality within the first two days. Hook wounds associated with "normally" lethal locations were documented during necropsies for 97% of the fish that died through Day 2. However, on-board observation of wound location at landing was not a good predictor of mortality. The researchers attributed this to the manner the fish were handled for tagging, i. e., upside-down in a padded trough. While this minimized handling stress and eliminated the use of anaesthetic, it obscured observation of the actual location of the hook wound. Therefore observation of wound distribution of fish at landing was not considered representative of the actual wound locations.

Hooking mortality varied significantly among boats, ranging from 12.6% - 25.2% through Day 2 for the four vessels evaluated. The distribution of hook wounds of dead fish (observed at

7

necropsy) was similar between the boats. For this to happen, some boats must have hooked a higher proportion of the fish they encountered in lethal locations. The researchers did not have an explanation for this relative difference in lethal hooking encounters.

The researchers also noted significant differences in mortality between size 5/0 and 6/0 hooks. These hook sizes were noted to be the most common in the Oregon commercial troll fishery. The smaller (5/0) hooks had an associated mortality of 17.1 %, versus 22.5 % for larger (6/0) hooks. A small sample of fish (53) were landed on 3/0 hooks. The mortality associated with these small hooks was 17.9%, similar to the rate for 5/0 hooks, but was not analyzed statistically due to the small sample size.

Legal-sized chinook had consistently lower cumulative mortality for Day 0 through Day 2 than did sublegal-sized chinook (Table 1). The differences were larger and significantly different through Day 0 and Day 1, but not through Day 2. Daily mortality more than tripled for legals from Day 1 to Day 2, but only increased by 10% for sublegals (Table 1). This differential increase may indicate that the netpen effects that caused the researchers to terminate holding fish after Day 2 were affecting larger fish to a greater degree; alternately, it may indicate that larger fish simply take longer to die from the hooking trauma.

Direct comparison of intermediate holding mortality between the Oregon study and the Alaska research is complicated by the different definitions of holding time to mortality. Holding time through Day 2 in the Oregon study was 49-53 hr, roughly the same as holding time to Day 3 in the Alaska study (50-69 hr). Cumulative mortality rates through these time periods were very similar in both geographic locales: 19.8% vs. 20.4% for sublegals in Oregon and Alaska, respectively; and 17.3% vs. 15.9% for legals in Oregon and Alaska, respectively (Table 1).

3.1.2 Commercial Troll - Recent Reviews

WDF et al. (1993)--- In 1993, Washington state and tribal fishery managers formed a technical team to review recent studies on hooking mortality rates of chinook and coho salmon. Based upon their review, they recommend hooking mortality rate estimates for use in Pacific Coast salmon fishery management. These recommendations were compared with recommendations developed by WDF in 1986 (Stohr and Fraidenburg 1986). Stohr and Fraidenburg (1986) recommended a single hooking mortality rate of 30% for chinook and coho salmon in both commercial troll and recreational fisheries, with a reduction to 26% if barbless hooks were used in the fishery.

At the time of the 1993 review by WDF et al., the only new information available on commercial troll hooking mortality since the CTC (1988) review was from the Alaska studies by Wertheimer (1988) and Wertheimer et al. (1989). WDF et al. (1993) concluded that although these studies recommended somewhat lower rates than the 30% from Stohr and Fraidenburg (1986), the evidence was not compelling enough to recommend a change from the currently used rate. WDF (1993) also concluded that fish size is significantly related to hooking mortality, and noted that

Wertheimer et al. (1989) recommended different mortality rates for sublegal and legal-sized chinook salmon. However, WDF et al. (1993) noted the difference was "small" (about 4%), and did not recommend different rates at the time. They further recommended future research to substantiate any difference between legal and sublegal chinook in the fisheries of interest.

STT (1994)--- In 1994, the STT of the PFMC undertook a review of non-landed mortality of chinook and coho salmon in PFMC ocean salmon fisheries. The purpose of the review was to determine if the current rate of 26% used for commercial and recreational fisheries managed by PFMC should be changed. The STT used data from individual studies they felt were applicable to Council fisheries. Their approach was to combine observations of mortality from the different studies to generate a weighted average across studies reporting immediate and delayed mortality.

The weighted averages generated by the STT for hook and release mortality for second ocean year and older chinook salmon caught on barbed hooks were 9% immediate mortality and 19% delayed mortality. Although they noted that one study did indicate that sublegal-sized fish had higher hook-and-release mortality, the STT (1994) did not think the difference was sufficient to recommend using fish size as a consideration in the rate for the commercial troll fishery. The STT (1994) summed their weighted averages of immediate and delayed mortality to generate an estimate of 28% for hook-and-release mortality. The STT also recommended three adjustments to the hook-and-release mortality estimate to derive a total non-landed mortality estimate. These were: (1) a reduction to 24% (0.85 x 28% or a discount of 0.15) for the use of barbless hooks; (2) a 2% increase in the rate to account for "associated" mortality (e.g., long-term mortality, regulation non-compliance); and (3) a 5% increase in the rate to account for "drop-off" mortality, i. e., fish that are hooked and assumed to be killed as a result of the encounter even though the fish do not reach the boat. The total non-landed mortality recommended by the STT for chinook salmon caught on commercial troll gear with barbless hooks was, therefore, 31%, rather than the 26% used by PFMC . Following the STT review, PFMC (1994) declined to change the 26% hook-and-release mortality rate used for PFMC commercial troll fisheries. They did add the additional 5% for drop-off mortality.

3.1.3 Commercial Troll - Discussion

Table 3 compares the hooking mortality rates recommended for commercial troll fisheries since the CTC (1988) review of the subject. While the CTC (1988) concluded a range of 20-30% was appropriate for hooking mortality in commercial troll fisheries, a point estimate of 30% is currently used in the CTC chinook model for all hook and line fisheries. The CTC (1988) noted that differences in scientific opinion among its members on hook-and-release mortality result from the relative merit put on particular studies, the relative importance of factors contributing to the outcomes from various studies, and each member's personal experience. Given these problems, the similarity of the recommended rates in Table 3 is striking. The main factors contributing to differences in the recommended rates are: (1) adjustments for hook type, specifically barbless hooks; (2) adjustments for size differences; and (3) adjustments for "associated" and "drop-off" mortality.

9

Table 3. Comparison of recommended hook and release mortality rates for chinook salmon caught in commercial troll fisheries.

Reference	Mortality (%)		Comments
	Legal	Sublegal	
CTC (1988)	20-30	20-30	CTC consensus
Wertheimer et al. (1989)	22	26	Barbed single hooks; total hook-and-release mortality
WDF et al. (1993)	30	30	Barbed single hooks; Delphi consensus
	26	26	Barbless single hooks; Delphi consensus
STT (1994)	28	28	Barbed single hooks; weighted average of studies
	31	31	Total non-landed mortality with barbless hooks
PFMC (1994)	31	31	Council decision on rate to apply for total non-landed mortality

Hook Type. Hook size has also been shown to affect the size of fish caught on commercial troll gear (Orsi 1987; Orsi et al. 1993). This relationship between hook size and fish size suggests that hook size will also affect the mortality rate of a given size class of fish. In fact, NRC (1996) reported significantly lower mortality across all fish sizes between 5/0 and 6/0 commercial scale hooks. However, this does not necessarily mean that small differences in hook size can be used to reduce incidental mortality, because smaller hooks will increase the proportion of small fish hooked. Also, the NRC (1996) test of hook size was not conclusive for two reasons. First, it was a simple chi-square analysis that did not incorporate critical parameters such as fish size or vessel into the analysis; because these factors also were shown to influence mortality, they may have confounded the hook size results. Second, the chi-square analysis did not include data reported for 3/0 hooks, the smallest hook size used. Although the sample size was small, if these results are included in the chi-square analysis, hook size is not significantly associated with mortality.

Barbless hooks are required in several Pacific Northwest fisheries on the assumption that their use reduces incidental hooking mortality. The PFMC discounts the hooking mortality rate by 0.15 for barbless hooks. Only one study (Butler and Loeffel 1972) has compared the mortality of barbed and barbless hooks on commercial troll gear. Butler and Loeffel (1972) found a significant reduction in immediate mortality associated with barbless hooks. Barbless hooks also had a lower delayed mortality, although the difference was not significant. Although this is the only study directly addressing the effect of barbless hooks on release mortality, it was well designed and had a large (2,126 chinook) sample size. On the basis of this study, the CTC decided to calculate different mortality rates for barbed and barbless hooks, adjusting rates observed or calculated for each of the hook types by the ratio of total mortality of barbed versus barbless hooks derived from Butler and Loeffel (1972).

The estimates of total mortality by hook type were generated by summing the immediate mortality observed by Butler and Loeffel (1972) with recalculated estimates of their delayed mortality estimates. Butler and Loeffel (1972) reported delayed mortality rates of 7.3% for barbed hooks, 1.06 times larger than the 6.9% they reported for barbless hooks. The corrected calculation of delayed mortality from their data for barbed and barbless tag releases combined was 14.2% (Wertheimer 1988). By applying the 1.06 barbed/barbless ratio, the corrected delayed mortality rate was partitioned to 14.7% for barbed hooks and 13.7% for barbless hooks. Immediate mortality observed by Butler and Loeffel (1972) was 8.0% for barbed and 6.1% for barbless. Combining these observations with the recalculated estimates of delayed mortality gives a total mortality of 22.7% for barbed and 19.8% for barbless. Thus barbed hooks had a mortality rate that was 1.15 times (15%) higher than did barbless hooks.

