Fisheries and Oceans Science | Pêches et Océans Sciences

C S A S | *S C C S*

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2001/154 | **Document de recherche 2001/154**

Mortality Rates of Coho Salmon Caught by Commercial Salmon Gillnets and the Effectiveness of Revival Tanks and Reduced Soak Time for Decreasing Coho Mortality Rates

N. B. Hargreaves[1] and C. Tovey[2]

[1]Fisheries and Oceans Canada
Science Branch, Stock Assessment Division
Pacific Biological Station
Nanaimo, B.C. Canada. V9T 6N7

[2] Fisheries Research Consultant
401-2101 W. 5th Ave.
Vancouver, B.C. V6K 4R8

ISSN 1480-4883
Ottawa, 2001

Canada

Abstract

In 1998 a number of events changed the conservation, management and harvest opportunities for salmon in the Pacific Region of Canada. Due to growing concerns about the declining abundance of key coho salmon (*Oncorhynchus kisutch*) populations in both northern and southern B.C., an intensive review and public consultation process was initiated by Fisheries and Oceans Canada. On May 12, 1998 the Department's Coho Response Team issued its report titled "Selective Fisheries Approach For Management of B.C. Salmon Fisheries in 1998". This report provided a Selective Fisheries Management Framework and new options for management of salmon fisheries that included near-zero mortality for critical coho populations and requirements for fishing gear and methods to become more selective. Selective fishing was defined as the ability to avoid, or release alive and unharmed, non-target stocks or species of concern.

Since 1998 more than 100 selective fisheries experiments have been conducted in B.C. by the First Nations, recreational and commercial salmon fishing sectors with direct support from the Department's Pacific Fisheries Adjustment and Restructuring program (PFAR). The main purpose of these selective fishing experiments was to develop new fishing gear and methods aimed at reducing the coho catches, and reduce the mortality rates of any coho that are captured incidentally while harvesting other target species or stocks of salmon.

The purpose of this Research Document was to summarize and evaluate the results obtained from selected selective fishing experiments conducted since 1998. The main focus was on the mortality rates of coho salmon caught with commercial salmon gillnets. The three components of coho mortality that were examined included: 1) the immediate mortality that occurred when coho were captured; 2) the additional mortality that occurred during subsequent holding of coho in revival tanks aboard the fishing vessels; and 3) the short-term (up to 48 hour) delayed mortality that occurred after the coho were released from the fishing vessels.

The other objective of this paper was to evaluate the effect on coho mortality of reduced net soak time, and the use of on-board revival tanks for resuscitating coho caught in commercial salmon gillnets. Short soak times and revival tanks were introduced by the Department in 1998 as mandatory requirements in commercial salmon gillnet fisheries.

The results presented in this Research Document indicate that the incidental mortality rates of coho caught in commercial gillnets are highly variable. The immediate (catch) mortality rates ranged from 47.4% to 0.0% among the 11 different studies that were examined in detail. The additional mortality that occurred during holding of coho in onboard revival tanks was typically in the range of 5-10%, although 30% of the coho held in revival tanks died in one study. The additional short-term mortality of coho that were held in net pens for up to 48 hours after release from the fishing vessels ranged from 2.3% to 27.3%.

In the two studies that had the most comprehensive data, much of the variation in coho mortality rate at the time of capture was explained by a linear relationship between coho mortality rate and gillnet soak time (the duration that the gillnet remained in the water for each fishing operation). In the Alberni Inlet experiment in 1998, which involved only 7 commercial gillnet vessels, more than 95% of the observed variation in coho catch mortality rate was explained by the variation in soak time. In the Skeena River demonstration gillnet fishery in 2000, which involved more than 30 commercial gillnet vessels, about 70% of the variation in coho catch mortality rates was explained by the variation in soak time.

It was concluded that coho catch mortality rates increase rapidly with increasing soak time, and that short soak times of less than 60 minutes (defined as first cork in to last cork out) are likely required to achieve coho mortality rates that are substantially lower than the rate (60%) that the Department of Fisheries and Oceans (DFO) has assumed for most commercial gillnet fisheries since 1998.

It was concluded that revival tanks are generally beneficial for improving the condition of many coho prior to release. Appropriate use of revival tanks likely also improves the post-release survival rates of coho that are released from commercial gillnet vessels.

The capability of revival tanks to revive coho caught in commercial gillnets decreases with increasing soak time. The data currently available are insufficient to confirm which of the current two main alternative designs (the DFO "blue box", or the newer JF revival tank) is more effective for reviving coho, particularly in either demonstration scale or regular full-fleet gillnet fisheries. Additional direct experiments (e.g. side-by-side comparisons with adequate experimental controls) are still required to clearly confirm if the new JF revival tank design is superior. The current data do suggest that the JF revival tank design likely provides little advantage over the standard DFO "Blue Box" revival tank when soak times are very short (e.g. <30 minutes; first cork in to last cork out). However, the new JF design may significantly reduce coho mortality rates for moderately longer soak times (e.g. 30-100 minute soak times), compared to the standard DFO revival tank. Neither the new JF revival tank or standard DFO revival tank designs are likely to be effective for reviving coho caught in sets with longer soak times (e.g. >100 minutes).

The authors emphasized that the analyses and conclusions in this Research Document apply only to the short-term mortality of coho and do not address the additional important question of what effect capture and release from commercial gillnets may ultimately have on coho mortality beyond 48 hours after release from fishing vessels, or on the ultimate spawning success of these coho salmon. It was also noted that the actual impact commercial gillnet fisheries on salmon stocks of concern depends on both the mortality rates and the encounter rates. This Research Document considers factors that affect the mortality rate of incidentally caught coho, but does not evaluate or consider the factors that affect coho encounter rates.

Résumé

En 1998, un certain nombre d'événements se sont produits qui ont modifié la conservation, la gestion et les possibilités de pêche du saumon dans la région pacifique du Canada. Pour répondre à l'inquiétude croissante que suscite le déclin des principales populations de saumon coho (*Oncorhynchus kisutch*) tant dans le nord que dans le sud de la C.-B., Pêches et Océans Canada a lancé un processus intensif d'examen de la situation et de consultation du public. Le 12 mai 1998, l'équipe du Ministère chargée d'étudier la situation du coho a présenté son rapport intitulé *Selective Fisheries Approach For Management of B.C. Salmon Fisheries in 1998*. Ce rapport a présenté un cadre de gestion des pêches sélectives et de nouvelles options de gestion des pêches du saumon, prévoyant notamment une mortalité presque nulle des populations de coho essentielles et l'obligation d'accroître la sélectivité des engins et techniques de pêche. On a défini la pêche sélective comme la capacité d'éviter de capturer des poissons appartenant à des stocks non visés ou à des espèces préoccupantes ou de remettre à l'eau indemnes de tels poissons.

Depuis 1998, des pêcheurs de saumon autochtones, récréatifs et commerciaux ont réalisé plus de 100 expériences de pêche sélective grâce au soutien direct du Programme d'adaptation et de restructuration des pêches du Pacifique (PARPP) du Ministère. Ces expériences visaient avant tout à mettre au point de nouveaux engins et des techniques de pêche qui réduisent les prises de saumons cohos ainsi que leur taux de mortalité lorsqu'ils sont capturés accidentellement dans la pêche d'autres espèces ou d'autres stocks de saumon.

Le présent document de recherche résume et évalue les résultats de certaines expériences de pêche sélective réalisées depuis 1998. Nous y avons mis l'accent sur les taux de mortalité du saumon coho capturé dans la pêche commerciale du saumon au filet maillant. Nous avons examiné trois composantes de la mortalité du coho : 1) la mortalité immédiate suivant la capture du coho dans le filet, 2) la mortalité des poissons ensuite gardés dans des bassins de réanimation à bord des bateaux de pêche et 3) la mortalité différée à court terme (jusqu'à 48 heures) après la remise à l'eau des poissons.

Le document vise aussi à évaluer les effets sur la mortalité du coho qu'ont des durées réduites de mouillage des filets et l'utilisation à bord des bateaux de pêche de bassins de réanimation des cohos pris au filet maillant. Depuis 1998, le Ministère oblige les pêcheurs commerciaux de saumon au filet maillant à mouiller leurs filets sur de courtes périodes et à utiliser des bassins de réanimation à bord de leurs bateaux.

Les résultats montrent que les taux de mortalité des cohos capturés accidentellement dans les filets maillants commerciaux sont très variables : dans les 11 études examinées en détail, ces taux de mortalité immédiate allaient de 0,0 % à 47,4 %. La mortalité supplémentaire des cohos gardés dans des bassins de réanimation se chiffrait habituellement à 5-10 %, bien qu'elle ait atteint 30 % dans une étude. La mortalité supplémentaire à court terme des poissons gardés dans des enclos jusqu'à 48 heures après leur remise à l'eau a varié entre 2,3 % et 27,3 %.

Dans les deux études aux données les plus complètes, la relation linéaire entre le taux de mortalité des cohos et la durée de mouillage du filet maillant expliquait une bonne partie de la variation du taux de mortalité au moment de la capture. Dans l'expérience de la baie d'Alberni menée en 1998 par seulement 7 bateaux de pêche commerciale au filet maillant, la variation du temps de mouillage expliquait plus de 95 % de la variation observée du taux de mortalité des cohos pris au filet. Dans la pêche de démonstration effectuée par plus de 30 bateaux de pêche commerciale en 2000 dans la rivière Skeena, la variation du temps de mouillage expliquait environ 70 % de la variation observée du taux de mortalité des cohos pris au filet maillant.

Nous concluons que le taux de mortalité des prises de cohos augmente rapidement avec le temps de mouillage et qu'il faut sans doute des temps de mouillage de moins de 60 minutes (du moment où le premier flotteur est mis à l'eau jusqu'au moment où le dernier est sorti de l'eau) pour obtenir des taux de mortalité sensiblement inférieurs au taux de 60 % que le ministère des Pêches et des Océans (MPO) suppose pour la plupart des pêches commerciales au filet maillant depuis 1998.

Nous concluons que les bassins de réanimation améliorent généralement l'état de nombreux cohos avant qu'ils soient remis à l'eau. La bonne utilisation de ces bassins accroît sans doute aussi les taux de survie des cohos après leur remise à l'eau.

La capacité de réanimer dans des bassins les cohos capturés au filet maillant décroît à mesure que les temps de mouillage augmentent. Les données actuellement disponibles sont insuffisantes pour déterminer lequel des deux principaux types de bassin (la « boîte bleue » du Ministère ou le nouveau bassin de réanimation JF) est le plus efficace, soit à l'échelle de démonstration ou dans la pêche au filet maillant régulière effectuée par l'ensemble de la flottille. D'autres expériences directes (c.-à-d. des comparaisons côte à côte avec des témoins expérimentaux adéquats) seront nécessaires pour confirmer clairement que le bassin de réanimation de type JF est supérieur. Les données actuelles portent à croire que ce type de bassin procure peu d'avantages par rapport au bassin standard « boîte bleue » du MPO lorsque les temps de mouillage sont très courts (c.-à-d. inférieurs à 30 minutes). Toutefois, pour des temps de mouillage plus longs, soit de 30 à 100 minutes, le nouveau bassin de type JF pourrait réduire significativement les taux de mortalité des cohos par rapport à ceux obtenus avec le bassin standard du MPO. Pour des temps de mouillage dépassant 100 minutes, il est vraisemblable qu'aucun des deux types de bassin ne soit efficace pour réanimer les cohos.

Nous insistons sur le fait que les analyses et les conclusions de ce document de recherche ne s'appliquent qu'à la mortalité à court terme des cohos capturés au filet maillant et n'abordent pas l'importante question de leur mortalité plus de 48 heures après la remise à l'eau ou de leur éventuel succès de reproduction. Nous faisons aussi remarquer que l'effet réel des pêches commerciales au filet maillant sur les stocks de saumon préoccupants dépend à la fois des taux de mortalité et des taux de rencontre. Le document de recherche tient compte de facteurs qui influent sur le taux de mortalité des cohos capturés accidentellement, mais pas des facteurs qui influent sur les taux de rencontre des cohos.

TABLE OF CONTENTS

LIST OF FIGURES

Introduction

In 1998 a number of events changed the conservation, management and harvest opportunities for salmon in the Pacific Region of Canada. Due to growing concerns about the declining abundance of key coho salmon (*Oncorhynchus kisutch*) populations in both northern and southern B.C., an intensive review and public consultation process was initiated by Fisheries and Oceans Canada. On May 12, 1998 the Department's Coho Response Team issued its report titled "Selective Fisheries Approach For Management of B.C. Salmon Fisheries in 1998". This report provided a Selective Fisheries Management Framework and new options for management of salmon fisheries that included near-zero mortality for critical coho populations and requirements for fishing gear and methods to become more selective. Selective fishing was defined as the ability to avoid, or release alive and unharmed, non-target stocks or species of concern.

On May 19, 1998 the Minister of Fisheries and Oceans Canada announced far-reaching conservation objectives to conserve and rebuild coho salmon on the west coast of Canada. The conservation objectives included a goal of zero mortality for critical upper Skeena River coho and Thompson River coho. Where Skeena and Thompson coho were not prevalent, only selective fisheries that had minimal risk of coho by-catch mortality were allowed. The Minister stated that these objectives would guide the planning and management of salmon fisheries for 1998 and beyond.

On June 19, 1998 the Minister of Fisheries and Oceans Canada announced the Coho Recovery Plan with $400 million of funding to support implementation. A total of $200 million was allocated to support development of selective fisheries, voluntary retirement commercial salmon licences and diversification of commercial fisheries.

On October 14, 1998 the Minister of Fisheries and Oceans Canada released the "New Directions for Canada's Pacific Salmon Fisheries". The *New Directions* indicated increased focus on conservation, sustainable use and improved decision making. The Minister stated that "We can no longer accept the status quo or continue to manage salmon from crisis to crisis. We must get ahead of the curve, and shift to a risk averse, conservation-based fishery". The principles provided in the *New Directions* identify a broad policy framework for future conservation and management of salmon resources in the Pacific Region of Canada. Selective fishing is a fundamental part of this *New Directions* framework.

In December 1998 the DFO released "An Allocation Framework for Pacific Salmon: 1999-2005." This Allocation Framework stated the principles that will guide salmon allocation decisions until at least 2005. These principles include selective fishing and it was stated that over time, allocation of salmon in the commercial harvest sector will favour those gear types that can demonstrate their ability to fish selectively.

On February 7, 2001 the Minister of Fisheries and Oceans Canada released "A Policy For Selective Fishing in Canada's Pacific Fisheries", which defines the policy and principles for selective fishing in Canada's Pacific fisheries. This policy emphasizes that selective

fishing is a requirement of conservation-based fisheries. The ability of harvesters to fish selectively, avoiding or releasing unharmed, non-target fish, is a fundamental requirement for Canada to meet the conservation objectives of the federal Fisheries Act, the anticipated requirements of the forthcoming Species at Risk Act, and Canada's international commitments to preserve biological diversity and responsibly conserve and harvest fish resources.

Since 1998 more than 100 selective fisheries experiments have been conducted in B.C. by the First Nations, recreational and commercial salmon fishing sectors with direct support from the Department's Pacific Fisheries Restructuring program (PFAR). The main purpose of these selective fishing experiments was to develop new fishing gear and methods aimed at reducing the coho catches, and reduce the mortality rates of any coho that are captured incidentally while harvesting other target species or stocks of salmon.

The purpose of this PSARC Working Paper is to summarize and evaluate the results obtained from selective fishing experiments conducted since 1998. The focus in this paper is on the mortality rates of coho salmon caught with commercial salmon gillnets, and an evaluation of the effectiveness of revival tanks and reduced net soak time for reducing the mortality rates of coho. The coho mortality that we examine includes three components: 1) the immediate mortality that occurred when coho were captured; 2) the additional short-term mortality that occurred during subsequent holding of coho in revival tanks aboard the fishing vessels; and 3) the delayed mortality that occurred after the coho were released from the fishing vessel. In this paper the data used to examine the delayed mortality are obtained from three experiments in which coho were held for up to 48 hours in ocean net pens after release from gillnet fishing vessels. This paper does not address the additional important question of what effect capture and release from commercial gillnets may ultimately have on the mortality beyond 48 hours after release from fishing vessels, or on the spawning success of these coho salmon.

