Physiological Indicators of Stress of Capture and Mortality Risk in Commercial Non-Retention Salmon Fisheries

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Summary

Over 300 coho salmon (*Oncoryhynchus kisutch*) were examined for their physical and metabolic condition following capture with three different commercial salmon fishing gear types (seine, troll and gillnet). Regardless of the gear type, all fish arrived on board in a severe state of metabolic exhaustion and physiological stress as based on the eleven physiological measurements we performed. In our opinion, exhaustion and stress of this severity would only permit aerobic swimming at a very low velocity or a few seconds of burst (anaerobic) activity if fish were released immediately after capture. The results indicate that the metabolic status of the muscle would severely limit further muscular activity and thus it is unlikely that these fish could avoid predators if released immediately after capture.

Measurement of red blood cell concentration in the blood showed that for most fish loss of blood due to poor handling practices and external damage to the skin and gills, was not a significant factor.

Differences in the level of exhaustion between gear types were small. This is also true for differences between the different methods of fishing within gear types (i.e., gillnet, 30 and 60 minute soak times; seine, ramp, brail, or brail with modified bunt). Some of these observed differences can be explained by differences in the normal time between landing the fish and the actual exhaustion at capture and degree of air exposure. The data is sufficient for us to say that seine fishing using brailing techniques compared with ramping, and gillnet fishing with 30 minute compared with 60 minute soak times, are less stressful to coho salmon.

This is the first comprehensive assessment of the metabolic status of fish held in recovery (blue) boxes for 30- and 60-minute periods following capture. Overall, we did not observe evidence of the type of metabolic recovery that is routinely observed under optimum conditions within the same period of recovery in laboratory studies . However, there were signs of recovery for several variables. This is encouraging and perhaps a better-designed recovery box would be more effective in promoting recovery. We did observe substantial recovery after a 24-h holding period in a net pen. Thus, extending the length of time held in blue boxes as a more effective method of promoting recovery before release should also be tested. We conclude that the blue boxes did not make

matters worse for the fish, and may have promoted more effective gill ventilation and restored blood oxygen status to normal.

Our recommendations for future experiments are:
Test recovery in a better designed box with compartments and adequate flow of water to allow fish to swim slowly into a water current;
Test longer recovery periods in the blue boxes in real-life fishing situations.
Correlate the physiological data with the ability of the fish to swim post-capture;

In our opinion, we cannot proceed with the current selective fisheries policy until we know whether recovery boxes are valuable in facilitating recovery and know more about the long term survival and spawning success of fish released after capture. Having a better designed blue box is critical to this assessment.

Perspective – the development of a science-fisheries industry partnership to assess the effectiveness of the policy of selective fisheries.

In recent years, with the growing concern about declines in some stocks of coho salmon various members of the commercial sector have taken the initiative to reduce the catch or retention of weaker stocks. In addition, they have experimented with changes to both gear and fishing technique to reduce the mortality of non-target species and increase the likelihood of survival following live release. For example, in 1997 Area D Gillnetters signed a joint project agreement with Fisheries and Oceans Canada (FOC) to test the effectiveness of the new Alaska twist web compared with the standard gillnet web as a conservation measure to protect the coho. In addition, they also all carried revival (also called blue) boxes on board to hold fish for a period of recovery before live release, with the expectation that this would increase the chances of survival and successful reproduction.

The seine fleet has also experimented with modifications to gear and fishing techniques. In response to the concerns arising from the 1994 salmon fishing season, seine boat operators Weigold and Cook (see Westcoast Fisherman, September 1995) proposed a pilot study to test "various release methods including the use of knotless bunts, tow-off skiffs and large knotless dipnets for removing fish from the net". In the summers of 1995-1997, special seine fishery experiments were conducted by J.O. Thomas and Associates in the Skeena River to test the effects of brailing and the use of recovery boxes on non-target species. A number of seine modifications thought to reduce subsequent mortality after live release of non-target species were described at a workshop in early May 1998, including the practice of brailing and direct release from the net using dipnets as well as the mandatory use of a revival box. At the same workshop, members of the troll fleet made a number of suggestions for more successful live release of weaker stocks including: continuous monitoring of gear, release of catch in the water and use of barbless hooks (see Speaking for the Salmon, 1998).

In May 1998, in response to the grave concerns about the health of some coho salmon stocks, the Minister of Fisheries and Oceans Canada announced a coast-wide policy of selective fisheries for the 1998 commercial salmon fishing season. A call for proposals to minimize bycatch of the endangered coho was issued to the industry and revival boxes were made mandatory for all gear types.

Physiological Indicators of the Stress of Capture

That fish show delayed mortality following severe exertion was first shown over 60 years ago and has been repeatedly demonstrated in studies aimed at understanding causes. Postcapture mortality rates have been reported as high as 70%. Though we do not yet understand the immediate cause of delayed mortality, it is clear that the complex set of changes associated with physiological stress play a central role in the sequel of events that can precede mortality. Thus, by focusing on markers of physiological stress, we can make predictions about the likelihood of survival for non-retention fish. The assumption is that a lower level of physiological stress during capture and handling will promote better survival upon release.