Size Differences. The recent research on commercial troll hooking mortality supports using a higher mortality rate for smaller chinook salmon. Both Wertheimer et al. (1989) and NRC (1996) observed 1.15 times higher mortality for sublegal chinook relative to legal chinook salmon. Wertheimer et al. (1989) presented a smoothed plot of observed mortality as a function of fish size. The plot indicates high mortality for small fish, declining rapidly for fish larger than 50 cm, then increasing again for fish larger than 80 cm. An explanation for the shape of the response curve is the size of the hook relative to the mouth size of the fish. The larger the hook

11

is relative to the size of the fish, the higher the probability of contact and damage to vital tissues when the fish is hooked in the mouth. However, the size of the hook relative to mouth size may also restrict the depth of ingestion. Very large fish may have a higher probability of ingesting the hook deeper, placing it closer to the gills, which would explain the upswing in mortality at the high end of the size range. Because trollers adjust lure and hook sizes to the size limits in their specific fishery, the CTC felt that size-specific rates for sublegal and legal size categories could be applied generally, even though size limits vary slightly amongst commercial troll fisheries.

The CTC decided to construct hook-and-release mortality rates for immediate and delayed mortality by legal and sub-legal size categories, based on studies where observed mortality was differentiated by these size categories. For immediate mortality, three studies met this criterion for sublegal chinook, and two for legal chinook (Table 4). For delayed mortality, observations were used from two studies to produce delayed mortality estimates through a 6-d holding period (Table 5). These estimates were then expanded to incorporate long-term delayed mortality by using the relationship between mortality observed for sublegal chinook by Wertheimer et al. (1989) and delayed mortality from Butler and Loeffel (1972) for sublegal chinook, recalculated by Wertheimer et al. (1989).

To construct the estimates of immediate mortality, the CTC generated a weighted average by summing total sampled and number of observed deaths across the applicable studies (Table 4). The number of deaths was adjusted for barbed or barbless hooks by the 1.15 factor, as appropriate. The resulting estimates of immediate mortality for sublegal and legal chinook were, respectively: 5.8% and 5.9% on barbed hooks; and 4.9% and 5.2% on barbless hooks (Table 4).

To construct the estimates of delayed mortality, the CTC applied a series of adjustments to the observed rates tabulated in Table 1. First, the estimates of immediate mortality constructed in Table 4 were subtracted from the observed total mortality rates in Table 1 to give estimates of delayed mortality only. Then these rates were standardized in Table 5 to a 6-d holding period by expanding the 2-d rates observed by NRC (1996) by the ratio of the 6-d to 3-d rates observed by Wertheimer et al. (1989). The 3-d observations were used because these corresponded most closely in total time held to the 2-d period observed by NRC (1996). Next, the 6-d rates were expanded by the ratio of total delayed hook-and-release mortality (recalculated by Wertheimer et al. (1989) for sublegal chinook from the tag-recovery data set of Butler and Loeffel (1972)) to the delayed mortality observed for sublegal fish by Wertheimer et al. (1989). These expanded rates were also adjusted for barbed or barbless hooks as appropriate (Table 5). The adjusted total delayed mortality rates from the two studies were then averaged to generate final delayed mortality estimates. The resulting estimates of delayed hook-and-release mortality for sublegal and legal chinook were, respectively: 19.7% and 15.2% on barbed hooks; and 17.1% and 13.3% on barbless hooks (Table 5).

Associated and Drop-off Mortality. The STT (1994) recommended increasing estimates of hooking mortality by 2% for "associated" mortality and 5% for "drop-off" mortality. They identified associated mortality as the additional mortality due to "predation, long-term mortality,

12

Table 4. Estimates of immediate mortality for chinook salmon in northeast Pacific commercial troll fisheries by sublegal and legal size categories for barbed and barbless hooks. In cases where only one hook type was used to collect the sample, number of deaths was adjusted between hook types by assuming a mortality ratio of 1.15:1 for barbed to barbless (see text). These adjusted numbers are shown in parentheses.

Reference	Barbed			Barbless		
	Sample Number	Mortality No.	%	Sample Number	Mortality No.	%
SUBLEGAL-SIZED CHINOOK SALMON						
Butler and Loeffel (1972)	1,066	85	8.0	1,041	63	6.1
Wertheimer et al. (1988,1989)	761	57	7.5	(761)	(50)	(6.5)
Murray and Riddell (1996)	(3,612)	(173)	(4.8)	3,612	150	4.2
Weighted Average Sublegals	**5,439**	**315**	**5.8**	**5,414**	**263**	**4.9**
LEGAL-SIZED CHINOOK SALMON						
Wertheimer et al. (1988,1989)	608	18	3.0	(608)	(16)	(2.6)
Murray and Riddell (1996)	(1,967)	(135)	(6.9)	1,967	117	6.0
Weighted Average Legals	**2,575**	**153**	**5.9**	**2,575**	**133**	**5.2**

Table 5. Summary of data and expansions used by the CTC to calculate estimated of delayed mortality rates for chinook salmon in northeast Pacific commercial troll fisheries by sublegal and legal size categories for barbed and barbless hooks. Rates were adjusted between hook types by assuming a mortality ratio of 1.15:1 for barbed to barbless (see text). Rates adusted for hook type are shown in parentheses. Delayed mortality observations are the observed total mortality from Table 1, adjusted for the estimates of immediate mortality from Table 4. Factors for holding time expansions are: the ratio of 6d / 2d calculated from Wertheimer et al. (1989) for legals and sublegals separately; and the ratio of total / 6d for sublegals, using recalculated total from Butler and Loeffel (1972, revised) and 6d estimate from Wertheimer et al. (1989). Obs. = observed, Exp. = expansion factor.

Reference	Barbed (% Mortality)					Barbless (% Mortality)				
	2d Obs.	2-6d Exp.	6d Obs.	6d-Tot Exp.	Total	2d Obs.	2-6d Exp.	6d Obs.	6d-Tot Exp.	Total
SUBLEGAL-SIZED CHINOOK SALMON										
Butler and Loeffel (1972, revised)					18.0					(15.7)
Wertheimer et al. (1988,1989)	14.6		16.0	1.13	18.0					(15.7)
NRC (1996a)					(21.3)	14.9	1.10	16.4	1.13	18.5
Average Sublegals (Wertheimer and NRC)					**19.7**					**17.1**
LEGAL-SIZED CHINOOK SALMON										
Wertheimer et al. (1988,1989)	10.0		12.6	1.13	14.2					(12.4)
NRC (1996a)					(16.3)	11.4	1.10	12.5	1.13	14.2
Average Legals (Wertheimer and NRC)					**15.2**					**13.3**

14

and regulation non-compliance;" and drop-off mortality as the fish that escape from the gear prior to being brought to the boat, but die as a result of the hooking encounter. The CTC decided to limit associated mortality to adjusting the estimated rate for long-term delayed mortality and to include predation mortality as a component of drop-off mortality. Regulation non-compliance was not considered a component of the non-landed mortality rate in this report. Because the CTC developed a mortality estimate that is adjusted for long-term effects, there was no need for an additional associated mortality add-on.

Although the STT (1994) showed no data to support the 5% drop-off mortality they proposed (computed as a proportion of the fish brought to the boat, both retained and released), the use of this rate implicitly assumes that some proportion of unlanded encounters experience either lethal hooking wounds or predator attacks. The CTC developed an estimate of drop-off mortality based on actual estimates of the unlanded encounter rates and explicit assumptions for the drop-off mortality rate. Two categories of drop-off mortality were considered: (1) *escaped encounters*, fish that are hooked but escape from the gear; and (2) *predation mortality*, fish that are removed or lethally maimed by predators.

The CTC assumed different mortality rates for these two drop-off mortality categories. For escaped encounters, the CTC used a lower mortality rate than the estimated hook-and-release mortality for fish brought to the boat and released. This decision was based on the assumption that fish with peripheral hook locations are much more likely to get off the gear than fish that are deeply hooked. Peripheral wound locations have significantly lower associated mortality rates (Butler and Loeffel 1972; Wertheimer 1988; Wertheimer et al. 1989; NRC 1996). The CTC assumed that mortality for fish that escaped from the gear was 5.1 % for barbed hooks. This is the 4.2% mortality observed after 6-d by Wertheimer et al. (1989) for chinook salmon hooked in periphery of the mouth, adjusted by a factor of 1.21 to account for long-term delayed mortality. For fish lost to predators, the CTC assumed 100% mortality. Based on these rates, the drop-off mortality for commercial trolling with barbed hooks can then be calculated as:

$$\text{Drop-off mortality rate} = (5.1\% \text{ escapee mortality})*(\% \text{ escaped encounters}) + (100\% \text{ predator mortality})*(\% \text{ predator encounters})$$

For barbless hooks, the escaped mortality rate would be 5.1/1.15 = 4.4%.

The only data available to the CTC at this time for escaped encounters are from NRC studies off the Oregon coast in 1996 (Doug McNair, NRC, personal communication). In this study, escaped encounters were categorized as "no shows" or "lost at boat." "No shows" are fish that hit the gear but are never seen from the boat. Thus, species identification is not possible. "Lost at boat" are salmon observed to get off the hook before they can be boated or released. Species identification is sometimes possible for these fish.

Rates for these two categories recorded by NRC were 3.1% for no shows and 4.7% for lost at boat, expressed as a percentage of the total chinook salmon (sublegal and legal) and coho salmon brought to the boat (Doug McNair, NRC, personal communication). The sum of no

15

shows and lost at boat, 7.8%, is the total percent escaped encounters. Using this encounter rate, escaped mortality would be 0.4% for barbed hooks, and 0.3% for barbless hooks.

"Lost to predators" includes fish removed or lethally maimed by a predator. Again, species identification is not always possible in this case, and encounters must be considered in context of total salmon brought to the boat. Two data sources were available for predator loss rates. In the NRC 1996 research, salmon lost to predators totaled 2.2% of the total chinook salmon (sublegal and legal) and coho salmon brought to the boat (Doug McNair, NRC, personal communication). In the Alaska troll fishery from 1980-1982, participants in the trollers' log book program had an average annual rate of 0.4% of salmon brought to the boat were lost to or maimed by predators (Table 6). The average predation mortality for these two regions is thus 1.3%.

Table 6. Predator encounter rates expressed as a percentage of the total salmon brought to the boat in 1980-1982 by commercial trollers participating in the Alaska troll log book program. From Krygier (1981, 1982, 1983).