Methods

All of the information and new data that are provided in this paper were obtained from selective fishing gillnet experiments that have been conducted in B.C. since 1998. We began our analyses by reviewing all of the final reports that were available as of January 2001 for individual selective fishing gillnet projects and experiments that were conducted by industry, Simon Fraser University and the DFO from 1998 to 2000. We also examined a report and summary database that was previously prepared for the PFAR program that provided a preliminary evaluation of the selective fishing experiments that were conducted in 1998 and 1999 with support from the Department's PFAR program (Blewett and Taylor 1999). After reviewing all this information it was clear that the number and variety of selective fishing measures that have been tested in the commercial gillnet sector since 1998 was too broad to evaluate in a single PSARC paper.

In this paper we examine the effectiveness of two main selective fishing measures for commercial gillnets: 1) net soak time; and 2) the use of onboard revival tanks for resuscitating coho. We chose to focus on these two factors because our preliminary

review suggested that these measures were currently the most promising for reducing mortality rates of coho that are caught in commercial salmon gillnets. Timely evaluation of the effectiveness of these two selective fishing measures is also important because both have already been implemented by the Department for several years. An operating coho revival tank has been a mandatory Condition of Licence for all commercial salmon fishing vessels since 1998. Reduced soak times have also been a requirement in most commercial salmon gillnet fisheries since 1998.

Our review of all the selective fishing projects conducted from 1998 to 2000 indicated that data suitable for our analyses was potentially available from 11 separate experiments or projects. The main criteria we used to select each study was that the data from each study had to be sufficiently detailed and complete to allow determination of coho mortality for at least one of the three components we wanted to examine: 1) the immediate mortality that occurred when coho were initially captured; 2) the additional short-term mortality that occurred during subsequent holding of coho in revival tanks aboard the fishing vessels; or 3) the delayed mortality that occurred after the coho were released from the fishing vessel. Only 3 of the 11 studies conducted since 1998 provided data for all three components of coho mortality.

For most of the 11 studies we obtained the original raw data from the proponents and then conducted our own analyses of coho mortality. Reports were available for all of these studies that described how each experiment was conducted and also summarized the results. In many cases, however, the data analyses and results that were provided in the final reports were not adequate or suitable for our purposes.

For the convenience of the reader, a summary is provided for each of the 11 studies that we present information for in this paper (Appendix 1). The final reports provided by the proponents for most of these studies have not been published and some are not readily accessible. The summaries in Appendix 1 provide a brief description of the original objectives and methods, and our analyses and results.

Catch mortality of coho

In this section we examine the immediate mortality of coho that is observed at the time of capture in a commercial gillnet. Note that this mortality includes only coho that were actually brought aboard the fishing vessels. None of the studies we examined provided any information on the potential additional mortality of coho that were caught by a gillnet but escaped or dropped out of the net before they could be brought aboard.

For all but one of the nine studies examined the criteria used for assessing the condition at the time of capture was the ranking scheme that was implemented by the Department in 1998. The condition of each coho was visually assessed by an independent observer immediately after it was brought aboard the fishing vessel. Each coho was classified into one of the following five standard Conditions (Table 1):

Table 1: Standard DFO visual classification system for assessing the condition of coho.

Condition	VISUAL CRITERIA
1	Vigorous, not bleeding
2	Vigorous, bleeding
3	Lethargic, not bleeding
4	Lethargic, bleeding
5	Dead (not moving or ventilating)

Only one of the nine studies we examined for this analysis used a different classification system to assess the condition coho. The selective gillnet experiment (demonstration fishery) that was conducted in the Skeena River in 2000 used additional criteria and also modified some of the above criteria as described below (Table 2). The criteria for condition rating 5 ("Dead") are effectively the same for both classification systems. Thus the different classification schemes did not affect our estimates of catch mortality of coho. However, the modified criteria used in this experiment for other rating categories are more problematic when using these data for evaluating the effectiveness of coho revival tanks and delayed mortality in net pens.

Table 2: Visual classification system used to assess the condition of coho in the selective gillnet experiment conducted in the Skeena River in 2000.

Rating	*Movement*	*External Damage*	*Bleeding/Wounds*	*Scale Loss*
1: Excellent	Vigorous/ active	No external damage	None	Minimal
2: Good	Vigorous/ active	Minor external damage	None/few cuts	Some
3: Fair	Lethargic/ sluggish	Minor external damage	Some/some cuts	Some
4: Poor	Lethargic/ sluggish - poor geotaxis	External body damage	Moderate/cuts	Some
5: Dead	No movement	NA	Significant	Significant
6: Predator mortality	No movement	Predator wounds	Predator wounds	NA

For our analyses we defined "catch mortality" (CM) as the number of coho that were caught in commercial gillnets that were rated as condition 5 ("Dead") when they were initially brought aboard the fishing vessels. The catch mortality rate (CMR) is defined as the catch mortality expressed as a proportion of the total coho that were caught:

CMR = (CM/Total coho caught)*100 equation #1.

The overall CMR for the nine studies that we examined ranged from 0% to 47.4% (Table 3).

Table 3: Summary of Catch Mortality Rates for coho caught in selective fishing projects using commercial gillnets.

Source of Mortality Data	Coho Catch Mortality rate (%)	Reference
Experimental Studies:		
Alberni Inlet 1998 (all soak times)	47.4	Hargreaves et. al 2001
SFU/Jake Fraser September 1999	20.2	Farrell et al. 2000
SFU/Jake Fraser October 1999	30.2	Farrell et al. 2001a
Area D Gillnet 1999 (Part A)	26.0	Achipelego Marine Research 2000
Demonstration Commercial Fisheries:		
Skeena 2000 (both weeks combined)	34.4	Prince Rupert Community Development Centre 2001
Skeena Week 1 only (Skeena approaches)	33.1	Prince Rupert Community Development Centre 2001
Skeena Week 2 only (mouth of Skeena)	35.2	Prince Rupert Community Development Centre 2001
Regular Commercial Fisheries:		
DFO observer program 1998	16.7	Fisheries & Oceans Canada 1999
DFO observer program 1999	13.5	Fisheries & Oceans Canada 2000
Test Fisheries:		
1998 DFO Test Fisheries	0.0	Fisheries & Oceans Canada 1999
1999 DFO Test Fisheries	1.1	Fisheries & Oceans Canada 2000

We investigated a number of possibilities that might explain the wide range in CMR that was observed in these nine studies and the most important was net soak time.

Effect of soak time on coho catch mortality rate

One of the major changes that was made in commercial salmon gillnet fisheries in 1998 was a mandatory requirement to reduce the amount of time that gillnets were permitted to remain in the water during each fishing operation or "set". The amount of time that a gillnet is in the water is commonly referred to as the "soak time". Prior to 1998 the soak

time for commercial salmon gillnet fisheries generally was not specified by the Department. Soak times of more than an hour were common and in some gillnet fisheries soak times were as long 12 to 24 hours. In 1998 the Department made shorter soak times mandatory in all commercial salmon gillnet fisheries in which non-target species or stocks of concern (in 1998 this was mainly Thompson or Skeena coho) might be encountered in the fishery. The Department defined the soak time for commercial gillnet fisheries as the time elapsed from when the last cork on the gillnet went into the water when setting the net, to the time when the first cork of the gillnet was removed from the water when retrieving the net. In southern B.C. the maximum soak time permitted was 30 minutes in 1998 but was increased to 60 minutes in both 1999 and 2000. In Central and Northern B.C. the Department allowed more flexibility in soak time but typically soak time has been substantially reduced in most commercial gillnet fisheries since 1998, compared to previous years.

Variation in soak time of commercial gillnets explains much of the observed variation in coho catch mortality rate in the studies that we examined. This is most clearly illustrated using the data from the Alberni Inlet 1998 study. This was the first year that short soak times were mandatory and the effect of soak time on coho mortality was one of the main factors that this study was specifically designed to test. The experimental design included a comparison of three different nominal soak times of 30, 45 and 60 minutes. However, in the actual results there was substantial variation around these nominal soak times due to a variety of reasons (e.g. logistic constraints in the fishery, weather conditions, sizes of catches). The resulting broad range in soak times, combined with the large number of sets that were made in this experiment, provided an extensive data set to examine the effect of soak time on coho catch mortality rate.

A total of 371 gillnet sets were made by the seven commercial gillnet vessels that participated in the Alberni Inlet 1998 experiment. Of these sets, 357 were rated by the onboard independent observers as "good". We rejected the data for the 14 remaining sets, which were rated as "poor" by the observers for a variety of reasons (tangled net, net hit and damaged by recreational fishing boat hitting the gillnet during the fishing operation, etc.). We also excluded the data for one additional set for which essential catch and release data were not recorded on the original field data sheet. Only 288 of the remaining 356 sets had sufficient information recorded for us to precisely determine the actual soak time for each set, which ranged from 19 to 68 minutes.

In this experiment the fishing time for each set was defined as the "soak time" (time elapsed from when the last cork went into the water when setting the gillnet, to the time when the first cork was removed from the water when retrieving the gillnet.) This was the same definition of soak time that was used by the Department for all other commercial gillnet fisheries in southern B.C. in 1998. Although the authors think the alternate definition of "total time" (i.e. time elapsed from first cork in to last cork out) is a preferable and more meaningful definition of fishing time, the data required to calculate "total time" were not recorded for many of the gillnet sets completed in the 1998 Alberni Inlet experiment. However, in this experiment there likely was little difference between the "soak time" and "total time" for most sets. We reached this conclusion by comparing

those sets for which only "soak time " was recorded, with the smaller portion of gillnet sets that had sufficient data recorded to calculate both "soak time" and "total time". The reason there was little (e.g. 3-6 minutes) difference between the "soak time" and "total time" for most gillnet sets in this experiment is probably that the catches of all fish species in each set were typically small. Large differences between "soak time" and "total time" typically occur either when there are problems with the fishing gear or when a large number of fish are caught and more time is required to pick the fish from the net.

To examine the effect of soak time on catch mortality we partitioned the data from the Alberni Inlet 1998 experiment into 10 soak time groups: 20, 25, 30, 35, 40, 45, 50, 55, 60 and 65 minutes. We then combined the coho catches and mortality rates for all gillnet sets with each of these nominal soak times, plus or minus 2 minutes. The results showed a strong increase in coho catch mortality rate with increasing soak time (Figure 1). A statistical analyses (z-Test) confirmed that many of the variations in mortality rate at different soak times were statistically significant. (Table 4).

Table 4: Coho catch mortality rates broken down by gillnet soak time.

Soak Time (minutes)	# Dead Coho	Total Coho Captured	Mortality Rate (percent)	z-Statistic
18-22	3	9	33.3	-0.251
23-27	34	102	33.3	-0.845
28-32	80	214	37.4	N/A (control)
33-37	25	76	32.9	-0.809
38-42	43	99	43.4	1.244
43-47	18	40	45.0	0.996
48-52	13	28	46.4	0.989
53-57	47	89	52.8	3.008
58-62	174	313	55.6	6.658
63-67	29	53	54.7	2.608
All (18-67)	466	1023	45.6	

Explanation of the z–Statistic

- The z-statistic was used to compare the statistical significance of the variations in coho mortality rates for different soak times. This test basically compares the actual proportion of coho dead for each soak time group to that predicted from an arbitrarily chosen "control" rate (in Table 4 the control was the 28-32 minute soak time).
- If CR = control rate (i.e. the percent estimated for the 28-32 minute soak time) then:
- ***z-stat = (Dead – Total * CR)/SQRT(Total * CR * (1 - CR))***
- a positive value of the z-Statistic value that exceeds 1.96, or a negative value that is less than –1.96, is significant at the 95% confidence level.

A linear regression model applied to the data in Table 4 indicates that about 91% of the variation in coho mortality rate is explained by the variation in soak time alone ($Y = 0.0057X + 0.1941$; $R^2 = 0.9123$; $p < 0.0001$; $N=10$, where Y is the mortality rate and X is the nominal soak time). Analyses of the residuals from this linear regression indicates that one data point (nominal soak time = 35 minutes and mortality rate = 32.9%) is a statistical outlier. Removal of this point from the linear regression results in a substantial improvement in the statistical fit, with soak time then explaining more than 97% of the observed variation in coho catch mortality rates ($Y = 0.0054X + 0.2126$; $R2 = 0.9709$; $p<0.00001$; $N = 9$). A similar result is obtained if this outlier data point is not excluded but the soak time is partitioned into only 5 categories (18-27, 28-37, 38-47, 48-57 and 58-67) instead of 10 categories. In this case the linear regression model fit indicates that soak time accounts for about 98% of the variation in coho catch mortality rates ($Y = 0.0059X + 0.1882$; $R^2 = 0.9808$; $p<0.001134$; $N = 5$).

Coho revival tanks

The Department made revival tanks a mandatory requirement for all commercial salmon vessels beginning in 1998 as part of the new management measures designed to conserve coho salmon. The purpose of revival tanks is to temporarily hold coho and other non-target species that are too stressed to release immediately after capture. The expectation was that, compared to simply discarding or releasing non-target fish immediately after capture, many non-target fish would have a better chance of survival if they were resuscitated in a revival tank prior to release. However, when the Department made revival tanks mandatory in 1998 it was still uncertain how effective these tanks would actually be.

The specifications for recovery tanks that were required as a Condition of Licence for commercial salmon gillnet vessels in 1998 varied between the three licence areas but these variations were minor. The following is the description that was included as part of the official Conditions of Licence for commercial salmon gillnet vessels in Area D (Statistical Areas 11 to 15, and 23 to 27):

> "***The licenced vessel shall be equipped with a revival tank, the purpose of which is to revive and hold those species of salmon, including steelhead, which the vessel is prohibited from retaining. The revival tank shall meet the following specifications:***
>
> ***(a) Constructed of non-transparent material;***
> ***(b) minimum inside dimensions of 90 cm x 40 cm x 40 cm;***
> ***(c) equipped with a tight fitting lid;***
> ***(d) designed so as to receive a continuous flow of oxygenated seawater throughout the tank.***
>
> ***The revival tank must be filled with water and there must be a constant exchange of oxygenated water at all times when fish are being held in the tank.***

The revival tank and equipment shall be kept clean and in operable condition and the tank shall be used for no other purpose than that outlined above."

In 1998 the Department provided more detailed design specifications and information for the revival tanks required on commercial seine vessels (Appendix 2). No similar detailed specifications were provided for commercial salmon gillnet or troll vessels because the revival tanks for gillnet and troll vessels were simply smaller in size than the revival tanks required for seine vessels. The requirement for a revival tank remained a mandatory Condition of Licence for all commercial salmon fishing vessels, and the specifications for the standard DFO revival tanks for gillnet vessels remained the same, in both 1999 and 2000. It is important to note that the revival tank specifications provided in the Conditions of Licence for commercial gillnet vessels did not specify the details of the plumbing or flow rates provided to the tank. As a result there was substantial variation between vessels in both the plumbing configuration and the pump used to deliver water to the revival tanks. The result was that the rate of flow of water into the revival tank also varied widely between vessels, and in some cases the flow rate sometimes decreased to zero (e.g. when the net drum was in use and the revival tank pump was powered by the same hydraulics system). This may have been a major factor contributing to the wide variation in mortality rates and condition of coho released from revival tanks, especially in cases where the water quality was poor or marginal for coho recovery (e.g. high water temperatures and/or low oxygen levels).

During the period from 1998 to 2000 a newer "Jake Fraser" type of coho revival tank was also developed and tested in several selective fishing experiments. This newer design is named after the commercial gillnet fisherman who did much of the design, fabrication and development of the prototypes. The "Jake Fraser" (JF) revival tank originated from discussions between Patricia Gallaugher (Simon Fraser University; SFU) and Brent Hargreaves (DFO) during the joint Industry/SFU/DFO selective fishing experiment that was conducted in Alberni Inlet in 1998. All commercial gillnet vessels that participated in this study were equipped with the standard DFO coho revival tank ("blue box"). During the first few days of this experiment P. Gallaugher observed coho in these standard revival DFO tanks on several different gillnet vessels. She concluded that the standard DFO design was not very effective and could likely be improved by applying some principles that had previously been developed for laboratory experiments at SFU. She discussed these ideas with B. Hargreaves, who agreed and immediately proceeded to build a prototype of the new revival tank. This new prototype was subsequently tested near the end of the Alberni Inlet 1998 experiment onboard the commercial fishing vessel Myshkin, which was skippered by Jake Fraser. The new revival tank showed some promise and Mr. Fraser became interested in further improving the design. During the winter of 1998 and summer of 1999 he built more prototypes and these were further tested in selective fishing experiments conducted by P. Gallaugher and Tony Farrell (SFU) and Jake Fraser in 1999 and 2000.