It has long been known that capture, confinement, air exposure and handling cause physiological stress in fish (see below). The effects observed in laboratory studies include:

- muscle fatigue as the result of exhaustive exercise leading up to capture;
- marked disturbances to acid base, osmotic and electrolyte balance due to the accumulation of metabolic wastes and fluid shifts;
- significant reductions in high energy fuels such as phosphocreatine (PCr), adenosine triphosphate (ATP) and muscle glycogen;
- elevated levels of anaerobic metabolites including plasma and muscle lactate;
- elevated hematocrit owing to stress hormone-induced red blood cell swelling, spleen transfusion, and fluid shifts;
- gill collapse resulting from air exposure; and
- release of stress hormones such as adrenaline and cortisol

In the short-term these stress-induced effects could impede swimming capacity after release. This could increase the mortality risk from predation and possibly reduce the potential for successful migration depending on where the release took place. In the long-term it would be expected that the energy required to restore homeostasis or steady-state would be diverted from investment activities such as gonadal development, potentially affecting the ability of live released salmon to get to the spawning grounds and reproduce successfully.

It is not well understood which changes during recovery are critical to (or predictive of) future swimming capacity and whether there are threshold levels for some physiological variables (for example, plasma and muscle lactate).

Summer 1998 joint DFO-fishing industry-SFU Barkley Sound study

Given the severity of the methods of capture used by all commercial gear types we predicted that the combined effects of exhaustive swimming, handling, air exposure and physiological stress would be at least as great if not greater than those observed under laboratory conditions. We also predicted that some of these effects would vary between gear types and gear modifications.

While it was mandatory for all commercial gear types to carry recovery boxes on board in 1998, and in spite of a description of recovery boxes being "very effective in increasing survival of non-target species in some cases” to our knowledge the use of recovery boxes had never been tested in an appropriately designed scientific study.

Moreover, given the evidence of the factors that cause physiological stress in fish we felt it was important to determine whether live-released fish survive to successfully escape predators in the short term and in the long term to reproduce on the spawning grounds. Without this information, it is impossible to assess whether or not the policy of "live release" of non-target species of salmon is an effective conservation measure.

With this in mind, we joined the DFO and members of the commercial salmon industry in a project designed to measure physiological variables which may be used as indicators of mortality risk for "live release" following capture. The experiments were conducted in Barkley Sound in September 1998. Representatives of the seine, gillnet and troll fleets targeted a healthy stock of Alberni Inlet coho salmon for these experiments. Our goal was "to assess the effectiveness of the new measures which were implemented or proposed by DFO and the salmon fishing industry in 1998, to reduce the incidental catches, and improve the survival of coho that were live-released from commercial seine, gillnet and troll fishing gear" (DFO background information document).

The overall experiment measured mortality as a function of a number of gear and fishing modifications. For all gear types, some fish were tagged immediately upon capture and transported to net pens where they were held for a 24-hour recovery before release. All boats carried recovery boxes on board. Fish were held in these boxes for either 30 or 60 minutes and compared to fish sampled directly upon landing to test the effectiveness of the blue box in facilitating recovery.
For the gillnet gear, we tested:

- the condition of fish after soak times of 30 or 60 minutes, and
- the condition of each group of fish after 30 or 60 minutes recovery in blue boxes

For the seine gear, we tested:
• the condition of fish captured by: traditional ramping, standard brailer, or standard brailer with modified bunt (fine mesh knotless and selectivity grids), and
• the condition of each group of fish after 30 or 60 minutes recovery in blue boxes

For the troll gear, we tested:

- the condition of fish released directly at the water line or immediately after being released from the hook and brought on board, and

- the condition of each group of fish after 30 minutes recovery in blue boxes

The purpose of the physiological study was to address the following three questions:

1) How stressed/fatigued/damaged were the fish upon landing?
2) What is the extent of recovery after 30 to 60 minutes in a blue (recovery) boxes or 24 hours in a net pen? and
3) Are there any differences between or within the gear types for 1 and 2 above?