Year	Salmon Brought to Boat	Salmon Mutilated by or Lost to Predators	Percent Lost
1980	183,452	979	0.5
1981	208,901	1019	0.4
1982	273,488	784	0.3
1980-82 Average			0.4

The estimate for the total drop-off mortality rate is the sum of these estimates for escaped encounter and predator mortality rates, as shown in Table 7.

Table 7. Estimates of escaped encounter, predator, and total drop-off mortality rates in commercial troll fisheries.

Area	Escaped Encounter Mortality Rate	Predator Mortality Rate	Total Drop-off Mortality Rate
SEAK	0.4%	0.4%	0.8%
Oregon coast	0.3%	2.2%	2.5%
Average (barbed)	0.4%	1.3%	1.7%
(barbless)	0.3%	1.3%	1.6%

There was substantial concern expressed within the CTC about using data from only one or two studies or regions to estimate the escaped encounter and predator loss rates. However, the consensus view was that it was better to use these sparse data and explicit assumptions for drop-off mortality rather than a number that is simply an intelligent guess. Because predator encounters can be expected to vary greatly from fishery to fishery due to geographic variation in the distribution of marine mammals and sharks that are the major predators, such data should be

applied on a fishery-specific basis when available. By using this approach, the CTC can adjust drop-off mortality on a fishery-specific basis when and if data are available for other troll fisheries. For fisheries where specific data are not available, the CTC will use the average rate for escaped encounters and predator losses.

Because drop-off mortality is calculated as a percentage of both retained and released chinook salmon, the drop-off mortality rate is only additive to the hook-and-release mortality rate (which is a percentage of the fish <u>released</u>) for non-retention fisheries, when both legal and sublegal fish are released. In troll fisheries where legal-sized chinook are retained, total non-landed mortality must be calculated as two different components: hook-and-release mortality of sublegal fish, and drop-off mortality of both legal and sublegal fish. Because drop-off mortality does apply to both legal and sublegal chinook, the number of drop-off deaths for each of these two size categories is the total estimated drop-off loss multiplied by the observed proportion of the chinook brought to the boat in that size category.

3.1.4 Commercial Troll - Recommendations

For commercial troll fisheries, the CTC recommends using hook-and-release mortality rates that are specific for hook type (barbed, barbless) and size categories (legal, sublegal) in CTC analyses. Total hook-and-release mortality rates recommended for these categories, determined by summing the estimates in Tables 4 and 5 for immediate and delayed mortality for each category, are:

Barbed, legal:	21.1%
Barbed, sublegal:	25.5%
Barbless, legal:	18.5%
Barbless, sublegal:	22.0%

The CTC also recommends calculating an additional mortality increment in CTC analyses for drop-off mortality. This rate, based on the total chinook brought to the boat (landed catch and released catch), is fishery specific, varying with hook type, escaped encounter rate, and predator encounter rate. Based on the current information available to the CTC, estimates of drop-off mortality are:

SEAK Troll (barbed hooks):	0.8%
Oregon Troll (barbless hooks):	2.5%
Average (barbed hooks):	1.7%
Average (barbless hooks):	1.6%

17

3.2 RECREATIONAL FISHERIES

Recreational anglers fishing for chinook salmon in marine waters typically use permutations of two distinct fishing methods: trolling or mooching. Trollers drag lures or baited hooks through the water at speeds of 0.5-2.0 knots. Common hook sizes are 2/0- 5/0 (recreational scale). To fish at depths appropriate for chinook salmon, trollers either attach weights (10-32 oz) or other devices to their fishing line or attach their line with a release device to a downrigger line, a separate, heavily weighted wire line. Fish must strike at the moving lure with some velocity, and are typically hooked in the mouth.

Mooching involves drifting a baited hook or tandem hooks, relying on current and wind to move the bait through the water. Hook sizes range from 1/0-4/0 (recreational scale). Light weights (1-5 oz) are attached to reach the desired depth. Fish usually strike the bait lightly, and anglers wait or even give slack line before striking back in order to allow the fish time to "take" the bait. Hooking location apparently varies dramatically with the type and presentation of the bait. In Washington, whole herring and herring "plugs" (head removed) are the most common bait, rigged so that the hook points to the front of the bait; salmon taking this bait are usually hooked in the mouth (NRC 1994a). In California, anchovies are commonly used as bait, rigged so the hook points towards the tail of the bait to facilitate the chinook salmon swallowing the bait. The small size of the bait and the way it is rigged results in a high proportion of the salmon hooked ingesting the bait and being hooked in the pharynx or gut (Grover 1995b).

3.2.1 Recreational Fisheries - Recent Studies

Several studies on hooking mortality of chinook salmon in recreational fisheries have been completed since the 1987 CTC review. These have included a wide range of geographic locales: Alaska, British Columbia, Washington, and California.

Alaska--- Bendock and Alexandersdottir (1993) used radio-tracking to examine mortality of maturing chinook salmon hooked and released by sport anglers in the Kenai River. Over three years, 446 chinook salmon were captured and tagged; each tagged fish was tracked for up to five days. Overall mortality was 7.6% (Table 8). Injury location was identified as the factor most significantly associated with mortality. Hook type (single or treble), number of hooks (one or two), and lure type (lure or lure/bait combination) did not significantly influence the observed mortality. The fish captured were all maturing, returning to the river to spawn. Most fish were large ($\geq$ 75 cm); Kenai River chinook are considered to have the largest average body size of any stock. Small males (<75 cm) had significantly higher mortality than did large males and females (11.5-17.5% versus 1.8-9.9% and 6.5-6.8%, respectively).

British Columbia--- Gjernes (1990) observed post-hooking mortality for 152 chinook salmon caught by researchers trolling flashers and hootchies in the Strait of Georgia. Lures were rigged

18

Table 8. Summary of recent studies of hooking mortality of chinook salmon caught in recreational fisheries.

Study	Fish Size Mean (range)	Observation Time	Sample Size	Number Deaths	Mortality (%)	Comments
Bendock and Alexandersdottir (1993)	87 cm (46-116)	5 days	446	31	7.6	Tracked with radio-telemetry
Gjernes (1990)	(35-82 cm) (35-44) (45-62) (> 62)	24-72 hr	152 32 98 22	15 4 8 3	9.9 12.5 8.2 13.6	Trolling, single-point barbed hooks.
Gjernes et al. (1993)	(<30 cm)	6-30 hr	124	37	29.8	Trolling, various hook types
NRC (1991)	67 cm (31-101)	24-48 hr	67	6	9.0	Mooching, tandem single-point barbless hooks.
NRC (1994a)	(30-60+ cm)	4 days	313	32	10.2	Varied gear type, barbless hooks
Grover (1995b)	Legal and Sublegal	24-34 hr	217	80	36.9	Mooching, single single-point barbless hooks

with two size 4/0 (recreational scale) single, barbless hooks in tandem, 5 cm apart. The fish caught ranged from 35-82 cm, and were held for 24-72 hr. Mortality for all fish combined was 9.9% (Table 8). Fish in the 45-62 cm range had observed mortality of 8.2%, compared to 12.5% for smaller (35-44 cm) and 14.0% for larger (> 62 cm) chinook salmon (Table 8). However, these differences were not statistically significant. All fish that died had hook injuries to major blood vessels associated with the gills or heart. There was no detectable difference in mortality between fish hooked with one of the tandem hooks compared with fish hooked with both hooks.

Gjernes et al. (1993) reported hooking mortality for sport-caught chinook and coho salmon in their first year of ocean residence in the Strait of Georgia. Fish were less than 30 cm in fork length. Angling was by volunteers aboard a charter vessel trolling lures with one of four hook configurations: barbed single, barbed treble, barbless single, and barbless treble. Fish were held for 6-30 hr. Observed mortality for chinook salmon was 30% (Table 8). Most fish that died succumbed within 15 min of landing. Injury location was identified as the most important explanatory variable. Treble hooks had lower mortality than single hooks, and barbless hooks had lower mortality than barbed hooks.

Puget Sound--- In 1989, NRC (1991) conducted a hooking mortality study in the Strait of Juan de Fuca. Volunteer anglers and biologists participated in catching the fish from small boats, using tandem mooching rigs with single-point barbless hooks. Fish were held from 24-48 hr. A total of 67 chinook ranging in size from 31-100 cm fork length were captured. Of these, 6 (9%) died during the observation period (Table 8). Most fish that died succumbed within a few hours of landing. Injury location was the only variable found to be significantly associated with mortality.

In 1992 and 1993, NRC (1994a) conducted another hooking mortality study for chinook salmon in Puget Sound. Volunteer anglers fished from charter boats, either mooching or trolling with downriggers. A variety of lures or bait was used; hook types were either single or tandem single-point barbless hooks. Chinook salmon ranging in size from 30-60+ cm fork length were held for four days in marine net pens. Overall mortality was 10.2% (Table 8). Injury location was again the variable most significantly associated with mortality. No difference was detected among the lure and hook types. Fish caught mooching with bait on tandem rigs had a mortality of 4%, well below the overall rate. This observation is important in the context of the results of the California studies outlined below.

California--- Grover (1995a) compared "calculated" mortality rates for chinook salmon caught by recreational anglers either mooching or trolling off the northern California coast. Anglers fished from commercial charter vessels, and observers categorized the injury location of their catch. Estimated mortality rates were generated by using the mortality rates reported by injury location in Wertheimer et al. (1989). Fish hooked in a post-phyraengeal location (gut-hooked), a wound location not observed by Wertheimer et al. (1989), had mortality set equal to that observed by Wertheimer et al. for gill hooked fish. Using these criteria, Grover (1995a) calculated that mortality was 4-6 times higher for both sublegal (< 20 in (50 cm) total length) and legal-sized chinook salmon (Table 9) caught on mooching gear than for chinook salmon caught

20

Table 9. Calculated mortality rates for legal and sublegal (< 20 in) sized chinook salmon caught by trolling or mooching off the California coast, 1993-1995. Mortality rates were calculated based on observations of wound locations, and the association of wound location with mortality. No. = number sampled for wound location, % = calculated mortality rate. From Grover (1995a).