Based on the successful results obtained by using this new JF revival tank in these SFU experiments, the Department encouraged all fisherman who participated in the selective commercial gillnet fishery conducted in the Skeena River in 2000 to use the new JF

revival tank. For 2001 the Conditions of Licence for commercial salmon gillnet vessels will also permit fishermen to use either the older DFO revival tank design or the newer JF design. In April 2001 the Department released the official specifications for the new JF revival tank, including the required plumbing configuration, flow rate and key requirements for effective use. These are available on the DFO internet web location: http://www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt.htm .

A substantial amount of new information on the performance of both the standard DFO and newer JF coho revival tanks has been obtained from selective fishing gillnet experiments, demonstration fisheries and regular commercial salmon gillnet fisheries conducted from 1998 to 2000. In the following section we evaluate the results for both revival tank designs. Note that this evaluation focuses on assessing the effectiveness and relative merits of the revival tank designs and does not address the question of the effectiveness of alternate release strategies (e.g. immediate in-water release without even taking the coho onboard). The possible benefits and practicality of these alternate release strategies for commercial gillnet vessels are not currently clear and require further investigation.

Effect of revival tanks on coho mortality

At the time this report was prepared results useful for evaluating the effectiveness of DFO standard recovery tank and newer JF revival tank in gillnet fisheries were available from several separate projects. These include: 1) the 1998 joint DFO/industry selective fisheries experiment conducted in Alberni Inlet; 2) data obtained by independent observers who worked aboard commercial gillnet vessels in the regular commercial gillnet fisheries conducted in southern B.C. in 1998; 3) a selective fishery experiment conducted by the Area D Gillnet Association in 1999 that targeted on sockeye in Johnstone Strait; 4) two selective fisheries gillnet experiment conducted by staff from Simon Fraser University (SFU) and Jake Fraser in September and October 1999, and data from the 1998 and 1999 DFO gillnet test fisheries conducted to assess salmon abundance and run timing in southern B.C. (mainly Johnstone Strait).

The results from these studies show that overall mortality rates of coho typically continued to increase for coho that were held onboard in standard DFO revival tanks. In most studies the mortality rate of coho increased another 3-15% above the initial catch mortality rate by the time that coho were released from the standard DFO revival tank (Table 5). In one case (the 1998 DFO Test Fisheries) the additional mortality rate that occurred during holding of coho in revival tanks was 30%. This appears to be exceptionally high and possibly should be ignored due to the small sample size. Although a total of 74 coho were caught in the 1998 DFO gillnet test fisheries, only 30 of these coho were actually placed in revival tanks.

Table 5: Post-capture mortality rates of coho held in standard DFO revival tanks and newer Jake Fraser type revival tanks onboard commercial salmon gillnet vessels.

Source of Mortality Data	Mortality rate		Reference
	DFO Revival Tank	Jake Fraser Revival Tank	
Experimental Studies:			
Alberni Inlet 1998 (all soak times)	1.6%	N/A	Hargreaves et. al 2001
SFU/Jake Fraser September 1999	N/A	-18.4%	Farrell et al. 2000
SFU/Jake Fraser October 1999	15.1%	-28.5%	Farrell et al. 2001a
Area D Gillnet 1999 (Part A)	3.5%	N/A	Achipelego Marine Research 2000
Demonstration Commercial Fisheries:			
Skeena 2000 (both weeks combined)	N/A	6.6%	Prince Rupert Community Development Centre 2001
Skeena Week 1 only (Skeena approaches)	N/A	7.2%	Prince Rupert Community Development Centre 2001
Skeena Week 2 only (mouth of Skeena)	N/A	7.1%	Prince Rupert Community Development Centre 2001
Regular Commercial Fisheries:			
DFO observer program 1998	10.8%	N/A	Fisheries & Oceans Canada 1999
DFO observer program 1999	5.4%	N/A	Fisheries & Oceans Canada 2000
Test Fisheries:			
1998 DFO Test Fisheries	30.0%	N/A	Fisheries & Oceans Canada 1999
1999 DFO Test Fisheries	11.9%	N/A	Fisheries & Oceans Canada 2000

The performance of the newer JF revival tank was similar to the standard DFO revival tank under some conditions, but remarkably better under other conditions (Table 5). The most surprising observation from SFU/Jake Fraser September 1999 experiment was that many of the coho that were initially rated as "Dead" were successfully revived using the new JF revival tank. Of the total 341 coho that were caught in this experiment 69

(20.2%) were initially rated as Category 5 ("Dead") at the time they were brought aboard the vessel. After 30-60 minutes holding in the JF revival tank, only 6 (1.8%) of these coho did not actually recover.

A second experiment (SFU/Jake Fraser October 1999) showed even higher rates of coho recovery. A total of 116 coho were placed in the new JF revival tank, of which 35 (30.2%) were initially visually rated at the time of capture as Category 5 ("Dead"). After recovery in the JF revival tank only 2 (1.7%) of these coho did not actually recover. In comparison, in simultaneous tests done in this same experiment, a total of 14 coho in Category 5 condition were placed in a standard DFO revival tank and only 7 (50%) of these fish actually recovered. Although the sample size for coho placed in the standard DFO revival tank is small, these results suggest that proper use of the new JF revival tank, combined with modified gillnet fishing and fish handling methods that were used in these SFU experiments, can result in substantially reduced coho mortality rates.

The mortality rate of coho that were held in revival tanks in the special Skeena River selective gillnet commercial fishery in 2000 was 6.6% overall (for both weeks combined), 7.2% for the first week and 7.1% for the second week of this fishery. It should be noted that at the time this paper was written it was still uncertain how many fishermen actually used the new JF design revival tank and how many used the standard DFO revival tank in this experiment. All fishermen were strongly encouraged to use the new JF revival tank and apparently many did. However, anecdotal information indicates that some fishermen may have used the standard DFO design ("blue box"), or may have modified the design of the JF revival tank to better suit their vessels. It is not clear how this may have affected the coho mortality results.

Mortality of coho after release from commercial gillnet vessels

One of the most important questions that is currently unresolved is what ultimately happens to coho that are captured and released from commercial fishing vessels. The strategy of the Department for managing salmon fisheries in the Pacific Region, particularly under the new Selective Fishing policy, is based on the assumption that a large portion of any coho that are caught and released from commercial fishing vessels will survive and eventually successfully spawn. Given what is currently known, this seems reasonable, but to a large degree this critical assumption remains untested. Directly assessing the long-term post–release survival rates of salmon is very difficult and expensive. However, the short-term mortality of coho that occurs within the first 24-48 hours after release has been assessed by holding coho in net pens immediately after they are released from commercial salmon gillnets.

Three selective fishing experiments conducted since 1998 have provided data on short-term post-release mortality of coho held in net pens. The results (Table 6) show that coho mortality continued to increase during the first 24-48 hours after they were released from commercial gillnet vessels. The additional post-release mortality that occurred in net pens was 28.4% for the Alberni Inlet 1998 study. The net pen mortality was higher (20%) for coho held in the standard DFO revival tank compared to the new JF revival

tank (3.4%) in the SFU/Jake Fraser September 1999 study. The net pen mortality was 11% for the overall (both weeks combined) selective gillnet fishery in the Skeena River 2000 experiment, compared to 4.7% for the first week only, and 12.7% for the second week only, of this experiment.

Table 6: Mortality rate of coho held in net pens for 3 – 48 hours after release from commercial gillnet vessels.

Source of Mortality Data	Net Pen Mortality Rate	Reference
Experimental Studies:		
Alberni Inlet 1998 (all soak times)	27.3%	Hargreaves et. al 2001
SFU/Jake Fraser October 1999 (standard DFO revival tank)	3.4%	Farrell et al. 2001a
SFU/Jake Fraser October 1999 (new JF revival tank)	20.0%	Farrell et al. 2001a
Demonstration Commercial Fisheries:		
Skeena 2000 (both weeks combined)	11.0%	Prince Rupert Community Development Centre 2001
Skeena Week 1 only (Skeena approaches)	4.7%	Prince Rupert Community Development Centre 2001
Skeena Week 2 only (mouth of Skeena)	12.7%	Prince Rupert Community Development Centre 2001

The results from these three experiments again show a wide range of mortality rates. The large difference in the net pen rate for coho held in the standard DFO revival tank (20%) versus the new JF revival tank (3.4%), and the data presented previously on catch mortality versus soak time, suggested to us that net pen mortality may depend on either the soak time or the condition of the coho. The sample sizes in the SFU/Jake Fraser experiments were too small to investigate these possibilities, but we were able to use data from the Alberni Inlet 1998 experiment.

The results from the Alberni Inlet 1998 experiment do not indicate any clear relationship between net pen mortality and the net soak time at the time of capture by commercial gillnet vessels. The net pen mortality rates ranged from 24.3% to 30.0% and the differences in net pen mortality for the three soak time groups we used were not statistically significant (Table 7).

Table 7: Mortality rate of coho held in net pens and the associated soak time for the gillnet set in which the coho were originally captured.

Net Soak Time (minutes)	# Dead	Total # Coho Held in Net Pen	Mortality Rate	z-Statistic
30	45	150	30.0%	N/A (control)
45	23	73	31.5%	0.281
60	27	111	24.3%	-1.305
All	95	334	28.4%	

Note: $z_0 = 1.96$ for 95% confidence interval.

The net pen mortality rate does appear to depend on the condition of coho at the time of release from the revival tanks aboard commercial gillnet vessel. Again using the data from the Alberni Inlet 1998 experiment, we partitioned the net pen mortality data into 5 groups that corresponded to the visual condition of each coho (Table 1) that was recorded by the independent observers at the time each coho was released from the revival tanks on the gillnet fishing vessels. We eliminated the data for coho in Condition 5 ("Dead") and the sample sizes for coho in Condition 2 (vigorous and bleeding) and condition 3 (lethargic and bleeding) were too small to yield reliable results.

The data for the two remaining coho condition categories indicated that coho mortality in the net pens was generally lower for coho that were released from the revival tanks aboard gillnet vessels in Condition 1 (Table 8), compared to Condition 3 (Table 9). The statistical analyses of these data indicate that none of the observed differences in net pen mortality rates versus soak time within each group (Condition 1 or Condition 3) are statistically significant. Therefore the data for all soak times were combined to allow a more direct comparison. The statistical analyses of the data grouped in this way confirmed that the mortality rate in the net pen was significantly lower for coho that were released from the gillnet vessels in Condition 1, compared to coho that were released in Condition 3 (Table 10).

Table 8: Mortality rate in net pen for coho that were in Condition 1 (vigorous, not bleeding) at the time of release from the revival tanks on the gillnet vessels.

Soak Time Grouping	# Dead Coho	Total # Coho Held in Net Pen	Mortality Rate	z-Statistic
30 minutes	26	120	21.7%	N/A (control)
45 minutes	10	54	18.5%	-0.562
60 minutes	15	84	17.9%	-0.848
Totals	51	258	19.8%	

Note: $z_0 = 1.96$ for 95% confidence interval.

Table 9: Mortality rate in net pen for coho that were in Condition 3 (lethargic, not bleeding) at the time or release from the revival tanks on the gillnet vessels.

Soak Time Grouping	# Dead Coho	Total # Coho Held in Net Pen	Mortality Rate	z-Statistic
30 minutes	16	29	55.2%	N/A (control)
45 minutes	8	18	44.2%	-0.915
60 minutes	9	21	42.9%	-1.135
Totals	33	68	48.5%	

Note: $z_0 = 1.96$ for 95% confidence interval.

Table 10: Comparison of the overall mortality rates for coho held in net pens and the associated visual condition ratings at the time of release from gillnet vessels.

Visual Condition Rating	# Dead	Total # Coho Held in Net Pen	Mortality Rate	z-Statistic
1	51	258	19.8%	-6.70
3	33	68	48.5%	N/A (control)
Both 1 and 3	84	326	25.8%	

Note: $z_0 = 1.96$ for 95% confidence interval.

Effect of revival tanks on the condition of coho

The evidence that coho condition at the time of release from the gillnet vessels affects at least the short-term post-release mortality rate of coho, encouraged us to examine further the change in condition of coho held in revival tanks.

A summary of the visual condition ratings for coho that were captured in both commercial gillnet fisheries and DFO test fisheries are provided below for 1998 (Table 11) and 1999 (Table 12).

Table 11: Summary of condition of coho from DFO observer programs in 1998.

1998 DFO Gillnet Test Fisheries

The table below indicates the number and percent of coho that entered the revival tanks at each capture condition (CC) that were later released in each condition (CR).

Capture Condition		Coho Condition at Release									
CC	*# of Coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	20	20	100%	N/A		N/A		N/A		0	0%
CC2	0	0		N/A		N/A		N/A		0	
CC3	4	1	25%	N/A		N/A		N/A		3	75%
CC4	6	0	0%	N/A		N/A		N/A		6	100%
CC5	0	0		N/A		N/A		N/A		0	0%
Total	*30*	*21*	*70%*	*N/A*		*N/A*		*N/A*		*9*	*30%*

Note: The DFO database obtained from Leroy Hop Wo (DFO, Nanaimo) contained a total of 278 cases for both test fisheries and regular commercial fisheries. A total of 74 cases were for gillnet test fisheries. Only 30 of these coho were apparently placed in a revival tank and had data for both CC and CR. Note that all coho that were released alive were ranked as Category CR1, apparently regardless of actual condition. All dead coho were ranked as Condition 5.

1998 Commercial Gillnet Fisheries

The table below indicates the number and percent of coho that entered the revival tanks at each capture condition (CC) that were later released in each condition (CR).

Capture Condition		Coho Condition at Release									
CC	*# of Coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	27	24	89%	0	0%	0	0%	0	0%	3	11%
CC2	17	11	65%	5	29%	1	6%	0	0%	0	0%
CC3	45	27	60%	0	0%	13	29%	0	0%	5	11%
CC4	13	2	15%	2	15%	4	31%	3	23%	2	15%
CC5	245	0	0%	0	0%	0	0%	0	0%	24	100%
Total	*126*	*64*	*51%*	*7*	*6%*	*18*	*14%*	*3*	*2%*	*34*	*27%*

Note: The DFO database obtained from Leroy Hop Wo (DFO, Nanaimo) contained a total of 278 cases for both test fisheries and regular commercial fisheries. A total of 204 cases were for gillnet commercial fisheries. Only 126 of these coho were apparently placed in a revival tank and had data for both CC and CR.

Table 12: Summary of condition of coho from DFO observer programs in 1999.

1999 DFO Gillnet Test Fisheries

The table below indicates the number and percent of coho that entered the revival tanks at each capture condition (CC) that were later released in each condition (CR).

Capture Condition		Condition at Release									
CC	*# of Coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	40	38	95%	0	0%	2	5%	0	0%	0	0%
CC2	3	3	100%	0	0%	0	0%	0	0%	0	0%
CC3	49	32	65%	1	2%	10	20%	0	0%	6	12%
CC4	16	3	19%	2	13%	5	31%	0	0%	6	38%
CC5	1	1	100%	0	0%	0	0%	0	0%	0	0%
Total	*109*	*77*	*71%*	*3*	*3%*	*17*	*16%*	*0*	*0%*	*12*	*11%*

Note: The DFO database obtained from Leroy Hop Wo (DFO, Nanaimo) contained a total of 110 coho for gillnet test fisheries. All 110 coho were placed in revival tanks but only 109 had data for both CC and CR.

1999 Commercial Gillnet Fisheries

The table below indicates the number and percent of coho that entered the revival tanks at each capture condition (CC) that were later released in each condition (CR).

Capture Condition		Coho Condition at Release									
CC	*# of Coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	11	11	100%	0	0%	0	0%	0	0%	0	0%
CC2	1	1	100%	0	0%	0	0%	0	0%	0	0%
CC3	16	12	75%	0	0%	3	19%	0	0%	1	6%
CC4	4	2	50%	0	0%	1	25%	0	0%	1	25%
CC5	5	0	0%	0	0%	0	0%	0	0%	5	100%
Total	*37*	*26*	*70%*	*0*	*0%*	*4*	*11%*	*0*	*0%*	*7*	*19%*

Note: 75 total cases. 37 cases with revival times, and thus it is assumed that a tank was used for revival.