The variables that were measured included: muscle glycogen, muscle lactate, muscle glucose, muscle phosphocreatine, plasma lactate and glucose (indicators of fatigue); hematocrit (indicator of bleeding, air exposure and stress); and plasma osmolality and ion (sodium, potassium and chloride) concentrations (indicators of physiological stress and osmotic shock)

Facts Discovered from Experimental Work

1. Almost 99% of fish sampled came on board with little to no blood loss as evidenced from (a) the high hematocrit (% red blood cells) and (b) the low number of fish with a visual condition rating of either 2 or 4 (those scores that identify cuts or bleeding). Therefore these fish were not anemic and suffered little to no blood loss. This finding demonstrates that commercial vessels can, with appropriate care, technique and gear, land fish in a condition that is conducive to recovery.
2. No fish died in the blue-box recovery tanks and fish looked livelier, less lethargic and brighter after being held in blue boxes. It is likely that this improvement of condition comes about because the blue-box recovery tank can promote repletion of blood and tissue oxygen stores.
3. A number of physiological indicators of stress were correlated with the visual criteria levels, indicating that these criteria are useful in predicting some of the stress effects of capture and handling.
4. The indices of metabolic status from blood and muscle tissue samples suggest that all coho were in a state of extreme fatigue when first landed on board the vessel, regardless of gear type. Given this metabolic state, it is our view that the potential of fish to swim to escape predators if released immediately on capture, would be very poor.
5. The indices of osmotic (water balance) and ion status from the blood samples suggest that while there were significant disturbances, these were not as severe as the muscle fatigue. It is our view, that this reflects good standards of fish capture and handling that minimize skin, scale and gill damage.
6. Coho held for 24 hours in a net pen following capture by seining methods showed signs of recovery. Mortality was less than 3%. Thus, there is evidence that, given the correct recovery conditions and time, commercially caught coho can recover from extreme muscular fatigue and stress and show little post-capture mortality. Minimizing air exposure during handling may have been important in this result.
7. A number of the plasma variables increased during the blue-box recovery period, but this was to be expected based on previous laboratory experiments. The fact that

plasma potassium concentrations decreased significantly during this recovery period indicated to us that the stress was not getting worse.

8. Holding coho for 30 or 60 minutes in a blue-box recovery tank resulted in very little improvement in muscle metabolic status. We expected that waste products (muscle lactate) would decrease and fuels (phosphocreatine and glycogen) would increase during the early stages of recovery. It is possible that the level of fatigue was so extreme that recovery would have taken much longer than one hour. It is also possible that the design of the blue-box recovery tanks could not effectively prevent further struggling, which may have delayed recovery.
9. Statistical differences were observed for some variables between different gear types and between fishing methods, but from a physiological standpoint the differences tended to be small since all fish were extremely fatigued. Notably, seine fishing using ramping versus brailing methods and gillnet fishing using 60 versus 30 minute soak times were more stressful to coho. In addition, plasma sodium, chloride, osmolarity, and lactate levels of coho caught by gillnet were greater at landing than for coho caught by seine and troll gear. This difference is likely explained by differences between gear types in the time between actual exhaustion of the fish when it encountered the fishing gear and landing on the vessel.

Recommendations for Future Work

1. Experiments should be performed to test a better design for the blue-box recovery tank for use on board commercial vessels. Since it is known that recovery from fatigue can be promoted in other salmonid species in laboratory experiments, a proven design should be used in future experiments involving commercial fishing vessels. These experiments could also include a simple but effective field measure of swimming performance.
2. Blue-box recovery tank experiments should be repeated in a commercial fishery. Recovery should be followed for two hours on board the vessel and for 48 hours using netpens. An effort should be made to minimize uncontrolled variability among box dimensions, loading rates, water flow characteristics and fish-handling details or the chance for reliable conclusions will be reduced.
3. The ability of fish to swim at various times post-capture should be measured directly rather than inferred from measures of metabolic status. It is possible that a correlation can be established to identify metabolic thresholds for effective swimming.
4. The present observer rating system, while useful, was incapable of detecting the extreme physiological exhaustion found in all coho. The observer scale should be expanded to include a more accurate assessment of behaviour/liveliness that could be correlated to objective physiological measures of performance capacity. Perhaps this could be done in conjunction with lab tests of alternate recovery tank designs.

Recommendations for the Fishing Industry

The types of fishing methods and fish handling used in the Alberni Inlet experiments clearly demonstrated that the industry has the capabilities to handle fish in such a way that recovery could be promoted. Reducing or eliminating air exposure of fish probably played a key role in this improvement.

1. We recommend specifics such as the following be considered for non-retention fishing: minimal time out of water for fish, small brailer-loads, small sets, dumping seine sets if need be due to too many fish, adequate deckcrew for rapid sorting, sustained good flow in recovery tanks, a higher skill-level in species identification, and sorting tables.
2. We recommend continued preference be given to the use of brailing over ramping methods for seine gear given the demonstrated benefit with respect to stress of non-retention fish.
3. We recommend continued preference be given to the use of a gillnet soak time of 30 min over a 60 min soak time given the demonstrated benefit with respect to stress of non-retention fish.
4. We recommend the continued use of recovery tanks for non-retention coho until superior alternatives have been developed and field-tested given the apparent benefit in terms of the visual condition ranking for non-retention fish.
5. We recommend a redesign of the standard recovery box to include partitions that produce compartments for holding the fish and a unidirectional flow of cool, clean water of high oxygen saturation, preferably such that the fish swim slowly into a water current.