YEAR	Legal		Sublegal		Combined	
	No.	**%**	**No.**	**%**	**No.**	**%**
TROLL						
1993	523	12%	232	13%	755	12%
1994	525	10%	149	13%	674	11%
1995	110	13%	79	14%	189	13%
MOOCH						
1993	504	61%	128	46%	632	58%
1994	549	63%	112	48%	661	60%
1995	361	75%	151	63%	512	73%

Table 10. Sample numbers, number dying, and percent mortality for chinook salmon by fish size and hook location; fish were caught by mooching with recreational gear off the California coast. Sublegal fish were < 20 in (50 cm) in length. Fish were held for 24-34 hr after capture. From Grover (1995b).

Size Category	Wound Location	Sample Size	Percent of Total	Number Dying	Percent Dead
Legal	Gut Area	64	63%	36	56%
	Mouth	31	31%	1	3%
	Gill Area	6	6%	2	33%
Sublegal	Gut Area	70	60%	33	47%
	Mouth	39	34%	4	10%
	Gill Area	7	6%	4	57%
All Sizes	Gut Area	134	62%	69	51%
	Mouth	70	32%	5	7%
	Gill Area	13	6%	6	46%

on trolling gear. The calculated rates ranged from 46-63% for sublegals and 61-75% for legals caught by mooching; and 13-14% for sublegals and 10-13% for legals caught by trolling. There was no significant difference in these calculated mortality rates between legal and sublegal fish caught by trolling. In contrast, the rates for legal-sized chinook salmon were significantly higher than the rates for sublegals when the fish were caught by mooching.

Grover (1995b) also conducted a hooking mortality study off of Point San Pedro, California, where chinook salmon were captured by mooching and held in a large ship-board live well for 24-36 hr. Over 67% of the 217 chinook salmon captured were hooked in the gut or gill area (Table 10). Of these, 51% of the gut-hooked fish and 46% of the gill hooked fish died during the holding period. In contrast, only 7% of fish hooked in the mouth area died (Table 10). Overall mortality for all wound locations was 37%. Necropsy of surviving gut-hooked fish suggested severe, probably lethal wounds to almost all of these fish; Grover (1995b) estimated that mortality would be 98% for this wound category over a longer holding period.

3.2.2 Recreational Fisheries - Recent Reviews

WDF et al. (1993)--- WDF et al. (1993) compared recent results for recreational fishing to the recommendation from Stohr and Fraidenburg (1986). The recommendation from Stohr and Fraidenburg (1986) was a single hooking mortality rate of 30% for chinook and coho salmon in both commercial troll and recreational fisheries, with a reduction to 26% if barbless hooks were used in the fishery. WDF et al. (1993) did not have information from the recent work in Puget Sound (NRC 1994a) or California (Grover 1995a; 1995b) at the time of their review.

WDF et al. (1993) made no recommendations on hooking mortality rates for chinook salmon in estuarine and riverine areas. The only study with information on the hooking mortality of chinook salmon in recreational fisheries in these habitats was Bendock and Alexanderdottir (1993). The large size of the fish in the Kenai River is not typical of chinook in the Pacific Northwest. Also, research on coho salmon in recreational fisheries in Alaska has indicated that there may be significant differences in hooking mortality in estuarine habitats versus freshwater habitats (Vincent-Lang et al. 1993). For these reasons, WDF et al. (1993) felt more information was needed on the vulnerability of salmon in estuarine and riverine areas before a hooking mortality rate could be established.

In marine recreational fisheries, WDF et al. (1993) recommended mortality rates be reduced relative to the 26-30% recommended by Stohr and Fraidenburg (1986). For chinook salmon, they recommended a rate of 10% for legal-sized fish, and 20% for sublegal-sized fish. They noted that the available information does not conclusively demonstrate differential rates due to size class, but they felt that the conservative approach was to assume such a difference. They cite Gjernes et al. (1993) for setting the rate for sublegal chinook salmon, and NRC (1991) and Gjernes (1990) for setting the rate for legal-sized chinook salmon. They also noted that they could not find data to conclusively support a different rate for barbed and barbless hooks in marine recreational fisheries.

22

STT (1994)--- The STT of the PFMC also reviewed recent studies of recreational hooking mortality, to determine if the current rate of 26% used for non-landed mortality in commercial and recreational fisheries managed by PFMC should be changed. The STT used data from individual studies they felt were applicable to PMFC fisheries. As with the commercial troll fisheries, their approach was to combine observations of mortality from the different studies to generate a weighted average across studies reporting immediate and delayed mortality. The SST did not have the results from Grover (1995a; 1995b) at the time of its review.

The hook-and-release mortality rate for marine recreational fisheries recommended by the STT for second-year and older chinook salmon was 8%. This rate was based on a weighted average for studies on both coho and chinook salmon. They felt there were no conclusive data to set different rates for barbed and barbless hooks. They did agree that some studies indicate differences in mortality with size of fish, but did not consider the data sufficient to warrant separate mortality rates by size class in PFMC ocean fisheries. They specifically excluded the results from Gjernes et al. (1993) for fish < 30 cm, noting that fish this small are not likely to be recovered in PFMC recreational fisheries. As such, they acknowledged that the rates they recommended may not be appropriate for fisheries in areas where encounters of small fish are significant.

Similar to their approach with commercial troll fisheries, the SST also recommended two adjustments to the hook-and-release mortality estimate to derive a total non-landed mortality estimate. These were: (1) a 2% increase in the rate to account for "associated" mortality (e.g., long-term mortality, regulation non-compliance); and (2) a 5% increase in the rate to account for "drop-off" mortality, i. e., fish that are hooked and assumed to be killed as a result of the encounter even though the fish do not reach the boat. The total non-landed mortality recommended by the STT for chinook salmon caught on recreational gear was therefore 15%, an 11 percentage point decrease from the 26% rate used by PFMC for barbless single hooks at the time of the STT review. PFMC (1994) accepted the new rate of 8% for hook-and-release mortality, and the additional 5% for drop-off mortality, but not the associated mortality increment. This resulted in a revised rate of 13% in PFMC recreational fisheries (Table 11).

3.2.3 Recreational Fisheries - Discussion

Table 11 compares the hooking mortality rates recommended for recreational chinook salmon fisheries since the CTC (1987) review of the subject. In general, recent studies have caused a decrease in recommended rates in these fisheries. However, the high mortality rates

Table 11. Comparison of recommended hook and release mortality rates for chinook salmon caught in recreational hook and line fisheries.

Reference	Mortality (%)		Comments
	Legal	Sublegal	
CTC (1988)	20-30	20-30	CTC consensus
Stohr and Fraidenburg (1986)	30	30	Barbed single hooks; Delphi consensus
	26	26	Barbless single hooks; Delphi consensus
WDF et al. (1993)	10	20	Marine recreational fisheries, barbless hooks
STT (1994)	8	8	Weighted average of hook-and-release mortality from studies using barbless hooks, fish > 30 cm
	15	15	Total non-landed mortality with barbless hooks for fish > 30 cm
PFMC (1994)	13	13	Council decision on rate for total non-landed mortality in PFMC fisheries

associated with mooching in California and small chinook in the Strait of Georgia suggest that rates must be applied in the context of the fishing technique and size of fish in a particular fishery. The main factors contributing to differences in the rates observed in recent studies (Table 8) and the recommendations in Table 11 are: (1) adjustments for hook type, specifically barbless hooks; (2) differences in fishing techniques; (3) adjustments for size differences; and (4) adjustments for "associated" and "drop-off" mortality.

Hook Type---Barbless hooks are required in several Pacific Northwest fisheries on the assumption that their use reduces incidental hooking mortality. For example, the PFMC discounts the hooking mortality rate by 0.15 for barbless hooks. Although the use of barbless hooks has been shown to reduce hooking mortality for nonanadromous trout caught with recreational gear (Taylor and White 1992), data for the effect of barbless hooks in marine recreational salmon fisheries are sparse. The STT (1994) did not think that the available information was sufficient to measure differences in hook-and-release rates between barbed and barbless hooks in marine recreational fisheries for chinook and coho salmon. Gjernes et al. (1993) did show significantly lower mortality for barbless hooks, but most of the difference was driven by low mortality for coho salmon caught on barbless treble hooks. For the small (< 30 cm) chinook salmon caught in this study, mortality was lower for barbless single-point hooks than for barbed single-point hooks, but was higher for barbless treble hooks than for barbed treble hooks (Table 1 in Gjernes et al.1993). Because the available data are not conclusive or consistent, the CTC decided not to consider barbed/barbless hook differences for estimating hook-and-release mortality in recreational fisheries.

Fishing Technique--- Recent research (Grover 1995a,b) documented high mortality associated with the "California mooching" fishing method. These rates are substantially larger than the mortality observed for either trolling or mooching using gear characteristic of recreational fishing in marine waters in the Pacific Northwest. At this time, the CTC agreed that rates for hook-and-release mortality for recreational fisheries of concern to the PSC should not incorporate data from the California mooching studies. However, if this fishing technique becomes more common in PSC fisheries, then the CTC estimates will need to be revised accordingly.

Size Differences--- The CTC decided that the available data supported different mortality rates for chinook salmon < 30 cm, but no differences among sizes for chinook salmon 35 cm or larger. The CTC thus estimated different recreational hook and release mortality rates for these two size categories of fish. Fish in the 30-34 cm size range were not covered in the studies; these sizes were split at 33 cm for assignment to the two size categories. Because chinook < 33cm are not common in PSC fisheries, the rate for the larger size class will be used, unless size distribution data from a particular recreational fishery indicates that the rate should be weighted for the proportion of small fish present.

For fish $\geq$33 cm, the CTC first developed estimates of immediate and delayed mortality. Gjernes (1990) reported 8.3% mortality within one hour of landing; NRC (1994a) observed 5.7% mortality within 3 hr of landing. The CTC used the average of these two observations, 7.0%, as an estimate of immediate mortality.