Condition of coho from Area D Gillnet sockeye selective fishing experiment in 1999

To evaluate the effectiveness of the standard DFO revival tank that was used in this experiment, we examined the change in condition of each coho between the time of capture and time of release from the revival tank. The final report provided for this experiment (Archipelago Marine Research 2000) indicates that a total of 115 coho were placed in revival tanks prior to release. However, when we examined the raw data for this experiment that was provided to us in electronic form we found it very difficult to determine which coho were actually placed in the revival tank. For the purpose of this paper we assumed that revival was attempted for all of the 140 coho for which both the "time at entry" into a revival tank and the condition of the coho at time of release was recorded. For 8 of these 140 coho, no data for time at release was provided, although the condition at release was recorded. The following summarizes the condition of coho at the time of capture and subsequent release from the revival tanks (Table 13).

Table 13: Number and condition of coho at the time of capture and subsequent release from the revival tanks in the 1999 Area D Gillnet sockeye selective fisheries experiment.

The table below shows the number and percent of coho in each condition at the time of capture (CC) and at the time of release from the revival tank (CR).

Capture Condition		Condition at Release									
CC	*# of coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	15	15	100%	0	0%	0	0%	0	0%	0	0%
CC2	0	0		0		0		0		0	
CC3	93	53	57%	0	0%	30	32%	1	1%	9	10%
CC4	8	1	13%	2	25%	0	0%	2	25%	3	38%
CC5	24	0	0%	0	0%	0	0%	0	0%	24	100%
Total	*140*	*69*	*49%*	*2*	*1%*	*30*	*21%*	*3*	*2%*	*36*	*26%*

Note: A total of 315 coho were caught in 168 of the 424 sets conducted during the experiment (Test 1, 2, and 3); 2) The survival database contains data for 315 coho, but the time of entry into the revival tank was recorded for only 140 of these 315 coho.

The above results indicate that the condition of many of the coho placed in the revival tanks in this experiment substantially improved between the time of capture and subsequent release from the revival tanks. Of the 140 coho that were placed in revival tanks, a total of 15 were in Condition 1, 0 were in Condition 2, 93 were in Condition 3, 8 were in Condition 4, and 24 were in Condition 5 at the time of capture. At the subsequent time of release from the revival tank the totals were 69, 2, 30, 3 and 24 for Conditions 1-5, respectively.

Inspection of the changes in condition of coho within each category shows that all 15 (100%) of the coho that were in Condition 1 at the time of capture were still in Condition 1 at the time of release from the revival tanks. Of the 93 coho that were in Condition 3 (Lethargic, not bleeding) at the time of capture, 53 (57%) had improved to Condition 1 (Vigorous, not bleeding) by the time they were released from the revival tanks. One other coho in Condition 3 at capture changed to Condition 4 (Lethargic, bleeding) at release, and 9 additional Condition 3 coho changed to Condition 5 (dead) by the time of release from the revival tank. Overall, the number of coho in Condition 1 increased from 15 at the time of capture to 69 at the time of release from the revival tanks.

The data available from this experiment are not adequate for assessing the success of the standard DFO revival tank for reviving coho captured in Condition 5 (dead). All 82 of the 315 coho that were captured in Condition 5 (dead) were also released in Condition 5. So all of the coho captured in Condition 5 that were placed in the revival tanks failed to revive in the revival tank. However, only 24 of these Condition 5 coho apparently were actually placed in revival tanks. Of these, only 16 coho had both time at entry into the revival tank as well as time at release. Eight of these had non-zero revival times (range: 11-44 minutes) but the other 8 had 0 minutes revival time. An additional 2 of the 20 Condition 5 coho had negative revival times (possibly an error in data entry) and 6 more coho had the time of entry into the revival tank entered, but no release time. The very small sample size (8 coho) and short time that most were held in the revival tank, makes it difficult to reach any strong conclusion about the capability of the standard DFO revival tank to revive coho captured in Condition 5 ("Dead").

Discussion and conclusions

The wide range of coho mortality rates that occurred in even the small number of studies that are reviewed in this paper is perhaps not surprising. The Department's emphasis on selective fishing is relatively recent and represents a fundamental shift in the way salmon fisheries are conducted and managed. It seems reasonable to anticipate that it may take some time for fishermen to fully accept and adapt to this new requirement.

The data from these studies does indicate that significant progress in reducing coho mortality rates of coho may eventually be possible. For example, the catch mortality rate was 47.4% in the early selective fishing experiment conducted in Alberni Inet in 1998, but only 13.5% for coho caught in the regular commercial gillnet fisheries in southern B.C. in 1999 (Table 3).

The general reduction in coho mortality rates since 1998 has not, however, been uniform and in some cases coho mortality rates still remain very high. For example, many people view the results from the selective gillnet experiment that was conducted in the northern B.C. (Skeena River) in 2000 as a major setback. In this experiment the catch mortality rate was 34%, the revival tank mortality was an additional 6.6%, and the short-term post-release (net pen) mortality was an additional 11%. These results were particularly disappointing in light of the fact that this experiment was designed as a selective fishing "demonstration" fishery in which fishermen were encouraged to use all the new knowledge that had been gained since 1998 on how to reduce coho encounters and mortality. The fishermen that participated in this demonstration fishery were also encouraged to use all the new selective fishing gear and improved fish handling techniques that had been so successful in reducing coho mortality in previous experiments, including the new Jake Fraser revival tank design. The reason(s) for the high coho mortality rates in this demonstration fishery are still uncertain.

The results from all these studies do support the conclusion that revival tanks are in fact beneficial for improving the condition of many coho prior to release. Appropriate use of revival tanks will also likely result in improved post-release survival rates of coho that are released from commercial gillnet vessels. Thus, the authors recommend that revival tanks should remain a mandatory requirement for all vessels that fish with commercial gillnets in regular commercial, demonstration, experimental or test fisheries in the Pacific Region, where there are conservation concerns for the mortality of incidentally caught coho salmon.

The data that are currently available suggest that the new Jake Fraser revival tank design may be more effective than the standard DFO revival tank design for reviving coho caught in commercial salmon gillnets. Use of revival tanks of either design clearly can result in the recovery of many visual Condition 3 coho (Lethargic, non-bleeding) to the improved Condition 1 (Vigorous, non-bleeding) in experimental, demonstration and commercial gillnet fisheries. However, the proportion of Condition 3 coho that revive to Condition 1 appears to typically be somewhat higher in the Jake Fraser type of revival tank. There is also some indication that Condition 3 (Lethargic, not bleeding) coho may recover quicker in the Jake Fraser type of revival tank.

The observed recovery of some Condition 5 ("Dead") coho in the Jake Fraser recovery box is also very promising. Under experimental conditions a much higher proportion (>95%) of the coho that initially were ranked as Condition 5 ("Dead") were revived in the Jake Fraser revival tank, compared to the standard DFO revival tank design (<50%). However, this capability has not yet been adequately tested and confirmed in either demonstration scale or regular full-fleet gillnet fisheries. The recovery of Condition 5 coho was also only rarely even attempted in the standard DFO revival tank, so the data are currently insufficient to assess to what extent this may also be possible using the standard DFO revival tanks.

All things considered, we suspect that the Jake Fraser recovery tank is a superior design and proper use will reduce the post-release mortality rates of coho. At this point this is based more on intuition than hard scientific data. However, there appears to potentially be much to gain, and no obvious additional conservation risk, to the Department permitting and encouraging gillnet fishermen to use the new Jake Fraser type of revival tank. It should be recognized, however, that there still has not yet been sufficient studies with adequate controls (e.g. direct side-by-side comparisons) to confirm that the Jake Fraser design is, in fact, significantly superior to the standard DFO revival tank design.

The reduction in mortality rate of coho that is actually achieved by using revival tanks will likely vary both between fisheries and for individual vessels within any fishery. Our analyses indicates that the potential reduction in mortality rates of coho caught by salmon gillnets in regular commercial fisheries is likely in the range of 5-10% for proper use of the standard DFO revival tank, and likely somewhat higher (e.g. 10-20%) for proper use of the new Jake Fraser revival tank. Even larger reductions in total coho mortality rates may be possible in some fisheries using the Jake Fraser revival tank. However, the actual achievement of these lower mortality rates also strongly depends on many associated and additional factors (short soak times, improved fish handling, proper design, installation and use of the revival tank, catch rates of target and non-target fish, compliance of the fishermen, etc.).

The capability of both the standard DFO and new Jake Fraser revival tanks to revive coho caught in commercial gillnets decreases rapidly with increasing soak time. The general relationship between coho mortality rates and gillnet soak was remarkably similar for both the tightly controlled scientific experiment that was conducted in Alberni Inlet in 1998 and the commercial demonstration fishery conducted in the Skeena River in 2000 (Figure 6). Our analyses indicate that the lower end of the potential reductions in mortality rate in the range of 5% for the DFO revival tank and 10% for the Jake Fraser revival tank, for soak times of 60 minutes or less (last cork in to first cork out). Achieving even lower coho mortality rates (e.g. 10% and 20% reduction, respectively) likely will require soak times no longer than 30 minutes.

A standard definition of soak time should be adopted by both the department and industry for planning and management of salmon fisheries where there are conservation concerns for coho. The various measures of soak time that are currently in use can be very confusing and the results of data analyses using these different measures are often different and difficult to directly compare. The current DFO definition of soak time (last cork in to first cork out) was adopted mainly to facilitate enforcement where mandatory soak time was prescribed for management of fisheries (e.g. maximum 30 minute soak times for all commercial gillnet fisheries in southern B.C. in 1998). The definition of "first cork in to last cork out" is recommended as the best definition to use for assessing impacts on coho and probably other bycatch species. This definition may be more difficult to enforce (e.g. the additional handling of fish in unexpected large catches may unavoidably extend the soak time beyond the target soak time), but makes more sense from the perspective of minimizing the incidental mortality rates of non-target species.

Additional research and development is necessary in order to determine the effectiveness of revival tanks for reducing short-term mortality rates, and improving the condition at release, of other salmon species and non-salmon species. This paper has evaluated only the information available for coho, although the principles of the revival tank designs are simple and likely should also apply to other salmon and many non-salmon species. Some modifications of the recovery box design likely will be required to maximize the benefits of revival tanks for other species (e.g. increased size of revival tanks to accommodate the largest chinook, steelhead and chum).

We emphasize that the analyses and conclusions in this paper apply only to the short term mortality of coho and do not address the question of long-term delayed mortality that may continue to occur after fish are released from revival tanks or net pens. It should also be recognized that many other factors that were not examined in this paper can also affect the mortality rate, condition and recovery of coho, including water temperature and quality (e.g. oxygen levels), the period of time fish are exposed to air after capture and fish handling practices. Although these factors likely contributed to some degree in all the studies we examined, the data currently available are insufficient to assess the importance of these additional factors.

Recommendations

1. Revival tanks should remain a mandatory requirement for all vessels that fish with commercial gillnets in regular commercial, demonstration, experimental or test fisheries in the Pacific Region, where there are conservation concerns for the mortality of incidentally caught coho salmon.

2. Additional experiments should be conducted to confirm the apparent greater effectiveness of the new Jake Fraser revival tank design, compared to the standard DFO revival tank. DFO should allow both types of revival tanks to be used until sufficient information is available to resolve this question.

3. The capability of both the standard DFO and new Jake Fraser revival tanks to revive coho caught in commercial gillnets decreases rapidly with increasing soak time. Achieving low coho mortality rates typically will require total fishing times (first cork in to last cork out) of less than 60 minutes.

4. A standard definition of soak time should be adopted by both the Department and industry for planning and management of all salmon fisheries where there are conservation concerns for coho. The definition of "first cork in to last cork out" is recommended as the best definition to use for assessing impacts on coho and probably other bycatch species.

5. Additional research and development should be done to determine the effectiveness of revival tanks and short soak times for reducing short-term mortality rates, and improving the condition at release, of other salmon and non-salmon species.

Acknowledgements

We thank the proponents of all the studies referenced in this working paper for providing us with the original data from their experiments, and for their patience in answering our endless questions. The funding required to support this work was provided by the Fisheries and Oceans Canada PFAR Selective Fishing program. Jake Fraser collaborated extensively with B. Hargreaves to finalize the official specifications for the new JF revival tank. Doug Takahashi (DFO, Habitat and Enhancement Branch, Vancouver) drafted all the technical drawings of the new JF revival tank (Appendix 5).

References cited

Archipelago Marine Research. 2000. Area D Gillnet Association selective fisheries project. Part 1. 47 pp. (project final report submitted to DFO Selective Fishing program).

Blewett, E. Associates Inc. and T. Taylor Consulting Service Inc. 1999. Selective Fisheries Review and Evaluation. 106 pp. (contract report submitted to DFO Selective Fishing program).

Farrell, A. P., P. E. Gallaugher, C. Clarke, N. DeLury, H. Kreiberg, W. Parkhouse and R. Routledge. 2000. Physiological status of coho salmon in commercial non-retention fisheries. Can. J. Fish. Aquat. Sci. 57: 1668-1678.

Farrell, A. P., P. E. Gallaugher, J. Fraser, D. Pike, P. Bowering, A. Hadwin, W. Parkhouse and R. Routledge. 2001a. Successful recovery of the physiological status of coho salmon on board a commercial gillnet vessel using a newly designed revival box. (submitted to journal *Science*).

Farrell, A. P., S. Buchanan, J. Fraser, P. E. Gallaugher, R. Joy and R. Routledge. 2001b. Dramatic reductions in gillnet mortality for incidentally caught coho (draft manuscript).

Fisheries and Oceans Canada. 1999. Observer and logbook monitoring programs for south coast commercial salmon fisheries: 1998 Summary report. 20 pp.

Fisheries and Oceans Canada. 2000. Observer and logbook monitoring programs for south coast commercial salmon fisheries: 1999 Summary Report. 20 pp.

Fraser, J. 1999. Redesign and testing of commercial salmon fishing revival tank and related techniques: a commercial gillnet perspective. 34 pp. (preliminary draft report submitted to DFO Selective Fishing program).

Hargreaves, N.B., B. Snyder, D. Chen and C. Tovey. 2001. Effects of soak time, onboard revival tanks and other new selective fishing measures on mortality and release condition of coho salmon caught with commercial salmon gillnets. Can. Journal Fish. Aquat. Sci. (in preparation).

Prince Rupert Community Development Centre. 2001. Modified revival box programme; Upper Skeena Cohoe. Interim Final Report. 26 pp. (project report submitted to DFO Selective Fishing program).

Wood, C.M., J. D. Turner, and M.S. Graham 1983. Why do fish die after severe exercise? J. Fish Biol. 22: 189-201.

Appendix 1: Summary of studies used for analyses

A1: Joint Industry/DFO/SFU Selective Fisheries Experiment In Alberni Inlet In 1998

Part A: Coho mortality at the time of catch, in revival tanks and in net pens.

In 1998 a major joint Industry/SFU/DFO experiment was conducted in Alberni Inlet on Vancouver Island, B.C. to assess the effectiveness of a variety of selective fishing methods for commercial salmon seine, gillnet and troll gear types (Blewett and Taylor 1999). The standard DFO revival tank ("blue box"; about 90 x 40 x 40cm) was used on the commercial gillnet vessels that participated in this experiment. The location of the water supply into the revival tanks varied between vessels and flow rates ranged from 0 to 25 liters per minute. Water temperatures ranged from 12 to 18 degrees Celsius, depending on the depth of the end of the intake hose. For gillnet fishing, target soak times of 30 minutes, 45 minutes and 60 minutes were tested. An independent observer aboard each fishing vessel visually assessed the condition of each coho at the time of capture and again at the time of subsequent release from the revival tanks. Most coho that were still alive at the time they came aboard the fishing vessels were tagged externally with color-coded and individually numbered Floy spagetti tags. Some tagged coho were subsequently held in a marine net pen for a variable length of time (3 - 48 hours) to assess longer-term ("post-release") mortality rates.

Results

The seven commercial gillnet vessels that participated in this experiment caught a total of 1,359 coho. The overall mortality rate of coho at the time of capture was 47.4%. The mortality rate increased to 49.1% after including the additional 21 coho that died during the time they were held in revival tanks aboard the gillnet vessels. A total of 97 of the 355 (27.3%) of the coho that were subsequently held in the net pen also died. If these numbers are simply added together, then the combined mortality rate (catch + revival tank + net pen) was 76.4%. The results from this experiment also indicated that there was a strong positive relationship ($R^2 > 0.96$; $p<.0001$) between mortality rate of coho and gillnet soak time, with mortality rates increasing steadily with soak times ranging from 20 minutes to more than 60 minutes.

It should be noted that the encounter rates of coho in this experiment likely were higher than is typical of most regular commercial gillnet fisheries because the vessels specifically targeted on coho.

Part B: Physiological Condition Of Coho Caught By Commercial Gillnets

The other major component of the 1998 experiment in Alberni Inlet was a study conducted by Simon Fraser University staff. The purpose of this study was to assess the

benefits of the standard DFO revival tank for reviving coho caught by commercial gillnet, seine and troll fishing gear. This assessment was based on measurement of a broad range of physiological indicators from muscle tissue and blood plasma that quantify physiological exhaustion.

The sampling procedures used in this SFU study are described in Farrell et al. 2000. Briefly, the condition of coho caught in the commercial gillnets was assessed visually by the independent observer immediately after coho were brought aboard the fishing vessel. Each coho was visually classified into one of five standard categories (1 = Vigorous and not bleeding, 2 = Vigorous and bleeding, 3 = Lethargic and not bleeding, 4 = Lethargic and bleeding, and 5 = dead (not moving or ventilating). A total of 116 coho were obtained from nominal 30 minute or 60 minute net soak times and randomly assigned to 0- (zero recovery), 30-, or 60-minute recovery period in the standard DFO revival tank and tissue and blood samples were taken at these three recovery times (0, 30 and 60 minutes), for each of the two net soak times (30 and 60 minutes) that were examined. An additional 125 coho caught by all three gear types (net, seine and troll; the number for each gear was not identified in the report) were transferred by small boat to a 6 meter^2 net pen immediately after capture. These fish were used to assess delayed mortality and physiological status after a 24-hour holding period in the net pen.

The sampling of the coho required removal of muscle tissue and blood samples. Each fish was stunned with a sharp blow to the head, placed immediately in a V-shaped wooden trough, the fork length measured, and tissue and blood samples were taken. The muscle sample was obtained by excising a sample of muscle tissue approximately 1.0 x 1.0 x 1.0 cm from below and slightly behind the dorsal fin. This tissue was removed and immediately frozen using metal tongs pre-cooled on dry ice. Frozen muscle tissue samples were placed in pre-labelled squares of aluminium foil and then stored on dry ice. This entire procedure took less than 45 seconds. A 5 ml. blood sample was then removed by puncture of the caudal blood vessel into a heparinized vacutainer. Hemocrit tubes were filled immediately from the blood samples. Blood samples were stored on ice for no longer than 20 minutes before they were centrifuged onboard the fishing vessel. Blood plasma and muscle tissue samples were stored on dry ice and subsequently in a freezer at –80 degrees Celsius until processed. The variables that were measured included muscle glycogen, muscle lactate, muscle glucose, muscle phosphocreatine (PCr) and plasma lactate (all indicators of fatigue and stress), hemocrit (Hct, an indicator of bleeding, air exposure and stress), plasma osmolarity and ion (Na^+, K^+ and Cl^-) concentrations (indicators of ionic and osmotic imbalances). The fork length of coho in this study ranged from 53.5 to 80.0 cm

Results

This was the first study that attempted to assess the physiological status of coho immediately after being caught by commercial fishing gear, after being allowed to recover for various periods in the standard DFO revival tank, or after holding for 24 hours in net pens. Most of the coho that were captured by gillnets in this study were visually assessed as either Condition 1 (Vigorous and not bleeding) or Condition 3

(Lethargic and not bleeding), and the physiological measurements were made for coho in these two categories only. Therefore the following summary applies only to fish that were not bleeding or rated as Condition 5 ("Dead") at the time of capture.

The results of the physiological measurements in this study were interpreted (Farrell et al. 2000) to indicate that coho were severely exhausted immediately upon capture, regardless of the commercial fishing method used (gillnet seine, or troll). They concluded that the measured physiological disturbances were as extreme as any that have been previously reported in the literature for exhausted fish.

The physiological measurements also showed no metabolic recovery had occurred in coho after holding for 1 to 2 hours after capture in the standard DFO revival tank aboard the capture vessel. Muscle lactate, muscle glycogen, muscle PCr and plasma lactate all remained characteristic of fatigued rather than recovering fish.

Despite the apparently high level of metabolic exhaustion of coho caught by all types of commercial gillnet, there was little delayed mortality. None of the coho in this study died while being held in the revival tanks, and only three of the 125 (2.4%) coho salmon that were transferred directly to the net pen immediately after capture by gillnet, seine and troll gear died during the subsequent 24 hour holding period.

The results from the net pen also indicated that physiological recovery of coho was possible in a net pen. There were no significant differences in physiological measures (plasma lactate or plasma glucose) for coho caught by the three gear types following 24 hours in the net pen. For all gear types, plasma lactate decreased significantly, and plasma glucose values were unchanged, after 24 hours holding in the net pen. The low lactate values were interpreted to indicate that coho were capable of recovering physiologically after capture with commercial fishing gear if they were allowed to recover for 24 hours in a net pen.

The following summary is a quotation directly from Farrell *et al*. 2000:

> "*In conclusion, extensive physiological measurements suggest that coho experienced severe metabolic disruptions regardless of the gear types and methods, and differences in physiological condition of coho salmon among and within fishing gear types were relatively small. With the exception of plasma* K^+ *, most of the variables that we measured did not recover when fish spent up to 1-h in a (*standard DFO*) recovery box onboard the commercial fish vessel. Therefore, we have reservations about the adequacy of the recovery box design in terms of promoting optimal recovery and feel that it should be redesigned to seek improvements. In contrast, a 24-h recovery in a net pen promoted recovery of plasma lactate and resulted in a low level of delayed mortality."*

A2 and A3: DFO Commercial Gillnet Observer Programs in 1998 and 1999

In the regular commercial salmon fisheries the standard DFO coho revival tank has been used by most fishermen since 1998. Data on coho mortality, and the condition of coho both at capture and at the time of release from the revival tanks, were collected by independent observers in both 1998 and 1999 as part of the observer programs implemented by DFO in southern B.C. Additional data were also obtained in both 1998 and 1999 by the independent observers who worked aboard commercial salmon vessels that conducted various test fishing programs for sockeye and chum (mainly in Johnstone Strait).

Results

The data obtained from the DFO observer programs in commercial fisheries and DFO test fisheries in 1998 and 1999 indicate that the standard DFO revival tank was effective for reviving coho caught incidentally in all three types of commercial salmon gear (gillnet, troll and seine). Many of the coho that were alive, but not in vigorous condition, at the time of capture subsequently recovered to vigorous condition after holding in the standard DFO revival tanks. Based on the 1998 results (sample size 1,018 coho) it was concluded that the overall short-term mortality rate for coho held in standard DFO revival tanks was about 5% for seines, 25% for troll and 40% for gillnets (Fisheries and Oceans Canada 1999). The results from a similar observer program conducted in 1999 (Fisheries and Oceans Canada 2000) indicated short-term mortality rates of 18% for gillnet and 3% for troll (there were no commercial seine fisheries in southern B.C. in 1999). These 1999 rates are substantially lower than in 1998 but should be interpreted cautiously due to the very small sample size (a total of 39 coho for both gillnet and troll combined). In addition, these mortality rate estimates for both 1998 and 1999 do not include any additional mortality that occurred after the coho were released from the fishing vessels.

A4: Area D Gillnet Selective Sockeye Experiment In 1999

In 1999 the commercial salmon Area D Gillnet Association conducted an experiment designed to assess the effectiveness of various selective fishing methods to allow harvest of sockeye while minimizing the impact on coho salmon. The selective fishing measures that were tested included avoidance of coho by assessing coho and sockeye abundance in three different regions, soak time, Alaska Twist gillnets nets, various hang ratios, time of day, and use of revival tanks.

In this experiment nine commercial gillnet vessels, fishing simultaneously in three groups of three vessels, fished in five separate locations in the upper portion of Johnstone Strait (Statistical Areas 11 and 12). Each gillnet vessel was issued an scientific licence that permitted experimental fishing for two days each week during July 25 to August 7, immediately prior to the regular commercial gillnet fishery openings in Johnstone Strait.

An independent observer aboard each vessel recorded the catches of all species and also detailed information for each coho captured. The data recorded for each coho included set

number, Statistical area and Subarea, location, fish number, start and end time in the revival tank, tank water temperature, condition at capture, condition at release and location (depth) of the coho in the mesh. The criteria used for the assessment of coho condition was the standard DFO five category visual rating scheme (Table 1).

All gillnet vessels were required to have onboard an operating revival tank that conformed to the specifications of the standard DFO coho revival tank. Many of the coho were placed in revival tanks immediately after capture. However, some of the coho that were captured in good condition were immediately released.

Results

For the purpose of this PSARC working paper we focused on the data relevant to evaluating the effectiveness of the revival tank. The final report provided for this experiment (Archipelago Marine Research 2000) provides additional details of the methods and results for all the other various components of this experiment.

A total of 10,838 salmon were caught in the 424 sets that were completed over the entire 5 days of this experiment, including 9,908 sockeye, 315 coho, 411 pink, 131 chum, 43 chinook, 15 steelhead and 15 Atlantic salmon.

The catch per unit effort for coho and sockeye varied substantially between the three main regions tested. The three vessels in Group A completed 141 sets for a total of 138.5 hours of fishing and had average catches of 0.61 per hour for coho and 23.2 per hour for sockeye. The three vessels in Group B completed 160 sets for a total of 164.1 hours of fishing and had the highest average catch of coho (1.2 per hour) and the lowest average catch of sockeye (18.3 per hour). The three vessels in Group C completed 123 sets for a total of 110.3 hours of fishing and had the lowest average catch of coho (0.38 per hour) and the highest average catch of sockeye (35.0 per hour).

At the time of capture 82 of the 315 (26.0%) coho were rated as Condition 5 ("Dead"). The remaining coho were assessed as alive at the time of capture, with 117 (37%) in Condition 1 (Vigorous, not bleeding), 1 in Condition 2 (Vigorous and bleeding), 105 in Condition 3 (Lethargic, not bleeding), and 10 in Condition 4 (Lethargic and bleeding).

At the time of release from the revival tanks the total number of coho in Condition 5 (Dead) had increased to 93, for an overall mortality rate (catch plus revival tank) of 29.5%.

We also examined the effects of soak time on coho mortality and change of condition in the revival tanks. A total 315 coho were caught in this experiment but the complete data required for this analyses for each coho (time and condition at entry into the revival tank, time and condition at release from the revival tank, and soak time) was available for only 87 fish. The final report provide for this experiment (Archipelago Marine Research 2000) states that soak time for each set was limited to a maximum of one hour but does not indicate how soak time was defined. To facilitate comparisons with the results from

other studies in this paper, we defined soak time as last cork in to first cork out and analyzed the data accordingly.

It was difficult to evaluate the effect of soak time on coho condition in this experiment because there was very little variation in soak time. Most of the sets in which the 87 coho were caught had soak times ranging from 53 to 67 minutes. Only 3 of the 87 coho were caught in sets with soak times less than 53 minutes and 4 other coho were caught in sets with soak times longer than 67 minutes. For all soak times combined, the total mortality rate of coho was 30% and 58% of the coho captured in Condition 3 recovered to Condition 1 by the time of release. The total mortality rate decreased slightly to 25% overall, and the portion of Condition 3 coho that recovered to Condition 1 decreased to 57%, when only those sets with soak times of 53-67 minutes were included in the analyses (Table 14).

Table 14:

The table below indicates the number and percent of coho from the survival database that were caught in sets with soak times between 53-67 minutes (60 minute soak time group) that entered the revival tanks at each capture condition (CC) and were later released in each release condition (CR)

Data only for gillnet sets included in 60 min soak time grouping.

Capture Condition		Condition at Release									
CC	*# of Coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	8	8	100%	0	0%	0	0%	0	0%	0	0%
CC2	0	0		0		0		0		0	
CC3	47	27	57%	0	0%	16	34%	1	2%	3	6%
CC4	4	0	0%	0	0%	0	0%	1	25%	3	75%
CC5	12	0	0%	0	0%	0	0%	0	0%	12	100%
Total	*71*	*35*	*49%*	*0*	*0%*	*16*	*23%*	*2*	*3%*	*18*	*25%*

Notes: 1) Analyses was possible only for the 60 minute soak grouping since only 3 of 87 coho placed in revival boxes were caught in sets with soak times <53 minutes and only 4 of 87 coho were caught in sets with soak times >67 minutes. All the remaining coho (71) were in the 60 minute soak time group.

A5 and A6: SFU Experiments in September and October 1999

In 1999 two separate experimental studies were conducted by Patricia Gallaugher and Tony Farrell (Simon Fraser University) and Jake Fraser (commercial salmon gillnet Area C fisherman). The objectives of these experiments were was to develop an improved revival tank and handling techniques for coho, and to determine the effectiveness of this redesigned revival tank and improved fish handling techniques for increasing recovery and post-release survival rates of coho. These experiments included testing of the new revival tank in two trials: 1) short term (60 and 120 minute) recovery test; and 2) recovery after 24 hrs in a net pen.

The DFO revival tank used in this study was the standard 40 cm x 40 cm x 90 cm "blue box" type, fitted with a 1.25 inch diameter water intake that was centered in one end, near the bottom of the tank, with a variable flow rate (>0.2 l/sec). The new "Jake Fraser" (JF)

revival tank was the same type of revival tank but was modified to incorporate a central longitudinal divider to create two separate compartments with individual water inlets and outlets. Each compartment was also equipped with an independent vertically sliding door and exit rubber chute that allowed fish to be released from the revival tank without additional handling. The flow rate of water into the new JF revival tank was also increased to 0.6 l/sec. per fish.

For the short term experiments the JF revival tank was used to test the following variables: 1) 60 and 120 minute recovery times in the modified revival tank; 2) variable recovery time of coho to Condition 1; 3) various air exposure times; 4) ability to swim at the fixed 60 and 120 minute recovery times; and 5) ability to swim at variable recovery times to Condition 1. A portable, floating self-contained swim tunnel was used for these swim tests, with a design based on a larger land-based model used in the laboratory at Simon Fraser University.

In September 1999 coho were caught in a targeted coho fishery in Alberni Inlet (Statistical Area 23, Subareas 1 and 2) by the commercial gillnet vessel Myshkin (CFV 25369). The gillnet used was panelled and consisted of one section that was 200 fathom long, 4 7/8 inch mesh, 90 mesh deep Alaska Twist and 2.2:1 hang ratio. The second section of net was up to 260 long, 60 fathom deep, 4 inch mesh, 4-strand 60 mesh Alaska twist, 2.2:1 hang ratio, with a weed line with 4 inch beckets. Net soak times (first cork in to last cork out) were usually 40 minutes or less and never exceeded 70 minutes. Coho were ranked as they came aboard using the DFO standard five-category visual ranking scheme (Table 1). After capture some coho were either immediately sampled for blood and muscle tissue stress indicators or they were sampled after recovering for 60 or 120 minutes in a revival tank. Other coho were transported to the swim tunnel for testing and subsequent sampling.