25

To estimate total delayed mortality, the CTC used a similar process to the one used to estimate commercial troll mortality. First, the available observed mortality rates were extrapolated to a standard 6-d holding period. Then, the estimate of immediate mortality was subtracted from these 6-d rates, to give a standardized estimate of intermediate delayed mortality. Finally, these delayed mortality estimates were expanded by 1.13, the 6-d to long-term expansion factor derived from the commercial troll studies.

To extrapolate observed mortality to a standard holding period, the observations of cumulative mortality were plotted as a function of time for the three available studies (Gjernes 1990; NRC 1991, 1994a). The resulting graph supports the concept of high initial mortality, followed by a lower rate for delayed mortality that declines over time (Figure 1). This mortality pattern can be modeled using an exponential decline,

$$N_f = S_o * N_i (e^{-zt})$$

where N_f is number surviving, S_o is immediate survival (1- immediate mortality), N_i is initial number sampled, z is daily instantaneous mortality, and t is time held in days. Solving for z where immediate mortality = 7.0% and mortality after 4 d = 10.2% gives z = 0.0088.
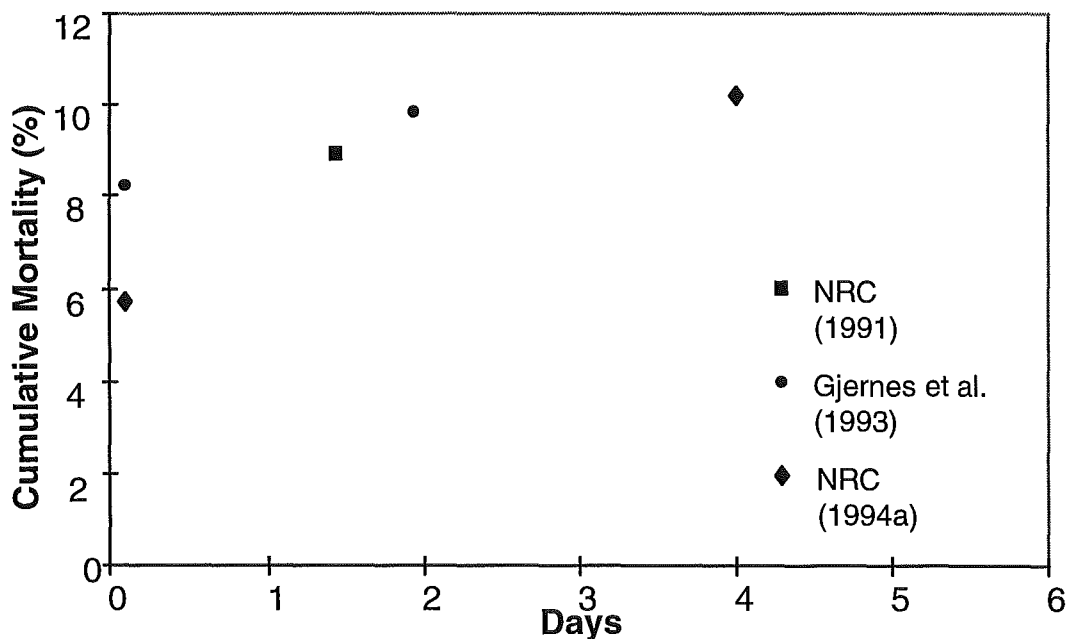

Figure 1. Observed mortality over time for chinook salmon (35 cm and larger) caught on recreational fishing gear in Washington and British Columbia.

The observations of delayed mortality can then be extrapolated by applying this instantaneous daily mortality rate for the additional days necessary (Table 12). (Because of the different methods of counting "days" applied by NRC and Wertheimer et al. (1989), this is best estimated by setting total days to t = 5). When the immediate mortality estimate is subtracted from these extrapolated estimates, the average 6-d mortality is 4.7% (Table 12). Expanding this number by 1.13 to account for long-term mortality gives an average estimate of 5.3% for total delayed mortality, and 12.3% for total hook-and-release mortality for chinook ≥ 33 cm (Table 12).

For chinook salmon <33 cm, the estimate of 29.8% from Gjernes et al. (1993) was also extrapolated to the standardized holding time using the daily instantaneous mortality rate calculated for larger chinook, and expanding the delayed mortality component by the factor of 1.13 to account for long-term mortality. This results in an estimate of total hook-and-release mortality for this size class of 35.7% (Table 12).

Associated and Drop-off Mortality. The STT (1994) recommended increasing estimates of hooking mortality by 2% for "associated" mortality and 5% for "drop-off" mortality. They identified associated mortality as the additional mortality due to "predation, long-term mortality, and regulation non-compliance;" and drop-off mortality as the fish that escape from the gear prior to being brought to the boat, but die as a result of the hooking encounter. The CTC decided to limit associated mortality to adjusting the estimated rate for long-term delayed mortality and to include predation mortality as a component of drop-off mortality. Regulation non-compliance was not considered a component of the non-landed mortality rate in this report. Because the CTC developed a mortality estimate that is adjusted for long-term effects, there was no need for an additional associated mortality add-on.

Although the STT (1994) showed no data to support the 5% drop-off mortality they proposed (computed as a proportion of the fish brought to the boat, both retained and released), the use of this rate implicitly assumes that some proportion of unlanded encounters experience either lethal hooking wounds or predator attacks. The CTC developed an estimate of drop-off mortality based on actual estimates of the unlanded encounter rates and explicit assumptions for the drop-off mortality rate. Two categories of drop-off mortality were considered: (1) *escaped encounters*, fish that are hooked but escape from the gear; and (2) *predation mortality*, fish that are removed or lethally maimed by predators.

The CTC assumed different mortality rates for these two drop-off mortality categories. Similar to the process for commercial troll gear, the CTC used a lower mortality rate for escaped encounters than the hook-and-release mortality estimated above for fish brought to the boat and released. This decision was based on the assumption that salmon hooked in recreational fisheries in peripheral hook locations are much more likely to get off the gear than those that are deeply hooked. Peripheral wound locations have significantly lower associated mortality rates (NRC 1991, 1994a; Grover 1995b). For an estimate of the mortality rate for escaped encounters, the CTC used the mortality rates observed by NRC (1991, 1994a) for chinook salmon hooked in the mouth area only, adjusted for holding times and long-term mortality. For this wound category, they observed 3.2% mortality (1/31) through two days (NRC 1991) in one study and 2.9%

27

Table 12. Summary of data and expansions used by the CTC to calculate estimated delayed and total hook-and-release mortality for chinook salmon in northeast Pacific recreational fisheries. Delayed mortality observations are the total observed mortality for each study (Table 8) minus the estimated average immediate mortality (7.0%). Methods for extrapolating and expanding observed delayed mortality to total delayed mortality are given in text.

Study	Days Held mean (range)	Observed Delayed Mortality (%)	Delayed Mortality (%) Extrapolated to 6 d	Delayed Mortality (%) Expanded from 6d to Total	Total Hook-and Release Mortality (%; Delayed + 7.0 Immediate)
Fish ≥ 33 cm					
Gjernes (1990)	2 (1-3)	2.9	5.2	5.9	12.9
NRC (1991)	1.5 (1-2)	2.0	4.8	5.4	12.4
NRC (1994a)	4	3.2	4.0	4.5	11.5
Average				5.3	12.3
Fish < 33 cm					
Gjernes et al. (1993)	0.75 (.25-1.25)	22.8	25.4	28.7	35.7

28

(4/137) mortality through four days in another (NRC 1994). A stepwise procedure similar to that used to construct the hook-and-release mortality estimate was also applied to these data to account for additional delayed mortality, resulting in a final estimate of 4.0% for escaped encounter mortality rates. For fish lost to predators, the CTC again assumed 100% mortality. Based on these rates, the drop-off mortality can then be calculated as:

Drop-off mortality (%) = (4.0% escapee mortality)*(% escaped encounters)
                     + (100% predation mortality)*(% predator encounters)

Data on lost (escaped) salmon rates and predator encounter rates were available from 1996 NRC research (Doug McNair, NRC, personal communication) for two time/area strata: (1) off the Oregon coast in summer; and (2) from Puget Sound in winter and spring. For both escaped encounters and predator encounters, the rates were very different between the two areas. Encounter rates were 125% in the Puget Sound stratum, and 36.3% in the Oregon coast stratum (Table 12). These encounter rates result in escaped encounters mortality estimates of 5.0% for Puget Sound, 1.5% for Oregon coast, and an average of 3.2%.

Predator encounters also varied between regions. For Puget Sound the rate was 9.5%, versus 1.5% for the Oregon Coast (Table 13). The rate for the Oregon Coast was similar to that observed for commercial troll gear in the same area and time (2.2 %; Doug McNair, NRC, personal communication). The CTC assumed that predator enounters would also be similar between recreational and commercial troll gear in sSoutheast Alaska, and therefore used the 0.4% predator encounter rate from commercial troll observations (Table 6) to represent predator encounter rates for the SEAK recreational fishery. These three sets of observations give an average of 3.7% for predator mortality (Table 13). Average total drop-off mortality (escaped + predator) is thus 6.9% (3.2% escapee mortality + 3.7% drop-off mortality; Table 13).

3.2.4 Recreational Fisheries - Recommendations

The CTC recommends using in CTC analyses total hook-and-release mortality rates for recreational fishing that are specific for two size categories:

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

The CTC will generally apply the rate for the larger size category, because second-ocean and older fish are by far the most common age classes encountered in PSC recreational fisheries. Where data are available indicating that small (<30 cm) chinook are a significant (> 1%) component of the fish encountered, then the rate will be weighted appropriately.

Table 13. Estimates of drop-off hook and release mortality for chinook salmon in northeast Pacific recreational fisheries, expressed as a percentage of the salmon landed or released from the boat. Escaped encounters are assumed to have a 4.0% mortality, and predator encounters are assumed to have a 100% mortality. Data for Puget Sound and Oregon coast are from NRC research (Doug McNair, NRC, personal communication). Data for Southeast Alaska are from commercial troll log-book data (see Table 6).