In October 1999 a second study was conducted in Alberni Inlet to test the results obtained with the new JF revival tank design when coho were held in longer-term (24 hour) experiments. Coho were captured using the same vessel and commercial gillnet gear as described above. For this study a 40 x 40 x 60 foot net pen was secured to a floating log boom and six smaller (4 x 5 x 6 foot) net pens were placed inside the larger net pen. Each coho was removed from the gillnet, the condition assessed visually, then placed in either the standard DFO revival tank or the new JF revival tank, tagged, and with no further handling, the time to first ventilation as well as amplitude of ventilation was recorded for visual Condition 5 (“Dead”) fish only. When each coho had recovered to a constant upright position it was transported by the capture vessel to the large net pen and released into one of the smaller net pens according to the catch condition (Condition 1, 3 or 5). One set of the three smaller net pens was used for the morning catch and the other three for the afternoon catch. After allowing 24 hours recovery time in the net pens some coho were sampled and other coho were swum in the swim tunnel and then sampled. Coho recovered to Condition 1 (Vigorous, not bleeding) were also swum in the swim tunnel without holding in the net pens to provide comparison “control” data for the Condition 5 coho that were allowed to recover for 24 hours in the net pens. The physiological measurements included a variety of muscle and blood plasma variables that

were used to quantify physical exhaustion, including muscle glycogen, muscle lactose, muscle glucose, muscle adenosine triphosphate (ATP), muscle phosphocreatine (PCr), plasma lactate, plasma cortisol (all indicators of fatigue and stress), hemocrit (Hct, an indicator of bleeding and stress), plasma osmolarity and ion (Na^+, K^+ and Cl^+) concentrations (indicators of ionic and osmotic imbalances). Additional details of the equipment and sampling methods used in both parts of this study are provided in Farrell et al. 1998, Fraser 1999 and Farrell at al. 2001a.

Results

The most surprising observation from the first (September 1999) part of this study was that many of the coho that were visually classified as Condition 5 ("Dead") were successfully revived using the new JF revival tank. Of the total 341 coho that were caught, 69 (20.2%) were initially classified as Condition 5 at the time they were brought aboard the vessel. After 30-60 minutes in the JF revival tank, only 6 (1.8%) of these coho did not actually recover.

The results from the second (October 1999) part of this study confirmed the results from the first experiment and also indicated that the new JF revival tank may promote better recovery of coho than the standard DFO revival tank. In this experiment a total of 116 coho were placed in the new JF revival tank, of which 35 (30.2%) were initially visually classified as Condition 5 ("Dead"). After recovery in the JF revival tank only 2 (1.7%) of these coho did not actually recover. In comparison, a total of 14 coho in Condition 5 were placed in the standard DFO revival tank and only 7 (50%) of these fish actually recovered. Although the sample size for coho placed in the standard DFO revival tank was very small, the proponents concluded that these results indicate that proper use of the new JF revival tank, combined with modified gillnet fishing and fish handling methods, can result in substantially reduced coho mortality rates.

The results from the net pen holding portion of this experiment were also interpreted by proponents to demonstrate that the new JK revival tank resulted in higher longer-term survival rates of coho than the standard DFO revival tank. Only 3.4% (1 of 29) of the coho that came aboard the capture vessel in Condition 5 and placed in the JF revival tank had died after subsequent 24 hours holding in the net pens. In contrast, 20% (1 of 5) of the coho in Condition 5 that were held in the standard DFO revival tank died after 24 hours in a net pen. Again, however, these results should probably be interpreted cautiously due to the very small sample sizes.

When the results of the on-board and net pen mortality in this experiment are combined, 94% (33 of 35) of the fish that came aboard the capture vessel in Condition 5 and were placed in the JF revival box were still alive 24 hours later in the net pen. Only 50% (7 of 14) of the Condition 5 coho that were placed in the standard DFO revival tank were still alive 24 hours later in the net pens.

This study also indicated that the mortality rate of coho generally tended to increase with longer net soak times (duration of net in the water for each set). Of the 355 coho that

were caught in sets with soak times less than 40 minutes, a total of 71 (20%) were initially classified as Condition 5. However, 32 of the 98 (32.6%) coho captured in sets with soak times of 41 to 70 minutes were classified as Condition 5.

The extensive results obtained in this study on the physiological condition of coho indicated that the new JF revival tank also promoted significant physiological recovery. Physiological data were obtained for coho at the time of capture, after holding in the JF revival tank for up to 2 hours, after holding in the net pens for 24 hours, and after swim tests at various water velocities in the swim tunnel. A total of 176 coho were used for tissue sampling, including 41 (14 vigorous, 14 lethargic and 13 apparently dead) that were sampled after 24 hour holding in the net pens. The results were interpreted by the proponents to indicate that coho sampled immediately after capture were physiologically exhausted and highly stressed. For coho placed in the JF revival tank, muscle metabolites recovered during the first hour of revival, but blood plasma ions and osmolarity recovered more slowly. This pattern of physiological recovery was similar for coho in all three visual conditions (Vigorous, Lethargic and "Dead"). The physiological status of coho after 24 hour recovery in the net pens indicated that there was a significant ongoing recovery, compared to the recovery that had occurred after 2 hours in the JF revival tank.

The results of the swimming performance tests for vigorous and lethargic coho showed that 61 of 78 fish (78%) put in the swim tunnel completed a swim test. After 1-h recovery in a JF recovery tank 100% of Condition 1 (Vigorous) fish and 93% Condition 3 (Lethargic) fish successfully completed a ramped-velocity swim test. Vigorous and lethargic coho salmon swam for at least 27 min and reached speeds >1.5 $m.s^{-1}$ (>2.2 body lengths per second) after recovering in the JF revival tank. Vigorous fish also swam for over 30 minutes and reached speeds of up to 2.97 $bl.s^{-1}$ after being revived for 1 h 20 minutes. The maximum swim velocity for vigorous fish did not increase significantly with either a fixed or a variable recovery time. Compared with vigorous fish, lethargic fish tended to swim for shorter times and have a lower maximum swim velocity, except when recovery in the JF revival tank was >1 hour. The combined success rate for vigorous fish (81%; N=31) was not much different than lethargic fish (77%; N=47). The proponents also noted that even coho tested immediately after capture, with no time to recover in the JF revival tank, were able to successfully perform the swim test.

Vigorous and apparently dead coho salmon also were subjected to the swim test after a 24-h recovery period in the net pens. The results indicated that the maximum swim velocity and total swim times were not significantly different for coho in these two categories. However, the swimming performance of the vigorous fish (1.98 body lengths per second) held for 24 hours in the net pens was significantly lower compared with vigorous fish tested after only a 2 h 20 min recovery period in the JF revival tank (2.97 $bl.s^{-1}$). This unexpected result was attributed by the proponents to a problem with handling coho during transfer to the swim tunnel.

The following summary is a quotation directly from Farrel et al 2001a:

> *"This study is the second to broadly examine the physiological status of wild coho salmon immediately after capture by commercial salmon fisheries to ascertain whether or not physiological recovery was possible. A new study was particularly important because the previous one (Farrell et al. 2000) had shown that the old design of recovery box (the so-called blue box) effected rather limited recovery of physiological status. Therefore, the primary purpose of the present study was to discovery whether or not coho salmon captured by gillnet could be revived on board a commercial vessel using a newly designed recovery box. Our major conclusion is that, in a setting relevant to commercial gillnet salmon fishing, a combination of soak times $\leq$70 min in duration, careful handling of coho salmon on board to minimize physical trauma, and fish revival for up to 2 h in a newly designed recovery box, promoted significant physiological recovery such that coho salmon were able to swim well despite being initially fatigued and stressed as a result of capture. The present results provide clear evidence that revived fish show significant metabolic, ionic and osmotic recovery. Therefore, we suggest that the new design features of the Jake Fraser recovery box promoted a more effective recovery of exhausted coho salmon than the blue box. Furthermore, physiological recovery was sufficiently quick that the majority of revived coho salmon could start a ramp-velocity swim test within 20 min of capture and reach velocities in excess of 1.5 $m.s^{-1}$. This observation provides further definitive evidence for physiological recovery and is a finding that is consistent with muscle ATP and muscle PCr being restored to stable levels during fish revival. Perhaps the most emphatic demonstration of the benefit of the recovery box was the successful revival of asphyxiated fish (those ranked as dead at capture). The recovery box design was such that it assisted gill ventilation when asphyxiated fish had stopped breathing for themselves. As a result, delayed mortality was only 2.5% (2 out of 80 fish)."*

A7: Skeena Demonstration Commercial Fishery In 2000

In 2000 a commercial gillnet demonstration fishery was conducted in two adjacent areas in northern B.C.: 1) the approach area to the Skeena River estuary; and 2) in the mouth of the Skeena River. Both portions of this demonstration fishery were conducted in locations that were designated as part of a Special Management Zone (SMZ) in the official DFO Integrated Fisheries Management Plan (IFMP). In 2000 the SMZ in the Skeena area started on 19th July and regular commercial gillnet fisheries in this region ended for the season two days later (21 July) due to the expected increasing prevalence of coho stocks of special conservation concern (mainly upper Skeena coho). The purpose of the gillnet demonstration fishery was to allow a portion of the Area C commercial gillnet fleet the opportunity to demonstrate the effectiveness of the new selective fishing practices to conserve coho salmon, while continuing to harvest Skeena sockeye during the SMZ period.

Fishermen were encouraged to employ as many selective fishing methods as possible or practical in this demonstration fishery, including use of the new JF coho revival tank,

short soak times (30 minute maximum; defined as first cork in to last cork out), daylight only fishing, improved fish handling practices, etc. Most fishermen received a special 3 hour training session for this demonstration fishery to ensure they understood the objectives and how to properly implement all the appropriate selective fishing methods that were to be used. Fishermen were all specifically requested to use the new JF revival tank design.

An independent observer was placed aboard each fishing vessel. All the observers had completed the at-sea observer training course designed by Malaspina College and DFO, and also had attended a half-day instructional session that identified their fish handling and data recording responsibilities for this demonstration fishery. Each observer recorded the time and condition of each coho as it came aboard the fishing vessel, each coho was tagged and placed in the revival tank. When in the opinion of the fisherman and the observer each coho had recovered sufficiently to be transferred, or was not going to recover, a transfer vessel was called to move the coho to a net pen holding facility.

After removal from the revival tank the coho were transferred by boat from the fishing vessel to a net pen facility where they were held for 24 hours to assess delayed mortality. The condition of each coho was assessed again when the coho were released from the net pen. The observer onboard the fishing vessel recorded the time and condition of each coho when it was removed from the revival tank and passed to the transfer vessel. The operator of the transfer vessel then again independently assessed the condition of each coho at the same time as each coho was received fish aboard the transfer boat. Each coho was then moved to the holding facility where the time and its condition on arrival was again recorded. Each coho was then measured, sexed and placed in a holding tank and monitored on an ongoing basis. The operator of the holding facility again assessed the condition of each coho after 24 hours holding and released all the live coho.

It is important to note that the visual criteria used by the observers for assessing the condition of the coho (Table 2) in this demonstration fishery were not identical to the standard DFO visual criteria (Table 1).

The first part the demonstration fishery was conducted in the approach area to the Skeena River. This fishery opened at 0600 hrs on July 28, 2000 and closed at 20:00 hrs on August 1, 2000, with 20 gillnet vessels fishing. The total reported catch was 21,583 sockeye, 3,927 pink, 147 coho, 295 chum, 14 chinook and 393 steelhead.

The second part of the demonstration fishery occurred in the mouth of the Skeena River. This fishery opened at 0600 hrs on August 4, 2000 and closed at 2000 hrs on August 8, 2000, initially with 20 gillnet vessels fishing. Two vessels experienced mechanical problems and stopped fishing. Only one of these vessels was replaced and 19 vessels were operating when the fishery closed. The total reported catch was 25,899 sockeye, 15,393 pinks, 221 coho, 214 chum and 76 chinook.

Concerns were raised about the selective seine fishery that was also conducted in the Skeena River and approach waters during the same time period as the second week of the selective gillnet demonstration fishery. Gillnet fishermen objected to the gillnet and seine

fisheries occurring in the same area and at the same time, because they were concerned that the activities of the seine fishery would compromise the results from the demonstration gillnet fishery. The seine vessels in this fishery were required to release all coho encountered, either immediately if the fish was in vigorous condition, or after holding them in a revival tank for coho that were not vigorous. One of the main concerns of the gillnet fishermen was that many of the coho released from the seines might be recaptured by the gillnets. It was felt that the additional handling, stress, etc. that resulted from the previous capture and release by the seine vessels would result in poorer condition and higher mortality rates for any coho that were recaptured by the gillnet vessels.

Results

Due to the importance of this experiment (it was the first demonstration scale selective gillnet experiment permitted by the Department) the results are provided in more detail than the summaries provided above for other selective gillnet studies.

The combined results for both weeks of this gillnet demonstration fishery showed the mortality rate for coho increased from 34.4% at the time of capture to 41.5% at the time coho were released from the revival tanks (Table 15a). The mortality rate increased further to 52% after including the additional delayed mortality that occurred after 24 hour holding in the net pens (Table 15c).

Table 15: Results for both weeks combined (Skeena 2000 demonstration fishery)

Change between Capture and Release after Using Revival Tanks in Skeena 2000 demonstration fishery : Weeks 1 and 2

Table 15a below indicates the number and percent of coho that entered the revival tanks at each capture condition (CC) that were rated in each condition at release (observers record of condition at transfer).

Capture Condition		Condition at Release									
CC	*# of Coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	52	24	46%	13	25%	8	15%	1	2%	6	12%
CC2	43	15	35%	17	40%	7	16%	2	5%	2	5%
CC3	69	9	13%	15	22%	32	46%	6	9%	7	10%
CC4	67	6	9%	4	6%	11	16%	24	36%	22	33%
CC5	121	3	2%	3	2%	2	2%	4	3%	109	90%
Total	*352*	*57*	*16%*	*52*	*15%*	*60*	*17%*	*37*	*11%*	*146*	*41%*

Note: 1) A total of 147 coho were caught in week 1 and 221 in week 2. There were a total of 1839 sets in the catch database. 1564 sets had no coho caught, and 275 had at least 1 coho caught.

Table 15b below indicates the number and percent of coho with each capture condition (CC), that were in each condition at the end of net pen treatment.

Capture Condition		Condition at Release From Net Pen			
CC	*# of Coho*	*Alive*		*Dead*	
CC1	52	44	85%	8	15%
CC2	43	36	84%	7	16%
CC3	69	49	71%	20	29%
CC4	67	31	46%	36	54%
CC5	121	10	8%	111	92%
Total	*352*	*170*	*48%*	*182*	*52%*

Table 15c below indicates the number and percent of coho that were released from the revival tanks at each release condition (CR) that were released alive (condition 1) or dead (condition 5) by the end of net pen treatment.

Release Condition		Condition at Release From Net Pen			
CC	*# of Coho*	*Alive*		*Dead*	
CR1	57	55	96%	2	4%
CR2	52	46	88%	6	12%
CR3	60	45	75%	15	25%
CR4	37	17	46%	20	54%
CR5	146	7	5%	139	95%
Total	*352*	*170*	*48%*	*182*	*52%*

The combined results for both weeks of fishing for the change in the condition of coho indicates that only 12 of the 121 coho (3.4%) that came aboard the capture vessels in Condition 5 ("Dead") actually recovered by the time they were released from the revival tanks (Table 15a). However, a total of 35 other coho also changed from Condition 1, 2, 3 or 4 to Condition 5 while aboard the fishing vessels. Of the 146 coho that were in Condition 5 when they were transferred out of the revival tanks, a total of 7 subsequently recovered to some other Condition after 24 hours holding in the net pens (Table 15c).

The coho mortality and condition data were also examined separately for each week of the Skeena 2000 demonstration fishery to address the concerns of the fishermen about the overlap in time and area fished coincident with the selective seine fishery.

The catch mortality, catch plus revival tank mortality, and total mortality (catch plus revival tank plus net pen mortality) for coho caught only during the first week of the demonstration gillnet fishery in the approach waters of the Skeena River was 33.1%, 40.3% and 44.6%, respectively (Table 16). Of the 46 coho that came aboard the capture vessels in Condition 5 ("Dead") only 8 (17%) actually recovered by the time they were released from the revival tanks (Table 16b). However, a total of 18 other coho also

changed from Category 1, 2, 3 or 4 to Category 5 while aboard the fishing vessel. Of the 56 coho that were in Condition 5 when they were transferred out of the revival tanks, only 3 subsequently recovered to some other condition category after 24 hours holding in the net pens (Table 16c).

Table 16: results for the first week only for the Skeena 2000 experiment (August 4-8, 2000)

Table 16a below indicates the number and percent of coho that entered the revival tanks at each capture condition (CC) that were rated in each condition at release (CR) (observers record of condition at transfer).