Fishery	Salmon Landed or Released	Escaped Encounters			Predator Encounters		Total Drop-off Mortality (%)
		Number	% Escaped	% Mortality	Number	% Mortality	
Puget Sound/ Winter-Spring	306	381	124.5	5.0	29	9.5	14.5
Oregon Coast/ Summer	765	278	36.3	1.5	9	1.2	2.7
Southeast Alaska	665,841	---	---	---	2,782	0.4	3.6[1]
Average				3.2		3.7	6.9

[1] Assumed average mortality (3.2%) for escaped encounters.

The CTC also recommends calculating an additional mortality increment for drop-off mortality in recreational fisheries. This rate, based on the total chinook boated (landed catch and released catch), is fishery specific, varying with escaped encounter rate and predator encounter rate. Based on the current information available to the CTC, the following fishery specific rates are recommended:

SEAK:	3.6%
Puget Sound:	14.5%
Oregon:	2.7% .

For fisheries where specific data are not available, the CTC will use the average of these rates, (6.9%), or rates from a comparable fishing area, to estimate escaped encounters and predator losses.

4. PURSE SEINE FISHERIES

Purse seines are large nets (350-550 m long) used to encircle and trap schools of salmon. Purse seines have sufficient floatation so that the nets are suspended from the surface. Purse rings are attached to the lead line so that a line run through the rings can be used to close the bottom of the net by drawing the line tight once the net has been closed, i. e., the ends brought together. The depth of the nets is typically regulated; however, these regulations vary between areas. In some areas, nets are deep enough to fish effectively to 35 m or more. The nets are retrieved using either a power block (known as table seining) or a net drum (known as drum seining). Drum seines are not permitted in Alaska.

Based primarily on studies by Van Alen and Seibel (1986,1987), the CTC (1988) concluded that total incidental mortality rates for chinook salmon released from purse seines probably range from 50% to 100%. The immediate mortality observed by Van Alen and Seibel (1986, 1987) varied greatly between areas and years, and averaged 52.1%. They also noted that 43% of the fish released alive had obvious injuries. The CTC has been using a total non-retention mortality rate of 90% in the chinook model for purse seines.

4.1 Purse Seines - Recent Studies

Subsequent to the CTC (1988) review, two studies have examined immediate mortality associated with catch and release of chinook salmon in seine fisheries. Rowse and Marshall (1989) and Rowse (1990) interviewed purse seiners in Southeast Alaska to determine the number of chinook salmon dead at landing for three size categories of fish. The results of these interviews for non-retention fishing periods are shown in Table 14, along with observations for "dead at landing" from Van Alen and Seibel (1986, 1987). Within any given year, large chinook salmon always had the lowest mortality (Table 14). The average immediate mortality was 49.0% for all sizes, combined over the four years for which data were available.

Three recent studies have examined release mortality associated with catch and release of chinook salmon in seine fisheries (Table 15). Candy et al. (1996) conducted a study in Johnstone Strait that used ultrasonic telemetry tags to track chinook salmon captured and released from commercial purse seiners. The authors did not monitor total catch or immediate mortality of chinook boarded but rather selected the first live chinook (>50 cm) for tagging and release. The vast majority of seine sets in Johnstone Strait only have one to a few chinook salmon per set so the tagging of a chinook seldom involved much selection. Candy et al. (1995) documented handling time, seine catch information, injuries to the fish, and detailed tracking information per chinook. A total of 47 chinook were tracked for between 2-33 hours. Nine chinook were assessed to have died during the tracking period and survival through 24 hours was estimated to be 77% (binomial confidence limits 62-87%). The survival rate includes an allowance for mortality of fish that were lost or abandoned before 24 hr, normally due to weather conditions

Table 14. Number and percentage of chinook salmon dead at landing by purse seiners during non-retention periods for chinook salmon in Southeast Alaska. Chinook salmon were categorized by three size ranges (total length) : small, $\leq$ 21 in (53 cm); medium, > 21 (53 cm) but < 28 in (71 cm); and large, $\geq$ 28 in (71 cm).

Study	Year	Small		Medium		Large		Combined	
		Landed	% Dead	Landed	% Dead	Landed	% Dead	Landed	% Dead
Van Alen and Seibel (1986)	1985	295	50.2	37	18.9	157	1.9	489	32.3
Van Alen and Seibel (1987)	1986	61	63.9	20	70.0	47	57.4	128	62.5
Rowse and Marshall (1989)	1987	807	69.1	352	84.9	268	35.1	1,427	68.8
Rowse (1990)	1988	715	67.8	632	28.0	1,551	17.6	2,898	32.3
Annual Average			62.8		50.5		28.0		49.0

Table 15. Summary of results from studies conducted to estimate catch-and-release mortality of chinook salmon from purse seine vessels.

Study	Hours Held or Tracked	Sample Size	Number Survived	Number Died	Mortality (%)	Comments
NRC (1994b)	3.2	4	4	0	0	Held in live tank aboard seiner. Puget Sound.
Ruggerone and June (1996)	50	91	90	1	1.1	Transferred in shipboard tank and held in net pen. SE Alaska.
Candy et al. (1996)	2-33	47	38	9	19.2 (23.0)	Tracked with ultrasonic telemetry. Johnstone Strait, B. C. Number in parantheses is adjusted 24-hr mortality, as reported by Candy et al. (1996).

33

during tracking. Mortality was significantly associated with landing time in the seine (i.e., the time from commencement of seine retrieval to the moment that the fish was handled by the tagger). Further, surviving chinook were observed to spend between 57-64% of their tracking interval at depths where they would be vulnerable to recapture by seine gear, but only one fish was recaptured during tracking. The authors suggest that with responsible handling, incidental mortality in the Johnstone Strait fishery could be substantially reduced compared to the assumed CTC mortality rate, especially in sets with small (<100) total salmon catch per set.

Release mortality of salmon from purse seines was examined by NRC (1994b). After capture, the fish were held in a live tank aboard the vessel for an average of 3 hours. Only four chinook were caught and all survived (Table 15). In addition, 75 chum and one coho held in the live tank had a 6.2% mortality rate.

Ruggerone and June (1996) conducted a study using purse seine gear in southeast Alaska near the Hidden Falls hatchery. Ninety-one chinook were captured, placed in a live tank on the vessel, and then were transferred to a saltwater netpen where they were observed. They were held for 1.9-2.8 days during which only one (1%) of the chinook died (Table 15). These chinook were caught in 16 sets that harvested approximately 6,300 chum salmon. The authors suggest this high survival indicates the potential for successfully releasing non-targeted chinook salmon when targeting on other salmon species. They also noted that these fish were close (30-45 d) to maturity, and that salmon may be more resistant to handling and stress when approaching maturation.

4.2 Purse Seines - Discussion

The recent studies demonstrate that chinook salmon mortality rates are potentially much lower for fish released from purse seines than have been previously assumed by the CTC (1988). Two of these three studies had procedures that were designed to keep fish alive after the initial seining operation; the third (Candy et al. 1996), which had the highest observed mortality rate, included fish caught in commercial seine fisheries.

However, the mortality rate on chinook released from seines is only a portion of the total incidental mortality associated with seine fisheries. Other components include immediate mortality (i.e., chinook dead when brought on board) and incomplete accounting for the catch of chinook, particularly of sub-legal sized chinook. Further, the total fishing morality rate in a seine fishery may be highly variable between fishing periods in one area and between different fisheries. For example, Alaskan seine boats use table seines and would involve longer landing times than power drum seines used in British Columbia and Washington State. Also, the mortality rate on chinook will be associated with the numbers of fish caught in each seine haul. Nagtegaal et al. (1988; 1990; 1993a,b; 1994) documented the frequency of seine set sizes, and the occurrence of legal and sub-legal sized chinook per set, during five years of observations in the Johnstone Strait and Juan de Fuca seine fisheries. The vast majority of sets have less than 100 sockeye per set, and less than one chinook per set (Figure 2). Most small chinook boarded

were dead or severely injured, but the condition of large chinook was much more variable. Immediate mortality of chinook would then be a function of the type of fishery, frequency of catch sizes (related to handling time and suffocation of the chinook), incidence of chinook in sets by time and area of the fishery, handling of the chinook during boarding, and size distribution of the chinook caught. Because the immediate mortality rates may be highly variable, fishery- and time- specific estimates may be necessary.
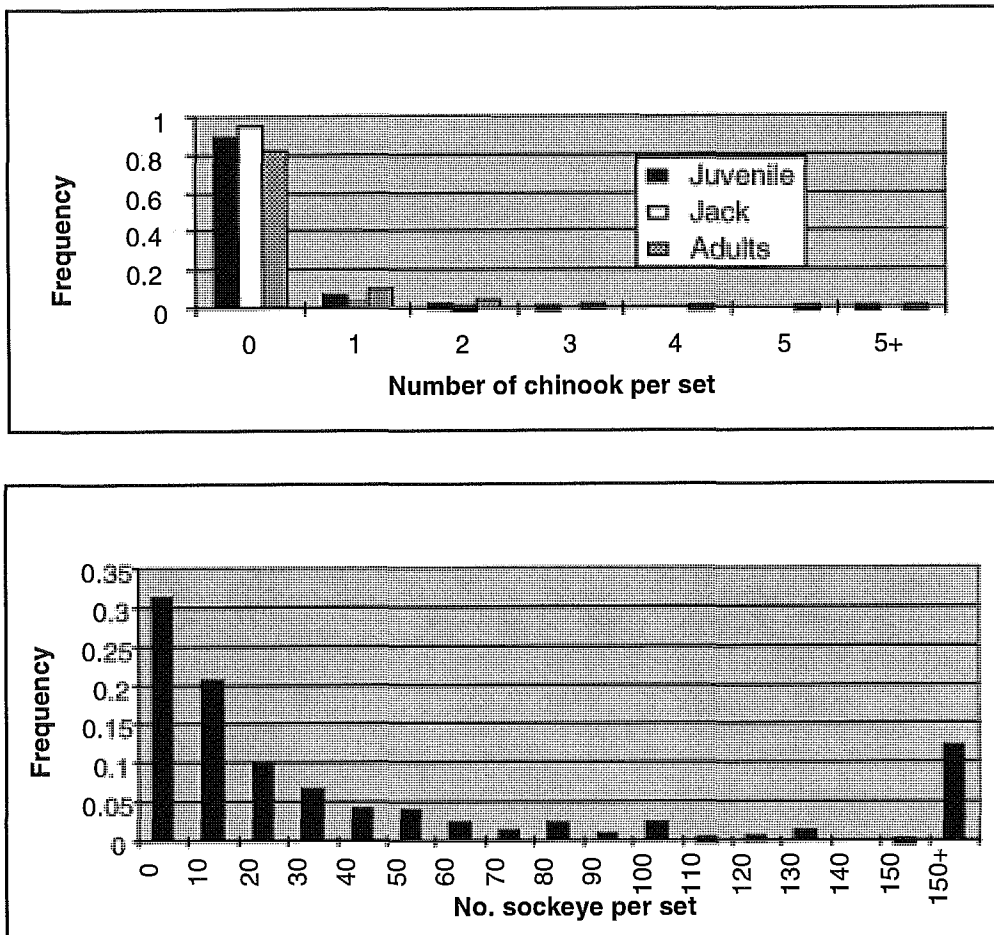

Figure 2. Chinook and sockeye salmon catch per seine set in Johnstone Strait, 1987-1990.