Capture Condition *Condition at Release*

CC	*# of Coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	13	7	54%	4	31%	0	0%	0	0%	2	15%
CC2	20	9	45%	10	50%	0	0%	1	5%	0	0%
CC3	29	7	24%	5	17%	10	34%	3	10%	4	14%
CC4	31	6	19%	1	3%	5	16%	7	23%	12	39%
CC5	46	2	4%	3	7%	1	2%	2	4%	38	83%
Total	*139*	*31*	*22%*	*23*	*17%*	*16*	*12%*	*13*	*9%*	*56*	*40%*

Note:1) A total of 147 coho were caught in week 1 in 122 sets. Data for 8 of these coho were excluded since they were released directly without revival attempt. Thus, survival data were available for a total of 139 coho for week 1 of the experiment.

Table 16b below indicates the number and percent of coho with each capture condition (CC), that were in each condition at the end of net pen treatment.

Capture Condition *Condition at Release From Net Pen*

CC	*# of Coho*	*Alive*		*Dead*	
CC1	13	10	77%	3	23%
CC2	20	19	95%	1	5%
CC3	29	24	83%	5	17%
CC4	31	15	48%	16	52%
CC5	46	9	20%	37	80%
Total	*139*	*77*	*55%*	*62*	*45%*

Table 16c below indicates the number and percent of coho that were released from the revival tanks at each release condition (CR) that were released alive (condition 1) or dead (condition 5) by the end of net pen treatment.

Release Condition *Condition at Release From Net Pen*

CC	*# of Coho*	*Alive*		*Dead*	
CR1	31	30	97%	1	3%
CR2	23	22	96%	1	4%
CR3	16	16	100%	0	0%
CR4	13	6	46%	7	54%
CR5	56	3	5%	53	95%
Total	*139*	*77*	*55%*	*62*	*45%*

The catch mortality, net pen mortality and total mortality rate for coho caught only during the second week of the demonstration gillnet fishery in the mouth of the Fraser River was 35.2%, 42.2% and 56.3%, respectively (Table 17). Of the 75 coho that came aboard the capture vessels in Condition 5 ("Dead") only 4 (5%) actually recovered by the time they were released from the revival tanks (Table 17a). However, a total of 19 other coho also changed from Category 1, 2, 3 or 4 to Category 5 while aboard the fishing vessel. Of the 90 coho that were in Condition 5 when they were transferred out of the revival tanks, only 4 subsequently recovered to some other condition category after 24 hours holding in the net pens (Table 17c).

Table 17: results for second week only of the Skeena 2000 experiment (August 4 – 8, 2000)

Table 17a below indicates the number and percent of coho that entered the revival tanks at each capture Condition (CC) that were rated in each condition at release (observers record of condition at transfer). All soak times combined.

Capture Condition		*Condition at Release*									
CC	*# of Coho*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
CC1	39	17	44%	9	23%	8	21%	1	3%	4	10%
CC2	23	6	26%	7	30%	7	30%	1	4%	2	9%
CC3	40	2	5%	10	25%	22	55%	3	8%	3	8%
CC4	36	0	0%	3	8%	6	17%	17	47%	10	28%
CC5	75	1	1%	0	0%	1	1%	2	3%	71	95%
Total	*213*	*26*	*12%*	*29*	*14%*	*44*	*21%*	*24*	*11%*	*90*	*42%*

Note: 1) A total of 221 coho were caught in 153 of 767 sets in week 2. Data for 8 coho were eliminated since they were released directly without revival attempt. Thus, survival data were available for 213 coho for week 2; 2) the condition rating scale used in this experiment was not the same as the standard DFO 5 point scale.

Table 17b below indicates the number and percent of coho with each capture condition (CC), that were in each condition at the end of net pen treatment.

Capture Condition		*Condition at Release From Net Pen*			
CC	*# of Coho*	*Alive*		*Dead*	
CC1	39	34	87%	5	13%
CC2	23	17	74%	6	26%
CC3	40	25	63%	15	38%
CC4	36	16	44%	20	56%
CC5	75	1	1%	74	99%
Total	*213*	*93*	*44%*	*120*	*56%*

Table 17c below indicates the number and percent of coho that were released from the revival tanks at each release condition (CR) that were released alive (condition 1)or dead (condition 5) by the end of net pen treatment

Release Condition		*Condition at Release From Net Pen*			
CC	*# of Coho*	*Alive*		*Dead*	
CR1	26	25	96%	1	4%
CR2	29	24	83%	5	17%
CR3	44	29	66%	15	34%
CR4	24	11	46%	13	54%
CR5	90	4	4%	86	96%
Total	*213*	*93*	*44%*	*120*	*56%*

To evaluate the possible influence of soak time on coho mortality and change in condition we also further partitioned the data for each week of the demonstration fishery into three "soak groups": 1) soak times less than 23 minutes; 2) soak times of 23-37 minutes; and 3) soak times longer than 37 minutes.

For this analyses we defined soak time as the time interval between when last cork of the gillnet entered the water and the first cork came out of the water. We used this definition to allow direct comparison with the results from other studies reviewed in this paper. However, it should be noted that this is not the same definition of soak time (first cork in, and last cork out) that was used by the fishermen in this demonstration fishery.

For convenience the relationship between these two measures of soak times for this experiment is plotted and a conversion equation is plotted (Figure 3). It is clear from this scatter plot that there is substantial variation between Soak Time (last cork in to first cork out) and Total Set Time (first cork in to last cork out). Much of this variation is accounted for the fact that there was a strong positive relationship between the time difference (difference = total set time – soak time) versus the total catch of all salmon for each set (Figure 4) in this experiment. This is not unexpected, because soak time (time interval between the time the net is set and the time when it is picked up) is typically independent of the size of the catch. However, total set time includes the time required to pick up the gillnet and also remove fish from the net, and so set time increases as total catch increases.

For the first week of the demonstration gillnet fishery the total mortality of coho was 27% for soak times <23 minutes, 50% for soak times of 23-37 minutes, and 44% for soak times of longer than 37 minutes. A total of 20%, 19% and 0%, for each of these soak times respectively, of the coho that came aboard the capture vessels in Condition 5 subsequently recovered to some other Condition in the revival tanks.

For the second week of the demonstration gillnet fishery the total mortality of coho was 66% for soak times <23 minutes, 53% for soak times of 23-37 minutes and 67% for soak times of longer than 37 minutes. A total of 0%, 5% and 0%, for each of these soak times respectively, of the coho that came aboard the capture vessels in Condition 5 subsequently recovered to some other Condition in the revival tanks.

A further breakdown of the coho mortality for each day of gillnet fishing for each week shows that total mortality (catch plus revival tank plus net pen) was generally lower for most days during the first week of fishing (Table 18a). Total mortality ranged from 30 to 44% for four of the five days of fishing during the first week, but was substantially higher (58%) on one day (29 July). Total mortality ranged from 52 to 56% for four of the five days of fishing during the second week (Table 18b), but again was substantially higher (70%) on one day (8 August).

Table 18. Breakdown of total daily mortality (%), and the number of coho in Condition 1 and 5 condition after capture, recovery in onboard revival tanks and subsequent holding for 24 hours in net pens for the Skeena 2000 demonstration gillnet fishery (Table provided by Dave Peacock, DFO Prince Rupert).

Table 18a: week 1 only

	Number of coho at release			***Total Mortality***
FISHING DAY	***Condition 1***	***Condition 5***	***Total***	
28-Jul-00	20	16	36	44%
29-Jul-00	14	19	33	58%
30-Jul-00	14	6	20	30%
31-Jul-00	18	11	29	38%
1-Aug-00	19	10	29	34%
TOTAL	85	62	147	42%

Table 18b: week 2 only

	Number of coho at release			***Total Mortality***
FISHING DAY	***Condition 1***	***Condition 5***	***Total***	
4-Aug-00	28	36	64	56%
5-Aug-00	30	32	62	52%
6-Aug-00	23	26	49	53%
7-Aug-00	16	20	36	56%
8-Aug-00	3	7	10	70%
TOTAL	100	121	221	55%

Note: "Total Mortality" includes coho that died prior to release from the fishing vessels, and also the additional coho that died during subsequent holding for 24 hours in the net pens.

We also examined scale loss as one possible indicator of the number of coho caught in the gillnet demonstration fishery that might have been previously caught by the seines in the coincident selective seine fishery. Data on the loss of scales (in percent) was estimated visually and recorded by the observers for each coho as it was brought aboard the gillnet vessels. It was assumed by fishermen that scale loss might be directly related to coho stress and heavy scale loss might also indicate previous capture of the coho by a seine vessel. For this analysis we arbitrarily restricted the data set to include only coho caught in the 23-37 minute soak time group, in order to reduce any bias that might exist in scale loss for coho caught in unusually short or long soak times (e.g. due to problems with the net). We also arbitrarily chose to separate the scale loss data into four categories (0-25%, 26-50%, 51-75% and 76-100%) because we did not know how accurately or

consistently the observers on all vessels were able to visually assess the amount of scale loss.

A histogram plot of scale loss for each week of the gillnet demonstration fishery indicates that the percent scale loss for coho followed a very similar pattern in both weeks (Figure 5). Most of the coho in both weeks had scale loss of 25% or less. The total number of coho that had lower scale loss (25% or less) was higher during the second week of the gillnet fishery. However, the percentage of coho with higher scale loss (26% or more) was consistently higher during the first week of the fishery than the second week. This suggests either that: 1) few of the coho caught by the gillnets in the second week actually had been previously caught and released by the seine vessels; or 2) scale loss is not very useful for trying to determine the proportion of coho previously caught by seines. The latter interpretation seems more likely to us.

Appendix 2

1998 specifications for the standard DFO revival tank

The following is a copy of the information and specifications that DFO provided for the original coho recovery tank that became a mandatory requirement for all commercial seine vessels in 1998. No similar detailed specifications were provided by DFO for the recovery box that was mandatory for commercial gillnets in 1998, but the main features of the seine and gillnet recovery boxes were the same. The major difference was that the overall dimensions of the gillnet recovery box were smaller.

Revival Tank Guidelines

Parts list and instructions for coho revival tank (Dyno PX 310)

PARTS

DIAMETER	COMPONENT	HOW MANY
1.5”	Test cap	2
1.5”	Inlet diffuser, black ABS (drain) pipe, 7” long	2
1.5”	ABS drain tee with thread cleanout	1
1.5”	PVC nipple, 4” long	2
2.0”	PVC spacer ring, 2” long	2
1.5”	PVC elbow, female thread X male thread	1
1.5”	PVC ball valve, thread by thread	1
1.5”	PVC nipple, 2” long	1
1.5”	Adapter, camlock or forestry Quick-Disconnect to thread	1
1.5”	PVC standpipe, 17” long, threaded each end	1
1.5”	PVC 90 threaded elbow	1
1.5”	PVC threaded coupling	1

Approximately $60.00

ASSEMBLY

1) **Inlet diffuser**: glue the 1.5 inch by 7-inch ABS pipe sections one into each side of the ABS tee and put a test cap over each end, seated fully. Lay the assembly on a flat surface and drill 7/8 inch holes in the pipe section between the test cap and the tee, 4 holes in each section, all holes in the same line, and centered on the highest point of the pipe section. If the tee came with a cleanout plug, set it aside (not used).

2) **Rest of inlet hookup**: thread the female-to-male 1.5-inch PVC 90 elbow into a 1.5-inch by 4-inch PVC nipple. Thread the PVC ball valve onto the other (male) end of the PVC elbow. Thread the 1.5-inch by 2-inch PVC nipple into the valve, and thread the quick-disconnect adapter onto the other end of the 2-inch nipple. Hand-tighten joints, use no wrenches.

3) **Drain-assembly**: thread the 1.5-inch by 17-inch standpipe into the PVC standard 90 elbow. Thread the second 1.5-inch by 4-inch PVC nipple into the other end of the elbow. Hand tighten joints only, use no wrenches.

4) **Inlet port**: at the opposite end of the tote from the factory drain-plug, drill a 1 $^{7/8}$-inch hole centered between the 2 vertical ribs and 5 inches up from the top of the gray handhold.

SETTING UP THE DECK

1) **Inlet**: slip one of the 2-inch by 2-inch spacers onto the thread end of the valve and hose adapter assembly. From outside the tote, insert the exposed thread end of the assembly through the hole provided in the tote at the opposite end from the drain plug. Inside the tote, screw the black T-bar inlet diffuser onto the valve and adapter assembly and hand tighten so that the holes in the diffuser face down into the tote. Do not tighten with wrenches etc. Connect your pumped seawater supply to the quick-disconnect end (this will vary from boat to boat, but under no circumstance should the supply line be less than 1-inch diameter).

2) **Outlet**: remove the factory drain plug (store it in the provided socket above the outlet). From inside the tote, pass the short end of the drain assembly through the drain hole. From outside the tote, slip the second 2-inch by 2-inch spacer onto the drain assembly and thread the PVC coupling on behind it. Hand tighten only.

The revival tank is now ready for use.

HOW TO USE

Water flow: your water supply must be able to provide enough flow to fill a standard 5-gal pail in 10-12 seconds (fill an empty tote in less than 2 minutes). Normal flow to the tank should be in the range of 20-24 Imperial gallons per minute (90-110 liters per minute). When the tank is running, the water level in the tank should be ¾ to 1 inch higher than the top of the standpipe on the drain.

Fish capacity: if your flow meets specifications, the tank can handle up to 100 lbs. of live coho.

Loading fish in: place each fish in the tank with 2 hands or by dipnet. It helps to point their head toward the inlet. Do not throw fish at the tank. Put the lid back on the tank as soon as you get each fish in (the darkness it provides is one of the biggest factors in calming the fish quickly).

Emptying: the tank may be emptied by careful removal of 1-2 fish at a time with a soft-mesh dipnet, or you can spill the entire contents after lowering it over the side. If you're spilling, it's best to upset the tank on its side, not its end (less chance of fish hurting themselves on the plumbing). Fish should not fall through the air when you release, do it at sea level if possible. For safe hoisting, assume that the tote, full load of seawater and 100 lbs. of fish weighs 750 lbs.

IMPORTANT NOTES

1. Use clean new water when loading fish in the tank. Do not use old (stale) water that has been in the tank for any length of time. Old water is not as good as new as it is more stagnant (less oxygen) and warmer.

2. Check the outlet standpipe every so often in case it is plugged with debris, seaweed etc.

3. If the flow to the tank is cut off for any reason, fish may begin to die from lack of oxygen within as little as 3 minutes. Do not take this chance deliberately. Circulating water is essential to provide oxygen to the fish.

4. Field repairs: if you break or lose parts of the tote, replacement parts of galvanized iron or other metals may be used if plastic is not available, but DO NOT UNDER ANY CIRCUMSTANCE REDUCE THE SIZE OF EITHER THE INLET OR THE OUTLET. The inlet diffuser is essential for preventing fish stress from turbulence, do not replace it with a plain elbow.

5. The lid is equally important for preventing stress because fish become calmer in the dark, so if you lose, get something else in place right away.

FISH HANDLING

1. Avoid placing bleeding fish in with other fish as the scent of blood will increase the activity of all the fish.

2. Do not handle fish with rough gloves, as this will remove the mucous or slime from the fish. Fish slime is important in protecting the fish. Use your hands, soft cotton gloves or a small knotless dipnet.

3. When the bycatch encounters are few and the opening is short keeping these fish until the end of the fishery would be beneficial in avoiding recapture by other fishing vessels. Under most circumstances, fish should not be held more than a few hours in the tank.

4. All fish when stressed will benefit from a calm and safe environment (revival tank), therefore, all fish (lively or lethargic) should, when possible, be placed in the tank, with the lid secured.

5. To avoid over-filling the tank (depending on tank capacity), lively fish may need to be released immediately.

For questions about fish handling and operating the tank, contact:

Henrik Kreiberg
Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, B.C. V9T 6N7

Figure 1: Coho Catch Mortality for Soak Groups between 20 and 65 +/- 2 Minutes for Alberni Inlet 1998 Experiment

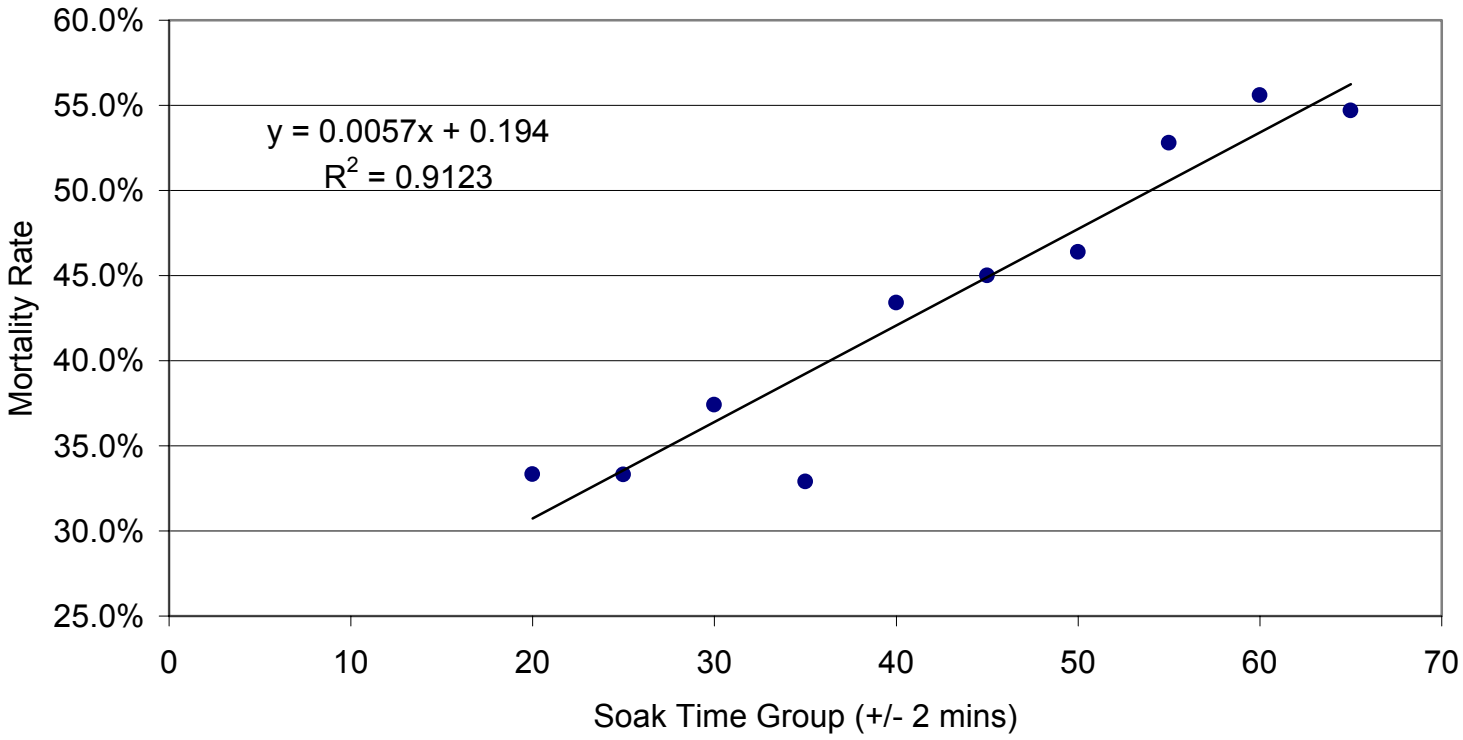

***Table F2:* - The effect of time in the revival tank on coho recovery in the**
Alberni Inlet 1998 selective fishery experiment

The table below indicates the number and percent of coho that entered the revival tanks in Condition 3 (CC3; lethargic and not bleeding) that were later released in each release condition (CR) by revival time group.

30 minute Soak Group

Capture Condition		Condition at Release									
Revival Times	*# of Coho CC3*	*CR1*		*CR2*		*CR3*		*CR4*		*CR5*	
0-10 minutes	20	10	50%	0	0%	6	30%	0	0%	4	20%
11-20 minutes	35	23	66%	0	0%	9	26%	1	3%	2	6%
21-30 minutes	27	24	89%	0	0%	2	7%	1	4%	0	0%
31-40 minutes	4	4	100%	0	0%	0	0%	0	0%	0	0%
41-50 minutes	6	6	100%	0	0%	0	0%	0	0%	0	0%
51-60 minutes	8	6	75%	0	0%	2	25%	0	0%	0	0%
>60 minutes	1	1	100%	0	0%	0	0%	0	0%	0	0%
Total	*101*	*74*	*73%*	*0*	*0%*	*19*	*19%*	*2*	*2%*	*6*	*6%*

Figure 2: Percent of Coho in Condition 3 at capture that revived to Condition 1 at the timeof release from the revival tanks in the Alberni Inlet 1998 experiment
10 Minute intervals for 30 min Soak Group (>60 min not included)

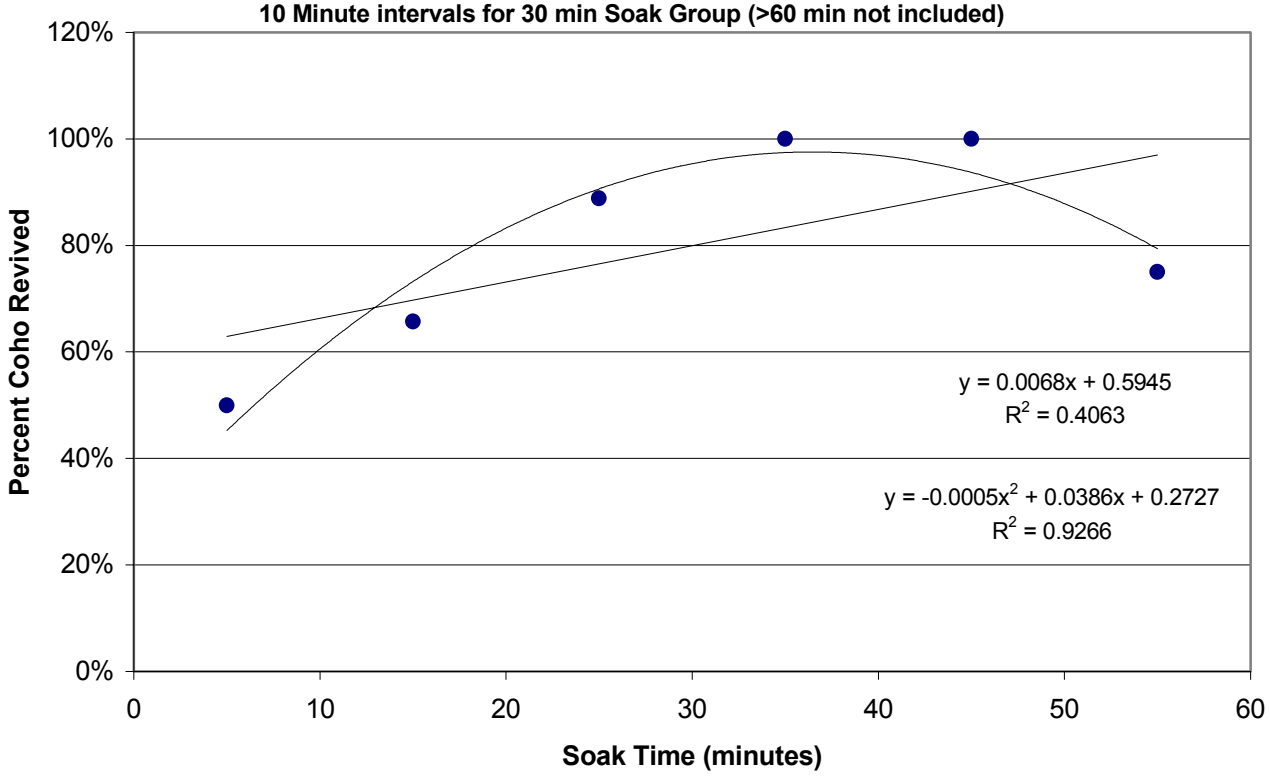

Figure 3: Relationship between Total Time (first cork in to last cork out) vs Soak Time (last cork in to first cork out) for the Skeena 2000 experiment

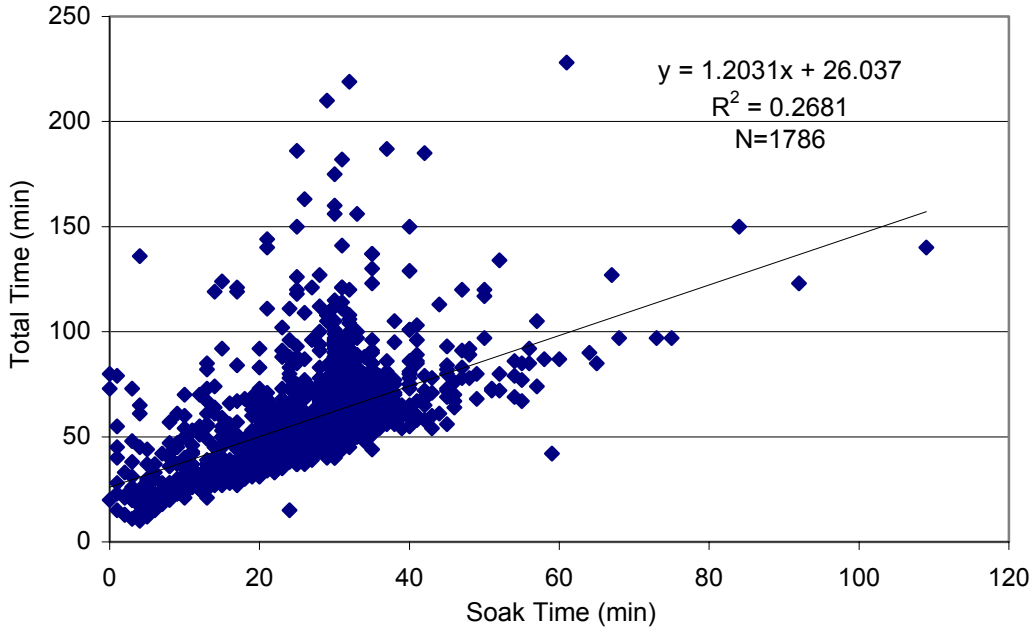

Figure 4: Total Time Minus Soak Time vs Total Catch by Set for the Skeena 2000 experiment

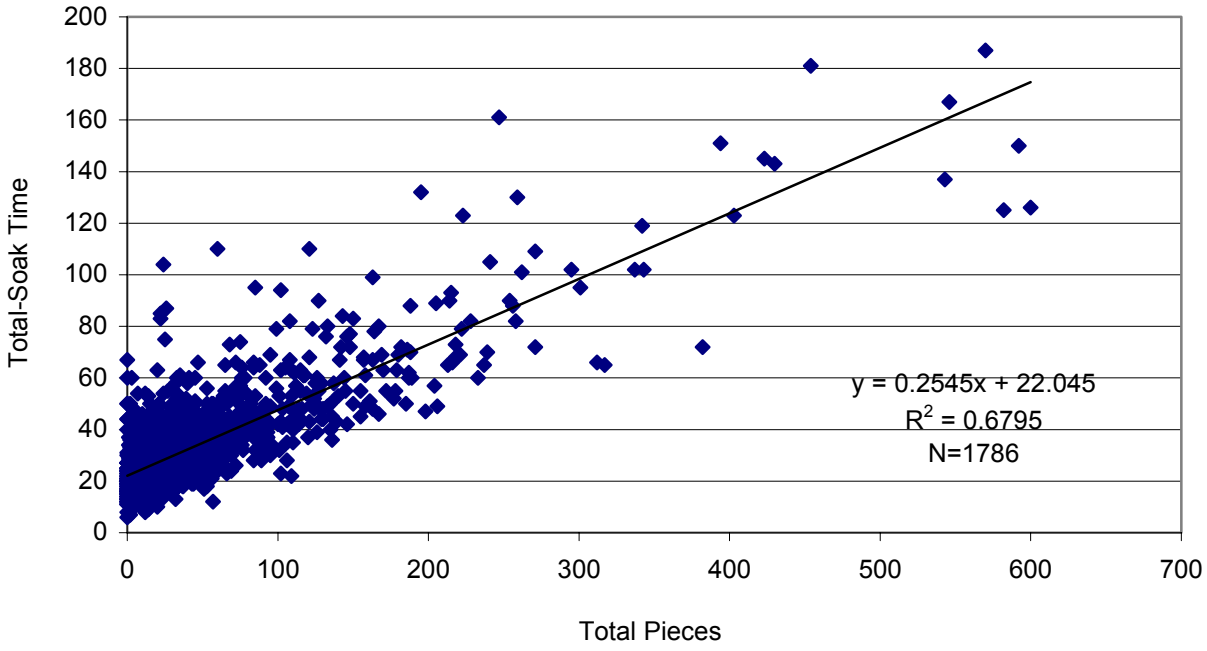

Table F5: data for histogram plot of Percent scale loss for coho in the Skeena 2000 experiment

Skeena River 2000 Experiment Percent Scale Loss						*Skeena River 2000 Experiment Percent Scale Loss*				
All Soak Time Week 1						All Soak Time Week 2				
Bin	*Frequency*	*%*	*Cum Freq.*	*Cum %.*		*Bin*	*Frequency*	*%*	*Cum Freq.*	*Cum %.*
25	77	61%	77	61%		25	183	87%	183	87%
50	29	23%	106	83%		50	21	10%	204	97%
75	7	6%	113	89%		75	1	0%	205	98%
100	14	11%	127	100%		100	5	2%	210	100%
Total	127					*Total*	210			

Note: 1) In week 1 147 coho were caught but only 138 of these had an entry for the % scale loss. 11 of those were entered as NA. Thus, there are 127 coho with % scale loss available for week 1; 2) In week 2 there were 221 coho caught but only 217 of these had an entry for the % scale loss. 7 of those were entered as NA. Thus there are 210 coho with % scale loss available for week 2.

Figure 5: Frequency Histogram of the Percent Scale Loss for Coho in Skeena River 2000 Selective Gillnet Demonstration fishery experiment

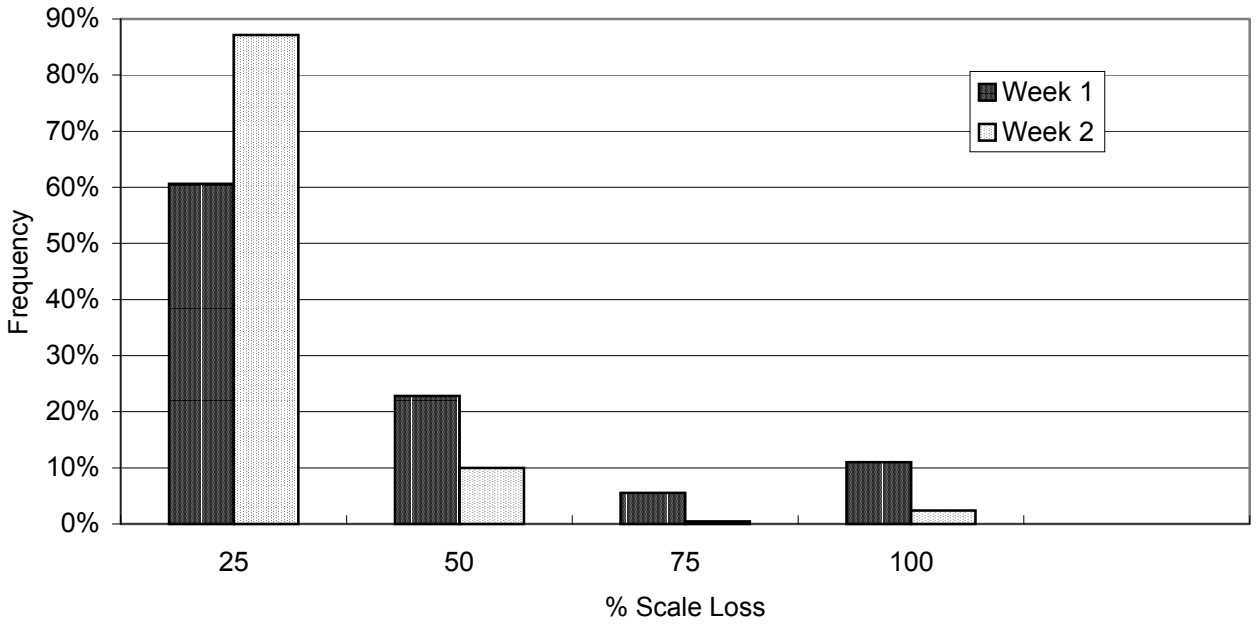

Figure 6: Comparison of the catch mortality rate versus soak time realationship for the Barkley Sound Sound 1998 experiment and the Skeena River 2000 demonstration commercial fishery. Solid trend lines indicate the least-squares linear regression fits to the data.