Immediate Mortality --- In its previous review, the CTC (1988) used an immediate mortality rate of 50.2%, the overall average from two years of observations by Van Alen and Seibel (1985,1986). By combining these data with those from Rowse and Marshall (1989) and Rowse (1990), a similar overall result of 49.0% immediate mortality was obtained for all size categories of chinook salmon combined (Table 14). However, the combined data sets indicate size-specific differences in immediate mortality. Immediate mortality by size category averaged 62.8% for small, 50.5% for medium, and 28.0% for large chinook.

35

Delayed Mortality --- Recent studies indicate that mortality of chinook salmon released from purse seines is considerably lower than the delayed mortality rate of 37.8% previously assumed by the CTC (1988). Two studies estimated mortality through at least 1-d following release, with results varying from 1.1% - 23 % (Table 15). The lower value was for chinook salmon caught within 45-60 d of spawning. Because most non-retention catch will be of chinook that are months or even years from spawning, for PSC fisheries the higher figure from Candy et al. (1996) will likely be the most appropriate estimate of delayed mortality. However, in terminal fisheries where incidental catch of chinook salmon is documented to consist of a substantial proportion of fish that are close to spawning, the delayed mortality estimate could be weighted accordingly by using the lower rate observed by Ruggerone and June (1996).

Underreporting--- Two sets of studies have examined the accuracy of catch accounting of seine caught chinook by size categories. The studies of Nagtegaal et al. (op. cit.) documented under-reporting of small chinook (all chinook <57 cm, <5 lb.) in the Johnstone Strait and Juan de Fuca seine fisheries during 1986-1990, but did not determine a consistent pattern in reporting of large chinook. Catch of small chinook included immature juveniles under 45 cm and immature and maturing (jack males) chinook between 45-57 cm. On average, these reports estimated the actual catch of small chinook to be 2.9 times the reported catch for Johnstone Strait 1986-1990, and 2.8 times for Juan de Fuca Strait 1987-1990. Similarly, in Southeast Alaska, Rowse (1989,1990) estimated the total mortality of chinook in 1987 and 1988 SEAK seine fisheries using dockside interviews and assuming a 70% mortality rate on chinook released. Chinook deaths which are not accounted through landing records were due to mortality of small chinook (<21 in), releases during non-retention periods, and chinook taken for personal use. Compared with the catch of legal-sized chinook reported during retention periods, her estimates of total mortality were 2.2 times the 1987 catch and 2.6 times the 1988 catch. These studies also indicated that a substantial proportion of incidental mortality of small chinook salmon may not be accounted for by current methods. However, encounter rates of small chinook salmon are highly variable by area and time. It is not appropriate to account for underreporting by adjusting the mortality rate in the chinook model, but some adjustment to the landed catch data, on a fishery specific basis, may be appropriate. If underreporting is occurring, expansions for tagged fish recovered in the seine fisheries will be too low, thus biasing exploitation rates low. The CTC will re-examine this issue in the context of encounter rate estimation.

4.3 Purse Seines - Recommendations

The CTC recommends using a rate of 72% for total chinook non-retention mortality for all size classes of fish combined in CTC analyses. This rate is based on an average immediate mortality of 49% and a delayed mortality of 23%.

When size-distribution information is available, the CTC recommends using the following estimates of immediate and total non-retention mortality:

	Immediate	Total
small chinook:	62.8%	85.8%
medium chinook:	50.5%	73.5%
large chinook:	28.0%	51.0%

In terminal fisheries where chinook salmon are released and a specific portion are close to spawning (< 60 d), the delayed mortality should be weighted to account for the lower rate of 1.1% observed for such fish.

The CTC will use these rates as generalized estimates of purse seine non-retention mortality. However, immediate mortality is fishery- and time-specific because of such factors as the type of fishery, frequency of set sizes (related to handling time and suffocation of the chinook), incidence of chinook in sets by time and area of the fishery, handling of the chinook during boarding, and size distribution of the chinook caught. When fishery specific information becomes available for particular model fisheries, the CTC will apply the more specific estimates.

5. GILL NET FISHERIES

Gill nets are flat, wall-like mesh panels constructed of fine threads, designed to entangle fish. Salmon gill nets are fitted with sufficient floatation so that they are suspended from the surface. The nets are fished either from boats (drift gill-nets) or attached by a line to shore (set gill-nets). Different mesh sizes are used depending on the target species of fish. Chinook salmon are always vulnerable to incidental catch regardless of mesh size because their size distribution overlaps that of the other salmon species. Two types of non-landed incidental mortality can result from gill nets: release mortality, which occurs when fish below a certain size or of a particular species are not retained; and drop-out mortality, which occurs when fish are captured by the net, but escape or fall out prior to landing.

5.1 Gill Nets - Release Mortality

Prior to this review, the CTC assumed 90% mortality for all net types. However, this mortality rate has not been applied in the chinook model, because chinook non-retention (CNR) restrictions in gill net fisheries have not been explicitly modeled. In gill net fisheries with specific catch limits for chinook (e.g., SEAK gill net fishery), CNR does effectively occur when the catch limit is approached or attained. Also, CNR fisheries have been considered by the PSC in the context of selective fisheries for hatchery chinook salmon (ASFEC 1995).

Release mortality rates are generally assumed to be high, but the rate is influenced by the time between capture and release, size and tension of the meshes, and the physiological state of the captured fish. Maturing sockeye salmon that escaped from gill nets in experimental saltwater holding nets had 80% mortality after 8 hr, compared with less than 10% for controls (Thompson et al. 1971). Gillnetters in the Skeena River recently began to release steelhead while fishing for sockeye salmon. Mortality for these fish was estimated at 60 to 75% (S. Cox-Rogers, CDFO, Personal Communication). Mortality rates of salmon released from high seas gill nets are also high; French and Dunn (1973) reported that immature salmon caught and released from high-seas gill nets were rarely recaptured, and had only 1-2% of the recapture frequency of salmon captured and released from longlines.

Carefully monitored gill nets are commonly used to collect adult salmon for broodstock or tagging, causing little or no mortality (e.g., Parker 1960, Eiler 1995, Johnson et al. 1981). WDF used gill nets to capture chinook salmon broodstock in the Skagit River with mixed success (Baranski 1980). Fish captured in the lower river during acclimation to freshwater experienced almost total mortality. However, fish captured one month later nearer the spawning grounds suffered less than 5% mortality. In 1993, gill nets were used in Quilcene Bay as selective gear to estimate release mortality rates of summer chum in a coho salmon fishery. A total of 39 chum salmon were caught, retained in pens, and monitored by agency biologists. The immediate mortality observed was 26%. The remaining fish survived until spawning. A similar program

38

conducted in 1992 yielded 59 chum salmon and an immediate mortality rate of 10% (D. Zajac, USFWS, Personal Communication).

The presence of net-marked fish returning to spawning streams demonstrates that some fish that are released or drop-out of gill nets do survive. Following the "no-sale" prohibition of chinook salmon caught in gill nets near the mouth of the Situk River in 1989 and 1990, about 55% and 48% of the large chinook salmon observed upstream at the Situk River weir were net marked (Scott McPherson, Alaska Department of Fish and Game, Personal Communiction).

These results indicate that gill net release mortality rates can be highly variable and may be substantially lower than 90% for salmon in their final year of life and close to maturity. Chinook salmon released from gill-nets in chinook model fisheries, however, are likely to be small, immature fish. Until data are available for this age and size range, the CTC will continue to use the 90% mortality rate previously assumed.

5.2 Gill Nets - Drop-out Mortality

Several studies have indicated that the drop-out mortality in gill net fisheries can be high, particularly if predators remove fish from the net (Geiger 1985; Beach et al. 1981). For example, harbor seal interactions with a gill net fishery for chinook salmon in South Puget Sound in 1982 resulted in an estimated drop-out mortality rate of 87% (January 18, 1983 letter from Jack Rensel to WDF). A technical team that assessed Puget Sound gill net fisheries (WDF and NWIFC 1984) indicated that the rate was likely to vary depending upon the predators in the area, the species netted, the intensity of fishing, and the type of gear. Drop-out rates of salmon from high-seas gill nets ranged from 14% after 2.5 hr to 41% after 11 hr, compared with less than 1.2% after 3 hr in nearshore (Puget Sound) gill nets (French and Dunn 1973).

5.3 Gill Nets - Recommendations

CNR gill net fisheries are unlikely to be implemented due to the high expected mortality rate of the fish released. However, CNR periods are likely in gill net fisheries where a limit on total chinook landings is imposed. No study directly addresses the mortality of immature chinook salmon caught and released from gill nets. Until such data are available, the CTC will continue its assumption of 90% release mortality for these fish for use in the chinook model.

The current region-specific drop-out rates used in the chinook model were derived from the literature discussed above. The CTC considers this a poorly investigated subject. The rates must be viewed as very uncertain and are expected to be highly variable from fishery to fishery due to variables such as mesh size, prevailing weather and sea conditions, and predator abundance. These rates will continue to be used, however, pending review of updated incidental mortality reports from the agencies. Gill net fisheries occur primarily in SEAK, Fraser River, Puget Sound, the Washington Coast, and Columbia River. Until better information is available, the CTC will use the following drop-out mortality rates for these fisheries:

SEAK:	2%
Fraser River:	8%
Puget Sound:	8% (includes some purse seine fisheries)
Washington Coast:	2%
Columbia River:	3%

6. LITERATURE CITED

ASFEC (Ad-hoc Selective Fishery Evaluation Committee). 1995. Selective fishery evaluation. Pacific Salmon Commission, Vancouver, British Columbia.

Baranski, C. 1980. Skagit summer broodstock collection program, 1975-1979. Washington Department of Fisheries Progress Report 104. 21pp.

Beach, R., A. Geiger, S. Jeffries, and S. Treacy. 1981. Marine mammals on the Columbia River and adjacent waters, 1981. Second annual report. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Seattle, Washington.

Bendock, T., and M. Alexandersdottir. 1993. Hooking mortality of chinook salmon released in the Kenai River, Alaska. North Am. Journal Fish. Manag. 13: 540-549.

Butler, J. A., and T. E. Loeffel. 1972. Experimental use of barbless hooks in Oregon's troll salmon fishery. Bulletin of the Pacific Marine Fisheries Commission. 8:24-30.

Candy, J.R., E.W. Carter, and B.Riddell. 1995. Summary of catch data, depth plots, track maps, and tag recoveries from adult chinook salmon (*Oncorhynchus tshawytscha*) telemetry, Johnstone Strait 1990-1992. Can. MS Rep. Fish. Aquat. Sci. 2342.

Candy, J. R., E. W. Carter, T. P. Quinn, and B. E. Riddell. 1996. Adult chinook salmon behavior and survival after catch and release from purse-seine vessels in Johnstone Strait, British Columbia. North American Journal Fisheries Management 16: 521-529.

CTC (Chinook Technical Committee). 1988. Chinook Technical Committee report to the November, 1987 meeting of the Pacific Salmon Commission. Pacific Salmon Commission Report TCCHINOOK (87)-5. Vancouver, British Columbia.

Eiler, J. H. 1995. A remote satellite-linked tracking system for studying Pacific salmon with radio telemetry. Trans. Am. Fish. Soc. 124: 184-193.

French, R. R., and J. R. Dunn. 1973. Loss of salmon from high-seas gillnetting with reference to the Japanese salmon mothership fishery. NMFS Fishery Bull. 81: 845-875.

Geiger, A. 1985. Documentation of marine mammal interactions with coastal salmon gillnet and other fisheries. Pp. 51-48. In: Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters. 1980-1982. National Marine Fisheries Service, Northwest and Alaska Region Fisheries Center Processed Report 85-04. Seattle, Washington.

Gjernes, T. 1990. Hooking mortality rates for sport-caught chinook and coho salmon. Dept. Fish. Oceans Canada Pacific Biological Laboratory Pacific Stock Assessment Review Committee Working Paper S90-35.

Gjernes, T., A. R. Kronlund, and T. J. Mulligan. 1993. Mortality of chinook and coho salmon in their first year of ocean life following catch and release by anglers. North Am. Journal Fish. Manag. 13: 524-539.

Grover, A. 1995a. Evaluation of hook mortality in the California ocean salmon fisheries, 1994 and 1995. Calif. Dept. Fish Game, Marine Resources Division, Healdsburg, CA.

Grover, A. 1995b. Cruise report 95-M-8. Calif. Dept. Fish Game, Marine Resources Division, Healdsburg, CA.

Kygier, E. E. 1981. 1980 troll logbook program. Alaska Trollers Association Final Report 1980 troll logbook program.

Kygier, E. E. 1982. 1981 troll logbook program. Alaska Trollers Association Final Report 1981 troll logbook program.

Kygier, E. E. 1983. 1982 troll logbook program. Alaska Trollers Association Final Report 1982 troll logbook program.

Murray, C. and B. Riddell. 1996. A review of the Strait of Georgia chinook harvest rate program. PSARC Res. Document S96-8.

Nagtegaal, D.A., P.J. Starr, and B.Riddell. 1988. A pilot study to estimate total chinook mortality with seine fishing in Johnstone Strait during 1986. Can. MS Rep. Fish. Aquat. Sci. 1977.

Nagtegaal, D.A., P.J. Starr, and B. Riddell. 1990. Estimation of total chinook mortality associated with seine fishing in Johnstone Strait, Sabine Channel, and Juan de Fuca Strait during 1987. Can. MS Rep. Fish. Aquat. Sci. 2062.

Nagtegaal, D.A., P.J. Starr, and B. Riddell. 1993a. Estimation of total chinook mortality associated with seine fishing in Johnstone Strait and Juan de Fuca Strait during 1988. Can. MS Rep. Fish. Aquat. Sci. 2203.

Nagtegaal, D.A., P.J. Starr, and B. Riddell. 1993b. Estimation of total chinook mortality associated with seine fishing in Johnstone Strait and Juan de Fuca Strait during 1988. Can. MS Rep. Fish. Aquat. Sci. 2214.

Nagtegaal and B. Riddell. 1994. Estimation of total chinook mortality associated with seine fishing in Johnstone Strait, Sabine Channel, and Juan de Fuca Strait during 1990. Can. MS Rep. Fish. Aquat. Sci. 2229.

NRC (Natural Resource Consultants). 1991. Hooking mortality study final project report. Saltonstall-Kennedy Grant NA89AB-H-00012. Natural Resource Consultants, Seattle, Washington.

NRC. 1994a. 1992-1993 hooking mortality study final project report. Saltonstall-Kennedy Grant NA26FD0138-01. Natural Resource Consultants, Seattle, Washington.

NRC. 1994b. Final results of the pilot Hood Canal non-target salmon survival study. Natural Resource Consultants, Seattle, Washington.

NRC. 1996. Draft final report on 1995 NEAP at-sea research projects. Natural Resource Consultants, Seattle, Washington.

Orsi, J. A. 1987. Small versus large trolling lures for sampling juvenile chinook salmon and coho salmon. Transactions American Fisheries Society 116: 50-53.

Orsi, J. A., A. C. Wertheimer, and H. J. Jaenicke. 1993. Influence of selected hook and lure types on catch, size, and mortality of commercially troll-caught chinook salmon. North American Journal Fisheries Management 13: 709-722.

Parker, R. R. 1960. Critical size and maximum yield for chinook salmon (*Oncorhynchus tshawytscha*). J. Fish. Res. Bd. Canada 17: 199-210.

PFMC (Pacific Fishery Management Council) 1994. Salmon hook-and-release mortality estimates adopted. PFMC Council News, October, 1994. P. 9.

Rowse, M. L. 1990. Chinook salmon catch and mortality associated with the 1988 Southeast Alaska purse seine fishery. ADF&G Tech. Fish. Report 90-03.

Rowse, M. L., and S. L. Marshall. 1989. Chinook salmon catch and mortality associated with the 1987 Southeast Alaska purse seine fishery. ADF&G Tech. Fish. Report 89-16.

Ruggerone, G. T., and J. June. 1996. Survival of chinook salmon captured and released by a purse seine vessel in Southeast Alaska. Natural Resource Consultants, Seattle, Washington.

Stohr, A. J., and M. E. Fraidenburg. 1986. A delphi assessment of chinook and coho salmon hooking mortality. Washington Department of Fisheries. Technical Report 94.

STT (Salmon Technical Team). 1994. Non-landed mortality of chinook and coho salmon in Pacific Fishery Management Council ocean recreational and commercial salmon fisheries. Pacific Fishery Management Council Technical Report.

Taylor, M. T., and K. R. White 1992. A meta-analysis of hooking mortality of nonanadromous trout. North American Journal Fisheries Management 12: 760-767.

43

Thompson, R. B., C. J. Hunter, and B. G. Patten. 1971. Studies of live and dead salmon that unmesh from gill nets. Int. North Pac. Fish. Comm. Ann. Rep. 1969: 108-112.

Van Alen, B., and M. Seibel. 1986. Observations on chinook salmon non-retention in the 1985 Southeast Alaska purse seine fishery. Alaska Dept. Fish and Game, Juneau, AK.

Van Alen, B., and M. Seibel. 1987. Observations on chinook salmon non-retention in the 1986 Southeast Alaska purse seine fishery. Alaska Dept. Fish and Game, Juneau, AK.

Vincent-Lang, D., M. Alexandersdottir, and D. McBride. 1993. Mortality of coho salmon caught and released using sport tackle in the Little Susitna River, Alaska. Fisheries Research 15: 339-356.

WDF (Washington Department of Fisheries) and NWIFC (Northwest Indian Fisheries Commission). 1984. Report of the Joint Tribal-State Technical Committee on Noncatch Net Mortalities. Washington Department of Fisheries, Olympia, Washington.

WDF (Washington Department of Fisheries), Puget Sound Treaty Indian Tribes, and Northwest Indian Fisheries Commission. 1993. A review of recent studies of hooking mortality for chinook and coho salmon with recommendations for fishery management and future research. Joint Report, Washington Department of Fisheries and Northwest Indian Fisheries Commission.

Wertheimer, A. C. 1988. Hooking mortality of incidentally caught chinook salmon. North American Journal of Fisheries Management 8: 346-355.

Wertheimer, A. C., A. Celewycz, D. G. Mortensen, H. W. Jaenicke and J. A. Orsi. 1989. Size-related hooking mortality of incidentally caught chinook salmon. Marine Fisheries Review 5(2): 28-35.

Wright, S. 1970. A review of the subject of hooking mortalities in Pacific salmon (Oncorhynchus). Pacific Marine Fisheries Commission Annual Report 23: 47-65.

44